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DETROIT AND ST. CLAIR RIVER TRANSIENT MODELS

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DETROIT AND ST, CLAIR RIVER TRANSIENT MODELS*

Frank H. Quinn and John C. Hagman**

A series of hydraulic transient models have been developed for the St. Clair and Detroit Rivers to simulate hourly and daily flow rates. These flows are necessary for water quantity and quality studies of the Great Lakes. This memorandum describes the mathematical models, their calibration, sensitivity, and applications so that modelers and water resource planners can make use of them in their studies.

1. INTRODUCTION

Because of the recently intensified concern about pollution and shore erosion, many studies have been undertaken to investigate water quality and to forecast water levels. Of special interest to those people studying Lakes Huron, St. Clair, and Erie are the flows in their connecting channels, the Detroit and St. Clair Rivers. The U.S. Army Corps of Engineers has periodically measured the flows in the Detroit and St. Clair Rivers, but such measurements are time consuming and expensive to make. It became apparent that flow measurements could not be made during every water quality study. Thus a method of accurate flow simulation was needed. Unfortunately, the existing stage-fall-discharge equations did not effectively simulate the unsteady flows characteristic of the Detroit and St. Clair Rivers on the time scales necessary for many water quality studies. Therefore, a transient or unsteady flow model was developed by the Lake Hydrology Group of the Great Lakes Environmental Research Laboratory.

The purpose of this Technical Memorandum is to describe the Detroit and St. Clair Rivers transient models, their calibration, sensitivity, and applications so that modelers and planners can make use of them in their studies. Samples of the computer programs and input and output formats are appended to this report.

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2. MATHEMATICAL THEORY

2.1 Equations of Continuity and Motion

The equations of continuity and motion in open channels can be expressed as terms of flow Q and stage Z above a fixed datum such that

$$\frac{\partial Z}{\partial t} + \frac{1}{T}\,\frac{\partial Q}{\partial X} = 0 \qquad (1)$$

and

$$\frac{1}{A}\,\frac{\partial Q}{\partial t} - \frac{2QT}{A^2}\,\frac{\partial Z}{\partial t} + \left(g - \frac{Q^2T}{A^3}\right)\frac{\partial Z}{\partial X} + \frac{gn^2Q|Q|}{2.208\ A^2R^{4/3}} = 0, \qquad (2)$$

where
- X = distance in the positive flow direction
- t = time
- A = channel cross-sectional area
- T = water surface top width of the channel
- g = acceleration due to gravity
- R = hydraulic radius
- n = Manning's roughness coefficient.

Equations (1) and (2) can be placed in finite difference form at point M in the grid shown in Fig. 1 and yield

$$\frac{Zu' + Zd' - Zu - Zd}{2\Delta t} + \frac{\Theta(Qd' - Qu') + (1 - \Theta)\ (Qd - Qu)}{TAX} = 0 \qquad (3)$$

$$\frac{Qu' + Qd' - Qu - Qd}{2\bar{A}\ At} - \frac{\bar{Q}T}{\bar{A}^2\ At} \cdot (Zu' + Zd' - Zu - Zd)$$

$$+ \left(g - \frac{\bar{Q}^2\ T}{\bar{A}^3}\right) \cdot \left[\frac{\Theta(Zdu') + (1 - \Theta)\ (Zd - Zu)}{\Delta X}\right]$$

$$+ \frac{gn^2\bar{Q}|\bar{Q}|}{2\ 208\ \bar{A}^2R^{4/3}} = 0, \qquad (4)$$

where prime indicates location and overbars indicate mean, such that

$$\Theta = \frac{\Delta t'}{\Delta t}$$

$$\bar{Q} = 0.5\ [\Theta(Qu' + Qd') + (1 - \Theta)(Qu + Qd)]$$

$$\bar{A} = 0.5\ [\Theta(Au' + Ad') + (1 - \Theta)(Au + Ad)].$$

Equations (3) and (4) form the basis of the model. A stable solution for (3) and (4) is provided by the weighting coefficient θ. Through empirical analyses and a test study (Quinn and Wylie, 1972), a θ value of 0.75 was chosen to provide stability to the computations.

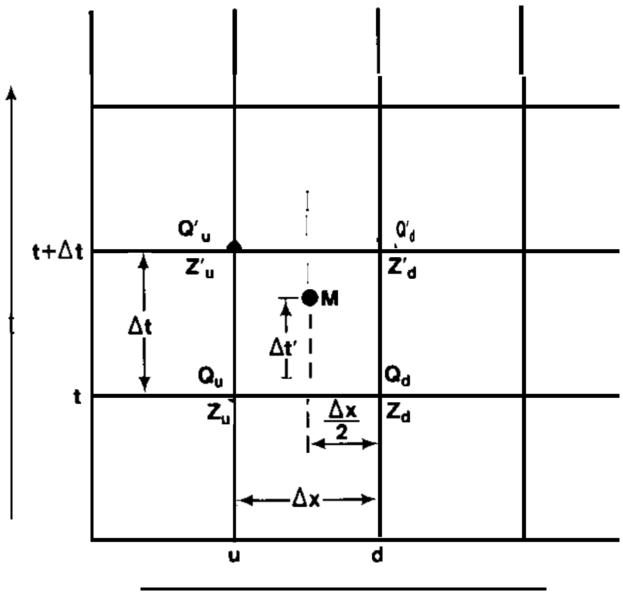

Figure 1. x-t grid for the implicit method.

2.2 Example

An idealized form of the total Detroit River connecting Lake St. Clair and Lake Erie is shown in Fig. 2.

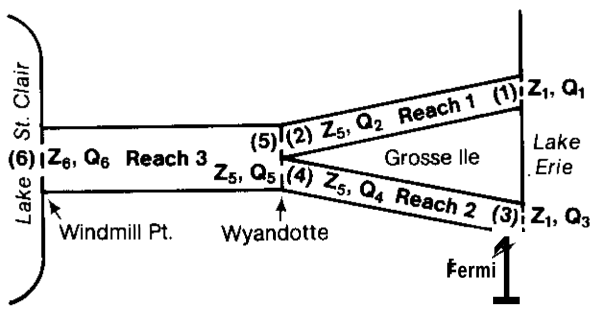

Figure 2. Idealized plan view of the Detroit River.

When equations (3) and (4) are applied to the three reaches in Fig. 2 and the continuity equation applied at Section 5, the following seven equations result:

$$f_{i(i=1,\ 2,\ 3)} = \frac{Z_i' + Z_{i+1}' - Z_i - Z_{i+1}}{2\Delta t} + \frac{\Theta(Q_i' - Q_{i+1}') + (1-\Theta)(Q_i - Q_{i+1})}{T_i\ \Delta X_i} = 0 \qquad (5)$$

$$f_{k(k=4,\ 5,\ 6)} = \frac{Q_i' + Q_{i+1}' - Q_i - Q_{i+1}}{2\bar{A}_i \Delta t} \quad \frac{\bar{Q}_i T_i}{\bar{A}_i^{2} \Delta t} \cdot (Z_j' + Z_{j+1}' - Z_j - Z_{j+1}) + \frac{g n^2\ \bar{Q}_i |\bar{Q}_i|}{2.208\ \bar{A}_i^{2} \bar{R}_i^{4/3}}$$

$$+ \left(g - \frac{\bar{Q}_i^{2} T_i}{\bar{A}_i^{3}}\right)\left[\frac{\Theta(Z_j' - Z_{j+1}') + (1-\Theta)(Z_j - Z_{j+1})}{\Delta X_i}\right] = 0, \qquad (6)$$

where j = 1, 3, 5, and $f_7 = Q_5' - Q_2' - Q_4' = 0.$ (7)

Since there is a common water surface at the junction ($Z_2' - Z_4' = Z_5'$), the equations contain only nine unknown variables:

Z_1', Z_5', Z_6', and Q_i' (i=1 to 6).

The water levels of Lakes St. Clair and Erie are recorded as a function of time. Thus the other seven unknowns can be solved for, using the seven simultaneous equations. The initial values of all nine variables must be known at time t, but can be computed from initial steady state conditions.

The nonlinear equations are handled numerically by using the Newton-Raphson approach (Hildebrand, 1956). The equations are altered at each time step to form a linear set of simultaneous equations, which are solved successively for unknown adjustments to the variables. The adjustments are applied to the original set of equations until an acceptable tolerance is achieved. The values of the variables in two consecutive iterations are related by a A quality such that:

$$Z_5' = (Z_5')_{trial} + \Delta Z_5 \qquad (8)$$

and

$$Q_i' = (Q_i')_{trial} + \Delta Q_i \qquad \text{for } i = 1 \text{ to } 6.$$

The Δ quantities or adjustments are evaluated by solving the following equations:

$$f_j + \frac{\partial f_j}{\partial Z_5'}\Delta Z_5 + \sum_{i=1}^{6} \frac{\partial f_j}{\partial Q_i'}\Delta Q_i = 0, \tag{9}$$

where j varies from 1 to 7.

The values of f_j and all partial derivatives are evaluated at the known values of the previous iteration. The seven adjustments represent the corrections to flows and water levels and are applied as in equation (8).

The partial derivations in equation (9) are given for reach 1 (Fig. 2) as follows:

$$\frac{\partial f_1}{\partial Z_5'} = \frac{1}{2\Delta t} \tag{10}$$

$$\frac{\partial f_1}{\partial Q_1'} = \frac{\partial f_1}{\partial Q_2} = \frac{\Theta}{T_1 \Delta X_1} \tag{11}$$

$$\frac{\partial f_4}{\partial Z_5'} = -\frac{\bar{Q}_1 T_1}{\bar{A}_1^{2}\Delta t} - \left(g - \frac{\bar{Q}_1^{2} T_1}{\bar{A}_1^{3}} \quad \frac{\Theta}{\Delta X_1}\right) \tag{12}$$

$$\frac{\partial f_4}{\partial Q_1'} = \frac{1}{2\bar{A}_1\Delta t} - \frac{T_1\Theta}{2\bar{A}_1^{2}\Delta t}(Z_1' + Z_5' - Z_1 - Z_5) + \frac{gn^2\bar{Q}_1\Theta}{2.208\, \bar{A}_1^{2} R_1^{4/3}}$$

$$\frac{T_1 Q_1 \Theta}{\bar{A}_1^{3}\Delta X_1}\left[\Theta(Z_1' - Z_5') + (1 - \Theta)(Z_1 - Z_5)\right] \tag{13}$$

$$\frac{\partial f_4}{\partial Q_2'} = \frac{\partial f_4}{\partial Q_1'} \ . \tag{14}$$

The variation of $\bar{A}_1$ with respect to Z_5' was not included in equation (10) or (12) owing to the minor importance of the variation. The coefficients in the equations can be easily manipulated in matrix form (Quinn and Wylie, 1972). Applications of the equations follow.

3. DETROIT RIVER MODELS

3.1 Model Scope

Two different Detroit River transient models have been developed. The total model spans the river from the head at Windmill Point in Detroit, Mich., near Lake St. Clair, to the mouth at Fermi, Mich., on Lake Erie, with an intermediate section at Wyandotte, Mich. This model of the river branches to give the flow in the channels on either side of Grosse Ile (Fig. 2). The upper river model spans the Detroit River from Windmill Point to Wyandotte, above Grosse Ile, with an intermediate section at Fort Wayne in Detroit.

These mathematical models use the one-dimensional equations for continuity and motion presented in Section 2. The unsteady flow of the river between the water level gages can be computed when the necessary hydraulic parameters are known for input into the equations and model calibration has taken place.

3.2 Hydraulic Parameters

The hydraulic parameters for the reaches spanned by the model are given in Table 1. The parameters include the mean area, reference area elevation, length of reach between gage locations, and width of channel. One can calculate the flows using the water levels recorded at the gages and the change in water level or fall between gages. The time step for the flows depends upon the time step of the water level data. The models have been run on l-hour, l-day, and l-month intervals.

3.3 Model Calibration

Calibration of the model consisted of adjusting the roughness coefficient, the unknown in the flow equation for each reach in the river. The equation used to compute the roughness coefficient is

$$n = \frac{1.486\ AR^{2/3}}{Q} \cdot \left(\frac{(WSUP - WSDN)}{L} + \frac{Q^2 \Delta A}{32.2\ LA^3} \right)^{1/2}, \qquad (15)$$

where
n = Manning roughness coefficient
A = mean channel area
R = hydraulic radius
Q = flow through channel
WSUP = water surface at upstream gage

Table 1. Detroit River Hydraulic Parameters

Reach from - to	Average width (ft)	Length (ft)	Reference elevation IGLD* (1955)	Base area (ft^2)
Windmill Point-Fort Wayne	3650	54,400	571.2	85,960
Fort Wayne-Wyandotte	3510	37,800	570.5	92,800
Windmill Point-Wyandotte	3590	*92,220*	570.93	88,780
Wyandotte-Fermi east of Grosse Ile	5055	48,630	570.80	81,700
Fermi east of Grosse Ile-Trenton Channel	1685	54,150	569.47	20,800

*IGLD - International Great Lakes Datum

WSDN = water surface at downstream gage
AA = change in area of river from upstream to downstream gage
L = length of reach from upstream to downstream gage.

Two methods were used to derive the Manning roughness coefficients for the various reaches between water level gages along the river. The first method was to derive the n's or roughness coefficients from actual discharge measurements by using equation (15). This method was used to establish roughness relationships for the reaches Windmill Point-Fort Wayne, Fort Wayne-Wyandotte, and the Trenton Channel between Wyandotte and Fermi. The second procedure, used for calibrating the Windmill-Wyandotte and the Wyandotte-Fermi reach east of Grosse Ile, applied averaged monthly summer flows from 1964-1973 as computed by the Windmill Point-Fort Wayne-Wyandotte model. In this manner consistency was maintained between the two Detroit River models. The roughness coefficient from Wyandotte to Fermi was derived by using the measured percentage of river flow east of Grosse Ile.

Figs. 3 through 5 depict the relationships established between the stage of the river of the named gage and the roughness coefficient for that reach, based upon flow measurements made by the Corps of Engineers. Figs. 6 and 7 show the relationships derived from computed and averaged flows and levels.

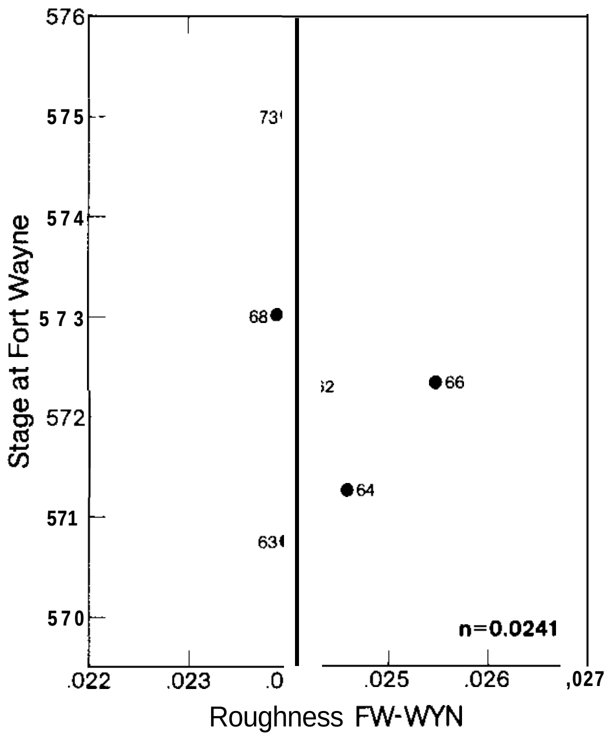

Figure 3. Manning's roughness coefficients Fort Wayne-Wyandotte reach.

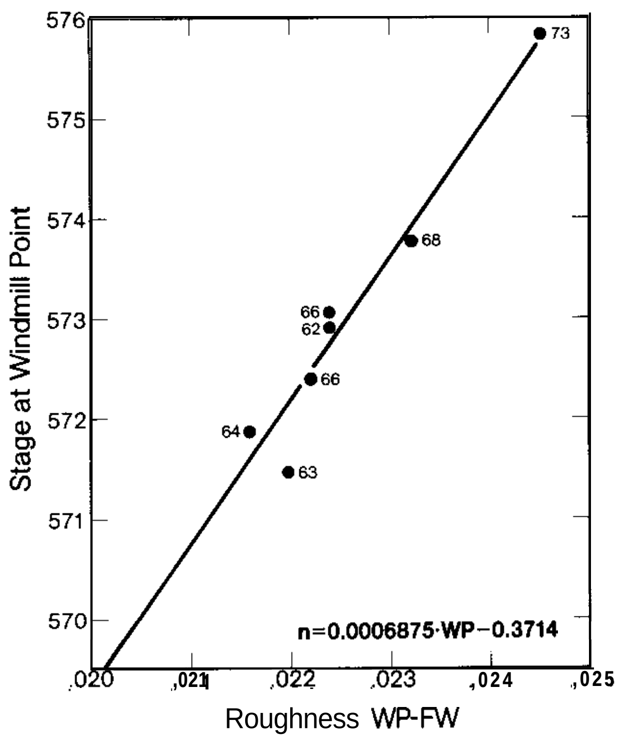

Figure 4. Manning's roughness coefficients Windmill Point-Fort Wayne reach.

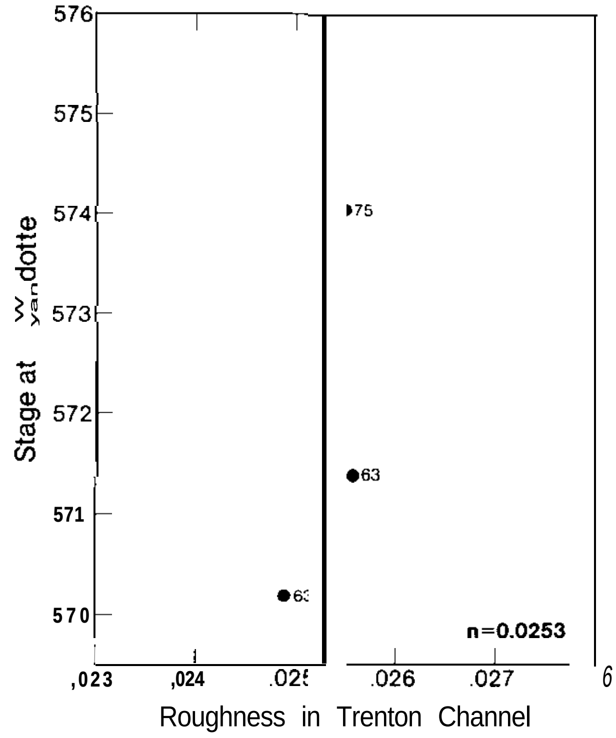

Figure 5. Manning's roughness coefficients Trenton Channel.

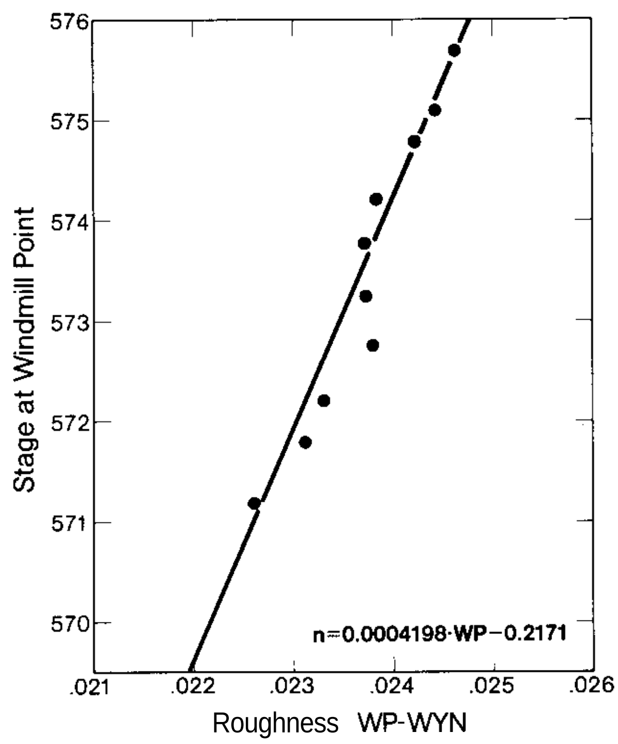

Figure 6. Manning's roughness coefficients Windmill Point-Wyandotte reach.

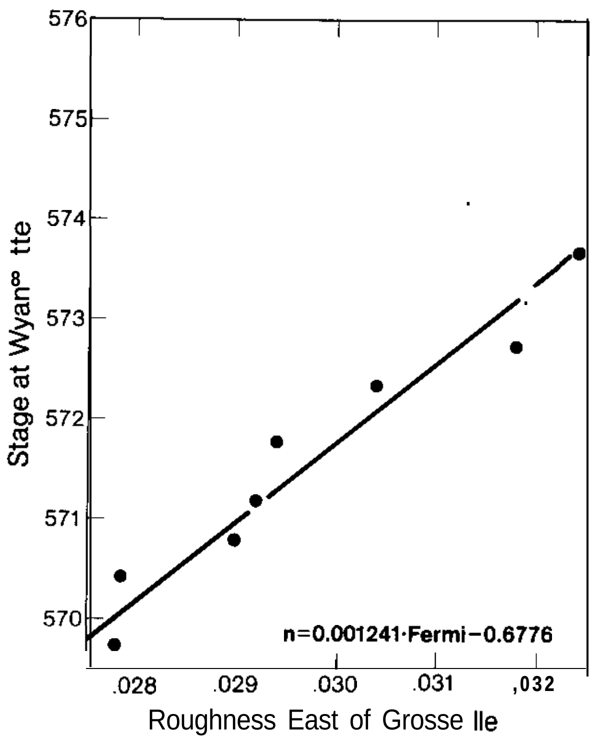

Figure 7. Manning's roughness coefficients east of Grosse Ile.

Table 2 summarizes the roughness coefficient and basis used to determine the coefficient for each reach along the Detroit River.

Table 2. Detroit River Roughness Coefficients

Reach from - to	Roughness coefficient, n	Flow basis
Windmill Point-Fort Wayne	0.0006875 WP - 0.3714	Measured flows
Windmill Point-Wyandotte	0.0004198 WP - 0.2171	Computed flows
Fort Wayne-Wyandotte	0.0241	Measured flows
Wyandotte-Fermi east of Grosse Ile	0.001241 Fermi - 0.6776	Computed flows
Wyandotte-Fermi Trenton Channel	0.0253	Measured flows

3.4 Sensitivity Analysis

An analysis was made of the sensitivity of the Detroit River model to changes in the water levels or roughness coefficients of the reaches. Water level data are generally accepted to be ±0.02 ft, which is the accuracy of the water level gages. Flows were computed to see the effect of a 0.02-ft water level change as well as a small percentage change in the roughness coefficient. Table 3 summarizes the effects of these various changes on the computed flows.

For every 2-percent change in the roughness, there is a l-percent change in the flows of the total river model. This is about the same effect as a 0.02-ft gage level change. Computed flows that agree within 2 percent or 4000 cubic feet per second (4 TCFS) can be considered equal.

Table 3. Detroit River Model Sensitivity

Change	Effect	Sensitivity (% change in flow)
Windmill Point + 0.02 ft	Increase flow 18 HCFS*	1%
Change roughness Fort Wayne-Wyandotte - 0.0006 or 2%	Increase flow 17 HCFS	1%
Increase roughness of Trenton Channel + 0.0003 or 1%	Decrease flow in channel 4 HCFS; no effect on total flow	1%
Wyandotte - 0.02 ft	Increase flow 20 HCFS	1%
Windmill Point + 0.02 ft and Wyandotte - 0.02 ft	Increase flow 30 HCFS	2%

*HCFS - hundreds of cubic feet per second.

3.5 Computer Programs

The computer program of the Detroit River Transient Model was first developed at the Lake Survey Center in the late 1960's. A newly calibrated version of the total river model program and an example of output for June 1976 are given in Appendix A. The program flags partial data with an asterisk and missing data with an "E" as estimated. This and other versions of the program are available from the Lake Hydrology Group of the Great Lakes Environmental Research Laboratory.

4. ST. CLAIR RIVER MODELS

4.1 Model Scope

Several St. Clair River models have been developed. They span part or all of the river from Fort Gratiot, near Port Huron, Mich., to St. Clair, Mich., midway down the river to Lake St. Clair. Four water level gages are placed along the river, including those at Fort Gratiot, the mouth of the Black River (MBR) in Port Huron, Dry Dock in Grant Place in Port Huron, and St. Clair.

Three gages are used in each of the mathematical models with the midstream gage used primarily for a check on the flow value made by comparing the measured water level at the midstream gage with the computed level from the model. Once again the models use the one-dimensional equations for continuity and motion presented earlier. The following St. Clair River models are currently operational:

Fort Gratiot-MBR-St. Clair

Fort Gratiot-MBR-Dry Dock

Fort Gratiot-Dry Dock-St. Clair

MBR-Dry Dock-St. Clair

4.2 Hydraulic Parameters

The hydraulic parameters used in the computation of the St. Clair River flow are displayed in Table 4. With this data and the water levels from any three gages along the St. Clair River, flows can be computed by using the calibrated roughness coefficients.

4.3 Model Calibration

Calibrating the St. Clair River roughness values involved computing the Manning roughness coefficients from measured river flows and recorded water levels. All roughness coefficients for reaches along the St. Clair River were computed by the same method using equation (15). As a check, flows were transferred from the Detroit River, including the effects of the net basin supply (precipitation, runoff, and evaporation) to the St. Clair River.

Figs. 8 through 12 depict the relationships between the computed roughness coefficients for each reach and the stage of the river at the adjacent water level gages during flow measurements from 1959 to 1973.

The downstream reaches were affected by the change in regime between 1959 and 1963, when the shipping lane was dredged. For these reaches a separate roughness coefficient was computed for each regime.

Some points were omitted from the plots due to possible gage errors or questionable measured flow values. The best-fit relationship between roughness and water levels was derived from the graphic plots and/or regression analyses. Table 5 summarizes the calibrated roughness coefficients for all reaches along the St. Clair River.

Some of the gages along the St. Clair River were moved during the period of the study, 1959-1976. Although an effort was made to measure any vertical change in gage level, there was a change in the apparent hydraulic regime due to a difference in the river velocity at the new gage location (Quinn, 1976). The Fort Gratiot and St. Clair water level gages were moved in 1970. All the hydraulic computations of discharge equations and transient model calibrations were based on the original gage locations. As a result of a comparison study, it was found that water levels from the new Fort Gratiot gage should be reduced by 0.18 ft and that water levels from the new St. Clair gage should be increased by 0.09 ft to agree with the measurements taken prior to 1970.

Table 4. St. Clair River Hydraulic Parameters

Reach from - to	Average width (ft)	Length (ft)	Reference elevation IGLD* (1955)	Base are* (ft)
Fort Gratiot-MBR	1550	12,560	576.3	51,140
Fort Gratiot-Dry Dock	1760	25,490	576.1	54,800
MBR-Dry Dock	2108	12,930	575.6	60,900
MBR-St. Clair	1930	60,410	574.5	51,205
Dry Dock-St. Clair	2490	47,150	574.8	64,600

*IGLD - International Great Lakes Datum.

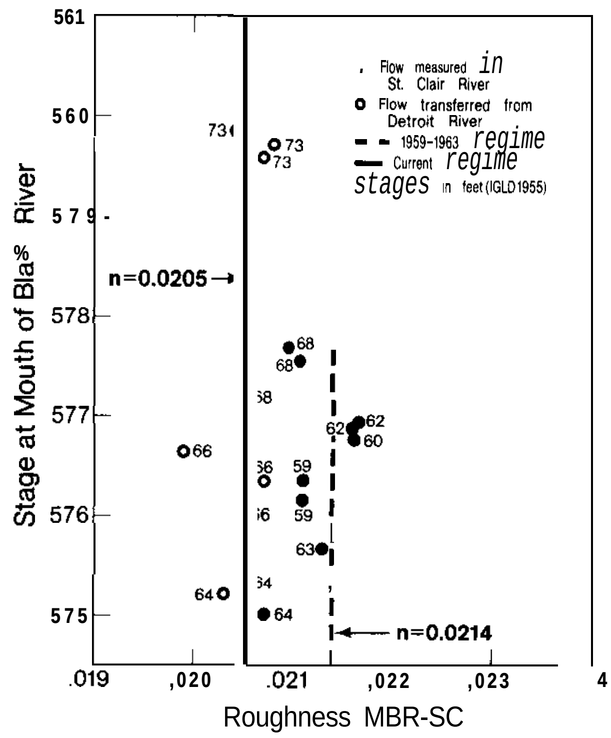

Figure 8. Manning's roughness coefficients mouth of Black River-St. Clair reach.

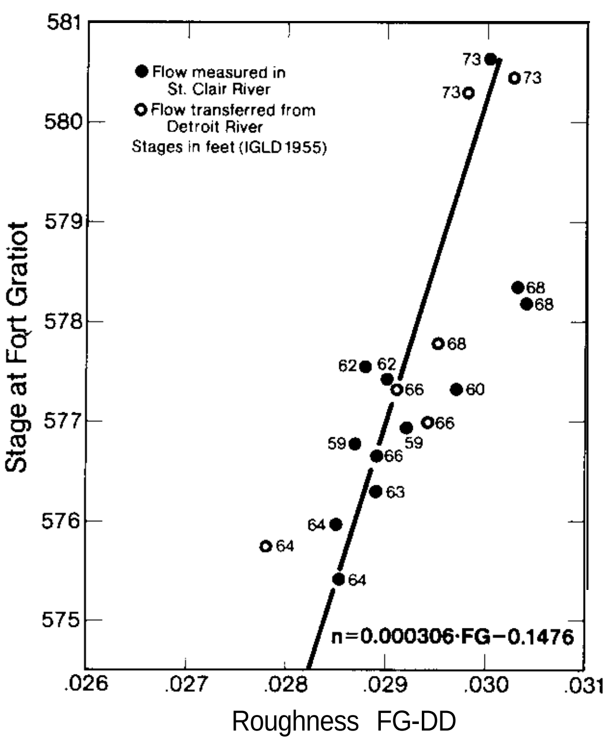

Figure 9. Manning's roughness coefficients Fort Gratiot-Dry Dock reach.

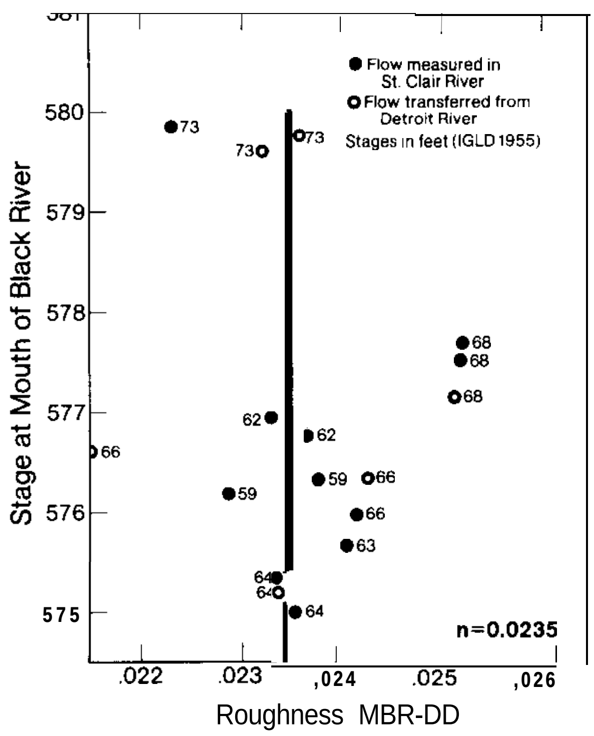

Figure 10. Manning's roughness coefficients mouth of Black River-Dry Dock reach.

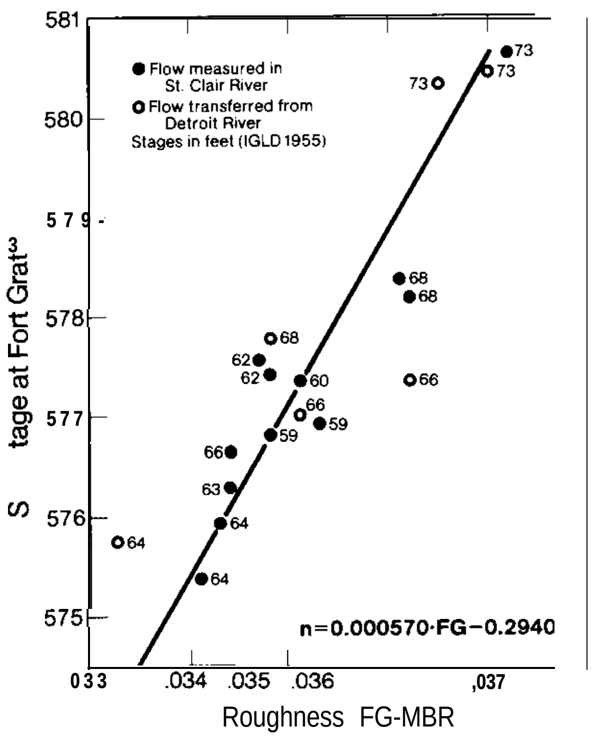

Figure 11. Manning's roughness coefficients Fort Gratiot-mouth of Black River reach.

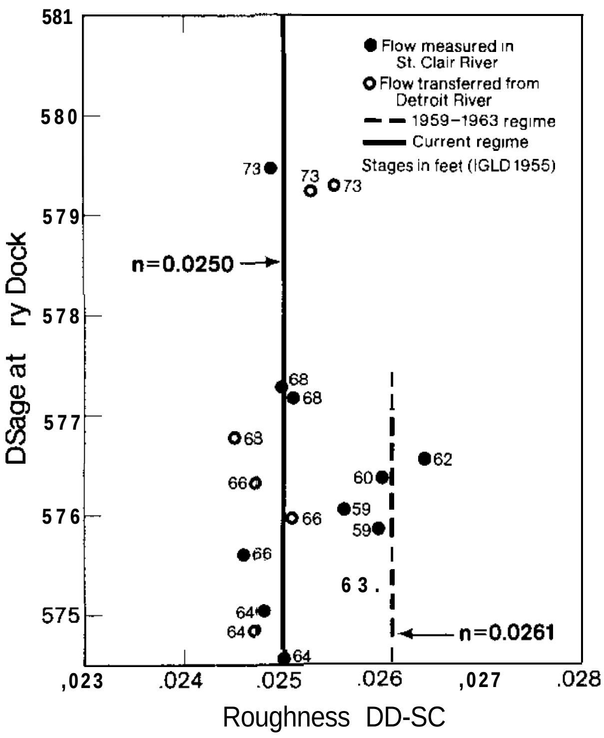

Figure 12. Manning*'s roughness coefficients Dry Dock-St. Clair reach.*

Table 5. ***St. Clair River Roughness Coefficients***

Reach	Roughness coefficient, n
Fort Gratiot-MBR	0.000570 FG - 0.2940
Fort Gratiot-Dry Dock	0.000306 FG - (- 0.1476)
MBR-Dry Dock	0.0235
MBR-St. Clair	0.0205 current regime; 0.0214 '59 - '63 regime
Dry Dock-St. Clair	0.0250 current regime; 0.0261 '59 - '63 regime

4.4 Sensitivity Analysis

The sensitivity of the St. Clair River model from Fort Gratiot to MBR to St. Clair was analyzed to see the effect of changes in roughness or water level data. Since the accuracy of the water level gages is ±0.02 ft, flows were computed with the Fort Gratiot and St. Clair gage levels changed by 0.02 ft to examine the effect on the computed flows. Table 6 summarizes the changes made, effect of the changes, and sensitivity of the model to the changes.

For every 2-percent change in roughness, there is less than a 1.5-percent change in flow. A water level gage error of 0.02 ft has less than 1-percent effect on the computed flow. Because of these potential errors, if different model flows agree with 4 thousand cubic feet per second (TCFS) or 2 percent, they can be accepted as equal.

Table 6. St. Clair River Model Sensitivity

Change	Effect	Sensitivity
Roughness decreased 0.0005 or 2.5%	Increase flow 30 HCFS*	2%
Roughness increased 0.001 or 5%	Decrease flow 58 HCFS	3%
Fort Gratiot + 0.02 ft	Increase flow 10 HCFS	<1%
St. Clair + 0.02 ft	Decrease flow 1.5 HCFS	<0.5%

*HCFS - hundreds of cubic feet per second.

4.5 computer Programs

St. Clair River models have been developed that use water level data either from punch cards or from computer disk pack files. Versions of the model can operate on hourly, daily, or monthly time steps. Appendix B is a listing of the Fort Gratiot-MBR-St. Clair monthly model with data card input. An example input is listed and an example output shown.

5. RECOMMENDATIONS

It has been shown that the transient hydraulic river models developed for the Detroit and St. Clair Rivers can efficiently simulate the actual measured river flows. It is therefore recommended that future studies use the computed flows derived from the river models rather than measured flows, which are expensive and time-consuming to perform. Additional calibration measurements should be performed as required.

There are many potential uses for the computed river flows produced by the models developed at GLERL. The authors believe that, owing to the inclusion of continuity and motion equations in the computation of flows, these models better represent the actual flow characteristics of the Detroit and St. Clair Rivers than conventional stage-fall-discharge equations.

Therefore, we recommend that flows computed from the transient models be used for water quality studies, input in ecological models, water level predictions and forecasts, and ice retardation identification. The models can also be used to simulate average flow velocities in the river cross sections. The models could also be adapted to other rivers for simulation of their flows. Both the models and computed flows can be obtained from the Lake Hydrology Group of the Great Lakes Environmental Research Laboratory.

6. REFERENCES

Hildebrand, F. B. (1956): *Introduction to Numerical Analysis.* McGraw-Hill, New York, 511 pp.

Quinn, F. H. (1976): Effect of Fort Gratiot and St. Clair gage relocations on the apparent hydraulic regime of the St. Clair River, GLERL Open File Report, GLERL Contribution No. 71, 6 pp.

Quinn, F. H., and E. B. Wylie (1972): Transient analysis of the Detroit River by implicit method. *Water Resour. Res.,* 8(6): 1461-1469.

APPENDIX A. Detroit River Transient Model and Output, 1976, 24.0-hr Increments

Starting elevations:	Windmill Point	= 514.79
	Wyandotte	= 573.42
	Lake Erie	= 571.99

```
      PROGRAM   DMODT     (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     1 TAPE22,TAPE23,TAPE24,TAPE11)
C       DETROIT  RIVER  TRANSIENT  ANALYSIS    UP-YYN-FERMI
C       FRANK  H.  QUINN  PROGRAMMER
      COMMON  IHOUR(24,31),MEAN(31),MEM ,MAXV(31),MAXD(31)
      COMMON  MINH(31),MIND(31)
      COMMON  MAXM(3),MINM(3),IC,IGEAGE,MONAA,IYRR,ID(10) .
      DIMENSION  SUM(12),AVE(12),IGAGE(3),ISET(3),IPAR(4,31)
      DIMENSION OLD(3),WS(80,4),Q(80,7),YVECT(7),C(7),XMTRX(7,7)
      DIMENSION  T(3),X(3),AN(3),A(3),U(3), R(3),WW(6),WV(6),QA(3),ADJ(3)
      DATA  IGES/≠EST ≠/
      DATA  IBLANK /≠     ≠/
      DATA    IAST    /≠* ≠/
C****  READ  IN  GAGE  NUMBERS:  FIRST DOWNSTREAM, UPSTREAM, THEN MIDSTREAM
C       THEN  THE  BEGINNING  YEAR  AND  MONTH  AND  THE  ENDING  YEAR  AND  MONTH
C       AND  FINALLY  ANY  GAGE  ADJUSTMENTS,  IF  NECESSARY.    *************
      READ(5,999) IGAGE,  IYRA,MONA,   IYRB,MONB ,(ADJ(I),I=1,3)
  999 FORMAT( 7I5,3F10.2)
      IFIRST = 0
      ISET(1) = 1
      ISET(2) = 3
      ISET(3) = 4
      ISTART = 13
      IEND = 43
      MX=5
      NX=6
      WRITE( NX,3000)
      NVAR  = 7
      AN(2)=.0253
    1 KKZ=11
      ANC=24.
      DO 2 I=1,12
    2 SUM(I)=0. ≡
      TH=.75
      TH1=.25
      MM=0
      M=13
      KA=24
      RON ◻ MONA
      IYR  =  IYRA
 2800  CONTINUE
      DO  2005  JJ  =  1.3
      IW ◻ 1
      IC  = IGAGE(JJ)/10000
      IGAG = IGAGE(JJ)     -IC*10000
      CALL  GAGEIO(IW,IC,IGAG ,MON,IYR,IB,IT,IDA,IDB,IDC,IER)
      IF( IER) 60,5000,60
 5000  CONTINUE
      KK = 1
      DO  2000  J=ISTART,IEND
      ICODE = IGAG
      DO  4000  I=1,24
      IF( IHOUR(I,KK)) 4005,4005,4000
```

Figure A.1. Detroit River model.

```
 4000 IPAR(ISET(JJ),KK) = IBLANK
      GO TO 4010
 4005 IPAR(ISET(JJ),KK) =        IAST
 4010 CONTINUE
      WS(J,ISET(JJ)) □ 0.0
      IF( MEAN(KK))  6000.6000.6005
 6000 WS(J,ISET(JJ)) = OLD(JJ)
      IPAR(ISET(JJ),KK) = IGES
      GO TO 6010
 6005 CONTINUE
      WS(J,ISET(JJ))=(MEAN(KK) . IB    )/100.0 +ADJ(JJ)
 6010 CONTINUE
      OLD(JJ) = WS(J,ISET(JJ))
 2000 KK □ KK+1
 2005 CONTINUE
      CALL  NODAYS( IYR,MON,0,NDM,NDY,JD)
      IF( IFIRST)  2500.2500.23
 2500 CONTINUE
      DO 8 I=1,12
      WS(I,1)=WS(13,1)
      WS(I,4)=WS(13,4)
    8 WS(I,3)=WS(13,3)
      WS(1,2)=WS(1,4)
C     PRINT  TITLES  AND  HEADINGS
   10 URITEC  NX.1020)  IYR
      WRITE( NX,1021)  ANC
      URITEC  NX,1025) WS(1,3),WS(1,2),WS(1,1)
      WRITE(  NX.1026)
      DT=ANC*3600.
      ASCDT=(27878400./DT)*430.
C**** INITIALIZE   MATRIX    •  
      DO  20  I  = 1,NVAR
      DO  20  J  = 1,NVAR
   20  XMTRX  (I,J) =  0.
C**** DEFINE  CONSTANT  CHANNEL  PARAMETERS   •  
C     DEFINE  CHANNEL  WIDTHS
      T(1) =  5055.
      T(2) =  1685.
      T(3) =  3590.
      X(1) =48630.
      X(2) =54150.
      X(3) □ 92220.
      M=1
Cf... COMPUTE  INITIAL  CONDITIONS   •  
      AN(1)=.0012407*WS(M,1)-.67755
   13 AN(3)= .0004198*WS(M,3)-.2171
      A(1)=81700. +T(1)*(.50*(WS(M,1)+WS(M,2))-570.80)
      A(2)=20800. +T(2)*(.50*(WS(M,1)+WS(M,2))-569.47)
      R(1)=A(1)/T(1)
      R(2)=A(2)/T(2)
      Q(1,1)=       1.486*A(1)*R(1)**(2./3.)*(WS(1,2)-WS(1,1))**.5/AN(1)
     1/X(1)**.5
      Q(1,3)=       1.486*A(2)*R(2)**(2./3.)*(WS(1,2)-WS(1,1))**.5/AN(2)
```

Figure A.1. Detroit River model (continued).

```
     1/X(2)**.5
      Q(1,2)=Q(1,1)
      Q(1,4)=Q(1,3)
      Q(1,5)=        Q(1,2)+Q(1,4)
      Q(1,6)=Q(1,5)
      WS( 2,2) = WS(1,2)
   36 DO 18 I=1,6
   18 Q(2,I)=Q(1,I)
      KB=48
      M=1
   23 CONTINUE
      N = M+1
      IF(WS(N,1)-1.)59,59,22
   22 AN(1)=.0012407*WS(M,1)-.67755
      AN(3)= .0004198*WS(M,3)-.2171
      DO 50 LL: 1.3
      QA(1)=TH/2.*(Q(N,1)+Q(N,2))+TH1/2.*(Q(M,1)+Q(M,2))
      QA(2)=TH/2.*(Q(N,3)+Q(N,4))+TH1/2.*(Q(M,3)+Q(M,4))
      QA(3)=TH/2.*(Q(N,5)+Q(N,6))+TH1/2.*(Q(M,5)+Q(M,6))
      U(1)= ABS(QA(1))
      U(2)= ABS(QA(2))
      U(3)= ABS(QA(3))
C**** COMPUTE AREAS AND HYDRAULIC RADIUS •
     0A(1)=81700.+T(1)*(TH/2.*(WS(N,1)+WS(N,2))+TH1/2.*(WS(M,1)+WS(M,2))
     1-570.80)
     0A(2)=20800.+T(2)*(TH/2.*(WS(N,1)+WS(N,2))+TH1/2.*(WS(M,1)+WS(M,2))
     1-569.47)
     0A(3)=88780.+T(3)*(TH/2.*(WS(N,2)+WS(N,3))+TH1/2.*(WS(M,2)+WS(M,3))
     1-570.93)
      DO 24 I-1.3
   24 R(I)=A(I)/T(I)
C**** COMPUTE Y VECTORS •
      WW(1)=       WS(N,1)+WS(N,2)-WS(M,1)-WS(M,2)
      WW(2)=WW(1)
      WW(3)=WS(N,2)+WS(N,3)-WS(M,2)-WS(M,3)
      J = 1
      DO 25 I = 1,3
      IJ = J+1
     0YVECT(I)=-(WW(I)/(2.*DT)+(TH*(Q(N,J)-Q(N,IJ))+TH1*(Q(M,J)-Q(M,IJ))
     1)/(T(I)*X(I)))
   25 J = J+2
      WW(6)=TH*(WS(N,2)-WS(N,3))+TH1*(WS(M,2)-WS(M,3))
      WW(4)=       TH*(WS(N,1)-WS(N,2))+TH1*(WS(M,1)-WS(M,2))
      WW(5)=WW(4)
      WV(4)=       WW(1)
      WV(5)=WV(4)
      WV(6)=WW(3)
      J = I
      DO 30 I = 1,3
      L=I+3
      IJ = J+1
     0Z1=32.2*AN(I)*AN(I)*QA(I)*U(I)          /(2.2082*A(I)**2.*R(I)**
     1(4./3.))
```

Figure A.1. Detroit River model (continued) .

```
      Z2=32.2-QA(I)*U(I)*T(I)/(    A(I)**3.)
      Z3=WW(L)/X(I)
      Z4=-QA(I)              *T(I)*WV(L)/(2.*DT*A(I)**2.)
     0Z5=QA(I)*(TH*(Q(N,J)-Q(N,IJ))+TH1*(Q(M,J)-Q(M,IJ)))/(A(I)**2.*X(I)
     1)
      Z6=(Q(N,IJ)+Q(N,J)-Q(M,IJ)-Q(M,J))/(2.*A(I)*DT)
   29 YVECT(L)=-(Z1+Z2*Z3+Z4+Z5+Z6)
   30 J = J+2
      IYYY=-(Q(N,5)-Q(N,2)-Q(N,4))
      YVECT(7)=IYYY
C**** COMPUTE MATRIX   ***************************************************
   31 XMTRX(7,4)=-1.
      XMTRX(7,6)=-1.
      XMTRX(7,7)=1.
      XMTRX(1,1)=                                   1./(2.*DT)
      XMTRX(2,1)=XMTRX(1,1)
      XMTRX(3,1)=XMTRX(1,1)
      XMTRX(1,4)=-TH/(T(1)*X(1))
      XMTRX(2,6)=-TH/(T(2)*X(2))
      XMTRX(3,2)=-TH/(T(3)*X(3))
      XMTRX(1,3)=-XMTRX(1,4)
      XMTRX(2,5)=-XMTRX(2,6)
      XMTRX(3,7)=-XMTRX(3, 2)
     0XMTRX(4,1)=-(32.2-QA(1)*U(1)*T(1)/(A(1)**3.))/ X(1)*TH -QA(1)*T(1)
     1/(2.*DT*A(1)**2.)
     0XMTRX(5,1)=-(32.2-QA(2)*U(2)*T(2)/(A(2)**3.))/ X(2)*TH -QA(2)*T(2)
     1/(2.*DT*A(2)**2.)
     0XMTRX(6,1)= (32.2-QA(3)*U(3)*T(3)/(A(3)**3.))/ X(3)*TH -QA(3)*T(3)
     1/(2.*DT*A(3)**2.)
      ZZZ1=ABS(QA(1))
     0P1=32.2*AN(1)**2.*ZZZ1 *TH/(2.2082*A(1)**2.*R(1)**(4./3.))-QA(1)
     1*T(1)/A(1)**3.*(TH*(WS(N,1)-WS(N,2))+TH1*(WS(M,1)-WS(M,2)))*TH/X(
     21)-TH*T(1)*(WS(N,1)+WS(N,2)-WS(M,1)-WS(M,2))/(4.*DT*A(1)**2.)+
     3TH*(TH*(Q(N,1)-Q(N,2))+TH1*(Q(M,1)-Q(M,2)))/(2.*A(1)**2.*X(1))
      ZZZ2=ABS(QA(2))
     0P2=32.2*AN(2)**2.*ZZZ2 *TH/(2.2082*A(2)**2.*R(2)**(4./3.))-QA(2)
     1*T(2)/A(2)**3.*(TH*(WS(N,1)-WS(N,2))+TH1*(WS(M,1)-WS(M,2)))*TH/X(
     22)-TH*T(2)*(WS(N,1)+WS(N,2)-WS(M,1)-WS(M,2))/(4.*DT*A(2)**2.)+
     3TH*(TH*(Q(N,3)-Q(N,4))+TH1*(Q(M,3)-Q(M,4)))/(2.*A(2)**2.*X(2))
      ZZZ3=ABS(QA(3))
     0P3=32.2*AN(3)**2.*ZZZ3 *TH/(2.2082*A(3)**2.*R(3)**(4./3.))-QA(3)
     1*T(3)/A(3)**3.*(TH*(WS(N,2)-WS(N,3))+TH1*(WS(M,2)-WS(M,3)))*TH/X(
     23)-TH*T(3)*(WS(N,2)+WS(N,3)-WS(M,2)-WS(M,3))/(4.*DT*A(3)**2.)+
     3TH*(TH*(Q(N,5)-Q(N,6))+TH1*(Q(M,5)-Q(M,6)))/(2.*A(3)**2.*X(3))
      XMTRX(4,3)=QA(1)*TH/(A(1)**2.*X(1))+1./(2.*A(1)*DT)+P1
      XMTRX(5,5)=QA(2)*TH/(A(2)**2.*X(2))+1./(2.*A(2)*DT)+P2
      XMTRX(6,7)=QA(3)*TH/(A(3)**2.*X(3))+1./(2.*A(3)*DT)+P3
      XMTRX(4,4)=-QA(1)*TH/(A(1)**2.*X(1))+1./(2.*A(1)*DT)+P1
      XMTRX(5,6)=-QA(2)*TH/(A(2)**2.*X(2))+1./(2.*A(2)*DT)+P2
      XMTRX(6,2)=-QA(3)*TH/(A(3)**2.*X(3))+1./(2.*A(3)*DT)+P3
  200 S1=-XMTRX(6,2)/XMTRX(3,2)
      S2=XMTRX(6,1)+S1*XMTRX(3,1)
      S3=XMTRX(6,7)+S1*XMTRX(3,7)
```

Figure A.1. Detroit River model (continued).

```
      S4=YVECT(6)+S1*YVECT(3)
      S5=-XMTRX(4,3)/XMTRX(1,3)
      S6=XMTRX(4,1)+S5*XMTRX(1,1)
      S7=XMTRX(4,4)+S5*XMTRX(1,4)
      S8=YVECT(4)+S5*YVECT(1)
      S9=-XMTRX(5,5)/XMTRX(2,5)
      S10=XMTRX(5,1)+S9*XMTRX(2,1)
      S11=XMTRX(5,6)+S9*XMTRX(2,6)
      S12=YVECT(5)+S9*YVECT(2)
  219 C(1)=(S8/S7+S12/S11-S4/S3)/(S6/S7+S10/S11-S2/S3)
      C(7)=S4/S3-S2/S3*C(1)
      C(4)=S8/S7-S6/S7*C(1)
      C(6)=S12/S11-S10/S11*C(1)
      C(2)=(YVECT(3)-XMTRX(3,7)*C(7)-XMTRX(3,1)*C(1))/XMTRX(3,2)
      C(3)=(YVECT(1)-XMTRX(1,4)*C(4)-XMTRX(1,1)*C(1))/XMTRX(1,3)
      C(5)=(YVECT(2)-XMTRX(2,6)*C(6)-XMTRX(2,1)*C(1))/XMTRX(2,5)
  253 WS(N,2) = WS(N,2) +C(1)
  260 Q(N,6)=Q(N,6)+C(2)
  265 Q(N,1) = Q(N,1) +C(3)
      Q(N,2) □ Q(N,2) . C(4)
      Q(N,3) = Q(N,3) . C(5)
      Q(N,4) = Q(N,4) . C(6)
      Q(N,5) = Q(N,5) . C(7)
   50 CONTINUE
      JB=N+1
      WS(JB,2)=2.*WS(N,2)-WS(M,2)
   51 Q(JB,6)=2.*Q(N,6)-Q(M,6)
      QT=Q(N,1)+Q(N,3)
      DEV=WS(N,2)-WS(N,4)
      MM=MM+1
      NM=MM-KKZ
      IF(NM)57,57,53
   53WRITE( NX,1045)NM,MON,WS(N,1),IPAR(1,NM), WS(N,2),
     1  YSCN.3). IPAR(3,NM),Q(N,1),Q(N,2),Q(N,3)
     2,Q(N,4),Q(N,5),Q(N,6),QT ,WS(N,4), IPAR(4,NM), DEV
      SUM(1)= SUM(1)+WS(N,1)
      SUM(2)= SUM(2)+WS(N,2)
      SUM(3)= SUM(3)+WS(N,3)
      SUM(4)= SUM(4)+Q(N,1)
      SUM(5)= SUM(5)+Q(N,2)
      SUM(6)= SUM(6)+Q(N,3)
      SUM(7)= SUM(7)+Q(N,4)
      SUM(8)= SUM(8)+Q(N,5)
      SUM(9)= SUM(9)+Q(N,6)
      SUM(10)=SUM(10)+QT
      SUM(11)=SUM(11)+WS(N,4)
      SUM(12)=SUM(12)+DEV
   57 DO 5B I=1,5
   58 Q(JB,I)=2.*Q(N,I)-Q(M,I)
       M=M+1
      IF( M-KB) 2333,2333,59
 2333  CONTINUE
      IF( NM-NDM) 23,59,59
```

Figure A.1. Detroit River model (continued).

```
   59 CONTINUE
   52 DO 65 I=1,12
   65 AVE(I)=SUM(I)/NM
      WRITE(NX,1060) (AVE(I),I=1,12)
      WRITE( NX,3000)
      IF(IYR-IYRB)3200,3300,3300
 3300 IF(MON-MONB)3200,60,60
 3200 IF(MON-12)3400,3100,3100
 3100 IYR=IYR+1
 3400 WRITE(NX,1020)IYR
      WRITE( NX,1021) ANC
      WRITE( NX.1026)
      DO 69 I=1,12
   69 SUM(I)=0.
      DO 63 I=1,6
      Q(1,I)=Q(N,I)
   63 Q(2,I)=Q(JB,I)
      WS(1,1)=WS(M,1)
      WS(1,2)=WS(M,2)
      WS(2,2)=WS(JB,2)
      WS(1,3)=WS(M,3)
C     UPDATE MONTH AND YEAR
      MON = MON+1
      IF( MON-13) 21001 2150.2150
 2150 MON=1
C     CHECK TO SEE IF ANY MORE DATA SHOULD BE PROCESSED
 2100 IF1 IYR-IYRB)2300,2200,60
 2200 IF( MON-MONB) 2300,2300,60
 2300 CONTINUE
      MM=0
      KKZ=0
      M=1
      KB=36
      ISTART = 2
      IEND = 32
      IFIRST = 1
      GO TO 2800
   60 WRITE( NX,3000)
      STOP
C**** FORMAT STATEMENTS **************************************************
 1020 FORMAT (/////37X,30H DETROIT RIVER TRANSIENT MODEL//50X, I4//)
 1021 FORMAT(39X,F5.1,1X,20HHOUR TIME INCREMENTS//)
 1025 FORMAT(24X,20HSTARTING ELEVATIONS,2X,17HWINDMILL POINT = , F6.2,
     1/46X,9HWYANDOTTE,6X,2H= ,F6.2,/46X,9HLAKE ERIE,6X,2H= ,F6.2//)
 10260FORMAT(7X,3HDAY,2X,3HMON,2X,4HERIE,5X,3HWYC,6X,2HWP,7X,3HQWE,6X,3H
     1QWW,6X,3HQTE,6X,3HQTW,6X,3HQWY,6X,3HQWP,6X,2HQE,6X,3HWYM,5X,3HDEV/
     2)
 1045 FORMAT(7X,I3,2X,I2,F8.2, A1,F8.2,F8.2,A1,
     2      7(F9.0), F8.2,A1,F6.2)
 1060 FORMAT(/7X,3HAVE,6X,F6.2,1X,2(2X,F6.2),1X,7(2X,F7.0),2X,F6.2,F7.2)
 3000 FORMAT(1H1)
      END
```

Figure A.1. Detroit River mode2 *(continued)*.

Table A.1. Detroit River Model January Output

DAY	MON	ERIE	WYC	UP	QWE	QWW	QTE
1	1	571.99	573.49	574.79	161723.	161723.	50638.
2	i	571.89	573.36	574.65	159030.	159225.	49916.
3	1	570.61	572.72	574.29	176557.	173023.	54187.
4	1	570.47	572.57	574.28	182034.	182663.	52088.
5	1	571.57	573.06	574.45*	164460.	167267.	48273.
6	1	571.61	573.28	574.66*	166185.	165734.	51600.
7	1	571.64	573.33	574.76	170613.	170916.	52254.
8	1	571.34	573.30	574.90	180125.	179400.	55366.
9	1	570.67	573.06	574.91	194083.	192595.	58250.
10	1	571.60	573.37	575.01	181683.	184527.	53299.
11	1	571.35	573.39	175.02	182600.	181223.	56795.
12	1	571.35	573.31	574.98	183800.	184111.	55355.
13	1	571.67	573.40	574.91	174309.	174985.	53188.
14	1	570.53	5'72.99	574.81	197590.	189419.	58900.
15	1	571.59	573.21	574.77	175559.	179040.	50657.
16	1	571.34	573.18	574.64	171053.	169370.	53369.
17	1	571.73	573.23	574.59	163685.	165079.	49282.
18	1	571.7:	573.27	574.58	161498.	161068.	50272.
19	1	571.56	573.15	574.49	162977.	162604.	50065.
20	1	511.35	573.01	574.38	164362.	163820.	50146.
21	1	571.29	572.96	574.35	165274.	165243.	49889.
2:	1	571.50	573.33	574.34	160241.	160784.	48461.
27	1	571.86	573.16	574.31	149856.	150613.	46002.
24	1	571.60	573.05	574.18	148955.	148159.	46335.
25	1	572.11	573.17	574.11	135980.	137323.	41881.
2h	1	571.45	572.34	574.12	152218.	150056.	47843.
27	1	571.52	572.91	574.11	152257.	153028.	45854.
28	1	571.51	'372.93	574.12	152043.	151810.	46567.
29	1	571.3'1	572.87	574.1:	156037.	155747.	47453.
30	1	571.30	573.55	574.17	147047.	148293.	44654.
31	1	571.5'	572.89	574.00	147012.	145772.	45621.
AVE		571.46	573.12	574.51	165692.	165633.	50466.

Table A.1. Detroit River Model *January Output* (continued)

DAY	MON	QTW	QWY	QWP	QE	WYM	PEV
1	1	50638.	212361.	212361.	212361.	573.42	.07
2	1	49766.	208991.	208344.	209546.	573.33	.05
3	1	52875.	225898.	223522.	230744.	572.60	.12
4	1	52322.	234985.	235370.	234122.	572.54	.03
5	1	49315.	216582.	21814 0.	212733.	573.11	-.05
b	1	51433.	217166.	217734.	217785.	573.46	-.18
7	1	52366.	223282.	223528.	222666.	573.65	-.32
8	1	55097.	234497.	234649.	235490.	573.651	-.39
9	1	57698.	250204.	249651.	252334.	573.36	-.30
10	1	5435';.	238882.	240139.	234982.	573.51	-.14
11	1	56284.	237507.	237175.	239395.	573.4'	-.04
12	1	55470.	239581.	239390.	239155.	573.33	-.02
13	1	53440.	228425.	228'43.	227497.	573.44	-.04
14	1	57723.	247142.	245792.	251490.	573.01	-.02
15	1	51949.	230989.	231894.	226215.	573.29	-.08
16	1	52744.	222115.	221416.	224422.	573.29	-.11
17	1	49800.	214879.	215110.	212967.	573.29	-.0h
18	1	50112.	211180.	211175.	211770.	573.21	.o 6
19	1	49926.	212531.	211790.	213042.	573.14	.01
20	1	49045.	213766.	213705.	214508.	573.12	-.11
21	1	49877.	215120.	215065.	215163.	573.22	-.26
22	1	48662.	209446.	209618.	20870:.	573.36	-.33
23	1	"6283.	196896.	157105.	195858.	573.44	-.28
24	1	46039.	194198.	193499.	195289.	573.30	-.25
25	1	42380.	179703.	180136.	177862.	573.41	-.24
26	1	47040.	197096.	196330.	200060.	573.15	-.21
27	1	46141.	199169.	149313.	198111.	573.11	-.20
28	1	46481.	198291.	198326.	198611.	573.07	-.14
29	1	47345.	203093.	202969.	203490.	572.99	-.12
30	1	45117.	103410.	194004.	191701.	573.14*	-.09
31	1	45160.	190932.	189879.	192633.	573.14E	-.25
AVE		50445.	216078.	215983.	216158.	573.24	-.12

Table A.2. Detroit River Model February Output

DAY	MON	ERIE	WYC	WP	QWE	QWW	QTE
1	2	571.38	572.72	573.84	146487.	146292.	44367.
2	2	571.00	572.53	573.75	152739.	151724.	46018.
3	2	571.53	572.67	573.70	138976.	140596.	41216.
4	2	571.31	572.58	573.61	139719.	138589.	42827.
5	2	571.77	572.76	573.66	129822.	131411.	39064.
6	2	571.33	572.64	573.69	141666.	140073.	43807.
7	2	570.95	572.46	573.68	152100.	151566.	45367.
8	2	570.85	572.39	573.65	153925.	153789.	45354.
9	2	571.46	572.67	573.76	142863.	144602.	42276.
10	2	571.34	572.62	573.67	141180.	140273.	43166.
11	2	571.06	572.46	573.60	146731.	146190.	43969.
12	2	571.38	572.61	573.68	141681.	142759.	42168.
13	2	571.40	572.70	573.78	143558.	143400.	43642.
14	2	571.53	572.84	573.96	146539.	147104.	44401.
15	2	571.32	572.80	574.01	153150.	152486.	46722.
16	2	571.76	573.08	574.26	151105.	152698.	45690.
17	2	571.45	573.13	574.50	165081.	164060.	51196.
lb	2	571.84	573.35	574.71	164132.	165635.	49897.
19	2	571.34	573.26	574.70	176197.	174566.	54845.
20	2	571.99	573.54	574.97	169712.	172016.	51341.
21	2	572.16	573.74	575.11	167386.	167333.	53123.
22	2	571.85	573.70	575.25	179304.	178644.	56466.
23	2	571.98	573.10	575.21	176083.	176556.	54714.
24	2	572.06	573.74	575.19	172922.	172984.	54387.
25	2	572.15	573.75	575.15	169591.	169764.	53407.
26	2	572.18	513.74	575.10	166968.	166950.	52824.
27	2	572.22	573.71	575.02	163403.	163432.	51709.
28	2	572.15	573.68	575.01	164573.	164376.	52144.
2"	2	572.26	573.12	575.01	162170.	162512.	51220.
AVE		571.62	573.08	574.32	155854.	155944.	47839.

Table A.Z. Detroit River Model February Output (continued)

DAY	MON	QTW	QWY	QWP	QE	WYM	DEV
1	2	44295.	190587.	190092.	190855.	573.14F	-.42
2	2	45641.	197364.	196814.	198757.	573.14E	-.61
3	2	41817.	182413.	182841.	180192.	572.67*	.oo
4	2	42408.	180997.	180391.	182546.	572.58	.00
5	2	39654.	171065.	171852.	168886.	572.82	-.06
6	2	43216.	183289.	182795.	185473.	512.62	.02
7	2	45169.	196735.	196409.	197467.	572.4:	.01
8	2	45304.	199093.	198958.	199279.	572.39	.00
9	2	42922.	187524.	188572.	185140.	572.74	-.07
10	2	42829.	183101.	182386.	184346.	572.76	-.14
11	2	43769.	189959.	189598.	190700.	572.61	-.15
12	2	4256H.	185327.	186043.	183650.	572.7:	-.12
13	2	43583.	186983.	187220.	187200.	512.72	-.02
14	2	44611.	191716.	192456.	190940.	572.83	.01
15	2	46476.	198962.	198740.	199872.	572.77	.03
16	2	46281.	198979.	200417.	196794.	573.09	-.01
17	2	50817.	214877.	215143.	216278.	573.13	.00
18	2	50455.	216091.	217108.	214029.	573.39	-.04
19	2	54240.	228806.	228426.	231042.	573.18	.08
20	2	52196.	224213.	225510.	221052.	573.48*	.06
21	2	53104.	220437.	220891.	220509.	573.48E	.26
22	2	56221.	234865.	234950.	235770.	573.48E	.22
23	2	54890.	231446.	231324.	230797.	573.48E	. 22
24	2	54410.	127394.	227475.	227309.	573.48E	.26
25	2	53471.	223235.	223137.	222098.	573.71*	.04
26	2	"2817.	219767.	219648.	215752.	573.69	.05
27	2	51720.	215152.	214916.	215112.	573.67	.04
28	2	52070.	216446.	216426.	216716.	573.60	.08
29	2	51347.	213859.	213958.	213390.	573.69	.03
AVE		47872.	203817.	203948.	203693.	573.09	-.01

Table A.3. Detroit River Model March Output

DAY	MON	ERIE	WYC	UP	QWE	QWW	QTE
1	3	573.07	574.18	575.26	148783.	151084.	47727.
3	3		574.48	575.48	144833.	145256.	48454.
?	3	573.40 572.73	574.28	575.61*	168316.	166528.	56207.
4	3	572.78	574.26	575.61E	168404.	169054.	54378.
5	3	571.67	573.51	575.07*	176389.	172765.	5703:.
6	3	572.03	573.71	575.35	180191.	182453.	54999.
7	3	571.82	573.72	575.30	181165.	179927.	57348.
8	3	572.80	574.20	575.57	168880.	172050.	52749.
9	3	573.12	574.42	575.51	157476.	157447.	52313.
10	3	572.68	574.17	575.47	165262.	163970.	54493.
11	3	572.98	574.27	575.48	158759.	159945.	51396.
12	3	573.21	574.36	575.42	149029.	149239.	49424.
13	3	571.68	573.60	575.09	176679.	172268.	57945.
14	3	572.45	573.77	575.07	161615.	164868.	49193.
15	3	572.84	574.15	575.32	155948.	156321.	51013.
16	3	572.51	573.39	575.28	163691.	162643.	53311.
17	3	572.11	573.74	575.12	168797.	167901.	53866.
16	3		574.04	375.20	153752.	156038.	48642.
19	3	572.85 572.72	574.02	575.14	152579.	151517.	50305.
2s	3	572.06	574.02	575.09	148043.	148669.	47906.
21	3	571.96	573.61	574.95	166140.	163452.	53983.
22	3	572.95	574.07	575.20	151526.	155163.	47262.
23	3	572.83	574.10	575.19	150845.	145463.	50257.
24	3	572.80	574.00	575.10	140997.	150220.	46643.
25	3	572.73	574.07	575.26	156961.	156882.	51225.
26	3	573.01	574.18	575.21	150153.	150520.	48878.
27	3	572.20	573.76	575.05	163308.	160726.	53538.
28	3	573.11	574.21	575.33	150971.	154413.	47688.
29	3	573.27	574.41	575.44	147071.	146554.	49460.
30	3	572.03	574.16	575.2'1	150860.	149885.	50015.
31	3	572.84	574.11	575.26	154033.	154104.	50342.
AVC		572.68	574.05	575.28	159368.	159410.	51613.

Table A.3. Detroit River Model March Output (continued)

DAY	MON	QTW	QWY	QWP	QE	WYM	DEV
1	3	48581.	199664.	201453.	196509.	574.10	.08
2	3	48611.	193867.	194593.	193287.	574.46	.02
3	3	55544.	222071.	221655.	224523.	574.17	.11
4	3	54619.	223674.	223758.	222782.	574.24	.02
5	3	55690.	228455.	225294.	233425.	573.57	.00
6	3	55838.	238291.	240560.	235190.	573.01	-.04
7	3	56868.	236815.	235815.	238513.	573.59	.13
8	3	53925.	225976.	228208.	221629.	574.20	-.00
9	3	52302.	209749.	209623.	209789.	574.36	.06
10	3	54014.	217984.	217092.	219755.	574.10	.07
11	3	51836.	211781.	212755.	210155.	574.21	.06
12	3	49507.	198741.	198625.	198453.	5.74.39	-.03
13	3	56308.	226576.	225834.	234624.	573.47	.13
14	3	50400.	215269.	216566.	210808.	573.79	-.02
15	3	51152.	207472.	208644.	206961.	574.06	.09
16	3	52972.	215565.	214671.	217002.	573.93	.06
17	3	53533.	221434.	220668.	222663.	573.61	.13
18	3	49490.	205528.	206775.	202393.	574.05	-.01
19	3	49910.	201427.	200785.	202884.	573.95	.07
20	3	48140.	196809.	196904.	195450.	574.01	.01
21	3	5298G.	216437.	215008.	220123.	573.48	.13
22	3	48612.	203775.	206053.	198788.	574.09	-.02
23	3	49744.	199207.	198500.	201102.	574.02	.08
24	3	48726.	198946.	198709.	198640.	573.38	.02
25	3	51195.	708077.	208737.	208186.	573.99	.08
26	3	49163.	200083.	200170.	199031.	574.16	.02
27	3	52579.	213305.	211650.	216846.	573.72	.04
28	3	48966.	203379.	205798.	198659.	574.20	.01
29	3	49287.	195841.	195623.	196481.	574.35	.06
30	3	49653.	199538.	198405.	200875.	574.12	.04
31	3	50368.	204472.	204763.	204375.	574.05	.06
AVE		51629.	211039.	211080.	210981.	574.01	.05

Table A.4. Detroit River Model April *Output*

DAY	MON	ERIE	WYC	WP	QWE	QWW	QTF
1	4	572.54	573.97	575.22	160814.	159956.	523RY.
2	4	572.77	574.08	575.2"	157517.	158435.	50665.
3	4	573.16	574.32	575.41	150446.	151347.	49395.
4	4	573.14	574.41	575.56	1 5 5659.	155484.	51828.
5	4	572.77	574.15	575.37	159581.	158454.	52666.
6	4	572.88	574.20	575.42	158962.	159641.	51636.
7	4	572.98	574.27	575.44	156529.	156615.	51454.
8	4	572.94	574.25	575.43	157150.	157007.	51717.
9	4	572.92	574.20	57" 5.36	155412.	155330.	51002.
10	4	572.76	574.10	575.2"	157258.	156790.	51505.
11	4	572.76	574.17	i75.44	162704.	162994.	52887.
12	4	572.7'7	574.13	5'75.36	159800.	159655.	5207b.
13	4	572.64	574.14	575.32	156429.	156621.	50985.
14	4	572.86	574.16	575.33	156035.	156042.	51049.
15	4	572.78	574.07	575.26	155815.	155529.	5092:.
1b	4	572.82	574.1,'	575.31	156571.	156814.	50991.
17	4	572.85	574.14	575.30	155336.	155333.	50771.
18	4	572.85	574.12	575.27	154226.	154198.	50426.
1"	4	572.76	574.09	575.27	156655.	156426.	51167.
20	4	572.96	574.20	575.34	153871.	154539.	50139.
21	4	572.97	574.21	575.32	152347.	152157.	50215.
22	4	572.50	573.92	575.14	158987.	157617.	51989.
23	4	572.86	574.14	575.34	157228.	158707.	50446.
24	4	573.66	574.63	575.59	141860.	143792.	47104.
25	4	573.71	574.88	575.96	152492.	152407.	52211.
26	4	572.70	574.2"	575.63	163514.	166514.	57143.
27	4	572.63	574.20	575.62	172537.	173232.	55387.
28	4	572.72	574.26	575.63	170367.	170410.	55381.
29	4	572.83	574.29	575.62	167159.	167426.	54440.
30	4	573.01	574.35	575.58	160881.	161241.	52756.
AVE		572.89	574.22	575.41	158005.	158026.	51758.

Table A.4. Detroit River Model April Output (continued)

DAY	MON	QTW	GUY	QWP	QF	WYM	DEV
1	4	52070.	212026.	211470.	213203.	573.91	.06
2	4	51006.	209441.	210045.	208181.	574.00	.08
3	4	49730.	201076.	201837.	199841.	57'4.26	.06
4	4	51763.	207247.	207597.	207487.	574.30	.11
5	4	"2248.	210702.	205450.	212247.	574.04	.06
6	4	51888.	211529.	212202.	210598.	574.14	.06
7	4	51486.	208101.	208092.	207984.	574.20	.07
6	4	51664.	208671.	208597.	208866.	574.16	.09
9	4	50972.	206302.	206025.	206413.	574.14	.06
10	4	51332.	208122.	207777.	208763.	574.02	.08
11	4	5299:.	215989.	216667.	215591.	574.07	.10
12	4	52022.	211677.	211156.	211876.	574.08	.05
13	4	51057.	207678.	207765.	207414.	574.08	.06
14	4	'1051.	207094.	207136.	207084.	574.10	.06
15	4	50819.	206348.	205978.	206740.	574.05	.04
1b	4	51081.	207895.	208242.	207562.	574.07	.06
17	4	50769.	206102.	205988.	206107.	574.09	.05
18	4	50416.	204613.	204535.	204652.	574.07	.05
19	4	51082.	207508.	207442.	207822.	574.01	.08
20	4	50387.	204926.	205412.	204011.	574.13	.07
21	4	50144.	202301.	202106.	202561.	574.16	.05
22	4	51480.	209096.	207971.	210576.	573.86	.06
23	4	51024.	209812.	211263.	207674.	574.10	.04
24	4	47821.	191613.	193026.	188964.	574.58	.05
25	4	52180.	204587.	205687.	204703.	574.80	.08
26	4	56029.	222544.	219836.	226656.	574.18	.11
27	4	55645.	228877.	229522.	227525.	574.12	.08
28	4	"5397.	225807.	22575R.	225748.	574.19	.07
29	4	54539.	221965.	222054.	221599.	574.23	.06
30	4	52890.	214131.	214144.	213638.	574.31	.04
AVE		51766.	209793.	209826.	209763.	574.15	.07

Table A.5. Detroit River Model May Output

DAY	MON	ERIE	WYC	WP	QWE	QWW	QTE
1	5	572.91	574.29	575.52	160988.	160560.	53113.
	5	572.48	574.03	575.37	167299.	166140.	54559.
3	5	572.08	573.80	575.26	174051.	173235.	55445.
4	5	572.6".	574.134	575.32	162545.	164407.	51315.
	5	572.61	573.99	575.19	157750.	156006.	51555.
6	5	573.18	574.48	575.72	161459.	163745.	52328.
7	5	572.90	574.44	575.78	160574.	168211.	56663.
8	5	572.79	574.33	575.72	171455.	171498.	55893.
9	5	572.77	574.32	575.71	171509.	171439.	56002.
10	5	572.87	574.34	575.68	168155.	168406.	54868.
11	5	572.82	574.36	575.73	170675.	170525.	55972.
12	5	572.96	574.38	575.68	165839.	166196.	54228.
1:	5	573.15	574.45	575.64	158869.	159235.	52470.
14	5	572.89	574.30	575.55	162326.	161439.	53822.
15	5	573.30	574.53	575.64	155068.	156508.	50855.
16	5	572.98	574.38	575.61	161520.	160218.	54129.
17	5	572.89	574.34	575.65	166373.	166554.	54445.
18	5	572.90	574.3'	575.61	165026.	164969.	54153.
19	5	512.57	574.13	575.48	168612.	167640.	55126.
20	5	572.71	574.16	575.49	166321.	166989.	53547.
21	5	572.89	574.30	575.56	164073.	164448.	53580.
22	5	572.97	574.34	575.58	161777.	161875.	53146.
23	5	572.96	574.34	575.59	1622313.	162165.	53406.
24	5	573.01	574.35	575.58	160643.	160777.	52852.
25	5	572.93	574.12	575.56	161894.	161624.	53371.
26	5	572.00	574.27	575.51	161246.	161195.	52880.
27	5	573.01	574.31	575.50	157916.	1513216.	51840.
28	5	573.03	574.34	575.52	1577'6.	157742.	52080.
29	5	573.12	574.38	575.54	156647.	156309.	51527.
30	5	573.08	574.37	575.54	156908.	156725.	52032.
31	5	572.95	574.32	575.55	160952.	160670.	53120.
AVE		572.88	574.29	575.56	163447.	163438.	53559.

Table A.5. Detroit River Model May Output (continued)

DAY	NON	QTW	QWY	QWP	QE	WYM	DEV
1	5	52954.	213514.	213198.	214101.	574.23	.06
2	5	54129.	220269.	219'37.	221858.	574.01	.02
3	5	55143.	228378.	227810.	229496.	573.66	.14
4	5	52007.	216414.	217367.	213860.	574.00	.04
5	5	51242.	208148.	207376.	209305.	573.04	.05
6	5	53176.	216921.	219775.	213787.	574.40	.08
7	5	56157.	224368.	223475.	226237.	574.37	.07
'8	5	55909.	227406.	227277.	227348.	574.28	.05
9	5	55976.	227415.	227409.	227511.	574.27	.05
10	5	54961.	223367.	223344.	223022.	574.29	.05
11	5	55916.	226441.	226615.	226647.	57'1.27	.09
12	5	'4361.	220557.	220426.	220068.	574.32	.0b
13	5	52606.	211842.	211951.	211339.	574.40	.05
14	5	53493.	214932.	214300.	216147.	574.24	.06
15	5	51390.	207898.	208833.	205923.	574.45	.05
16	5	53645.	213862.	213184.	215649.	574.30	.08
17	5	54513.	721067.	221284.	220818.	574.26	.08
18	5	54132.	219101.	218932.	219179.	574.24	.09
19	5	54758.	222398.	2215713.	223758.	574.03	.10
20	5	53794.	220783.	221178.	219868.	574.09	.07
21	5	53719.	218167.	218610.	217653.	574.22	.08
22	5	53182.	215057.	215005.	214923.	574.27	.07
23	5	53390.	215555.	215609.	215615.	574.27	.07
24	5	52901.	213678.	213667.	213494.	574.28	.07
25	5	53271.	214895.	214749.	215265.	574.25	.07
26	5	52861.	214056.	213863.	214126.	574.20	.07
27	5	51951.	210167.	210304.	209756.	574.26	.05
28	5	52075.	209817.	209886.	209836.	574.28	.06
29	5	51625.	207934.	208078.	207575.	574.33	.05
30	5	51964.	208689.	208614.	208940.	574.31	.06
31	5	53024.	213695.	213615.	214081.	574.25	.07
AVE		53556.	316993.	216489.	217006.	574.22	.07

Table A.6. Detroit River Model June Output

DAY	MON	ERIE	WYC	WP	QWE	QWW	GTE
1	6	573.01	574.37	575.61	161699.	162000.	53128.
^	4	573.07	574.40	'275.62	160249.	160329.	52971.
3	6	573.11	574.42	575.62	159070.	159152.	52640.
4	6	573.03	574.38	575.59	160118.	159851.	53022.
	6	572.95	574.32	575.55	161089.	160916.	53064.
6	6	572.83	574.25	575.52	163321.	163026.	53595.
7	6	572.82	574.22	575.45	162838.	162867.	53152.
4	6	572.78	574.20	575.48	163443.	163320.	53386.
9	6	572.8:	574.21	575.47	162211.	162342.	52879.
10	6	572.81	574.18	575.41	160278.	160154.	52379.
11	6	572 .59	574.10	575.4:	166256.	165725.	54144.
12	4	573.24	574.40	575.52	153154.	155128.	49664.
13	h	572.84	574.23	575.43	158960.	157232.	53184.
14	6	572.78	574.13	575.36	159711.	159985.	51797.
15	6	572.70	574.3"	575.32	160046.	159721.	52200.
16	6	572.56	574.07	575.40	166581.	166387.	53943.
17	6	572.80	574.20	575.48	163561.	164326.	52825.
18	6	572.88	574.24	575.46	160047.	160018.	52444.
19	6	572.81	574.25	575.54	164558.	164462.	5'874.
20	6	572.78	574.25	575.56	166260.	166225.	54242.
21	6	572.90	574.30	575.57	163547.	163884.	53394.
22	6	572.94	574.30	575.53	160800.	160768.	52836.
23	6	572.81	574.24	575.51	143471.	163117.	57644.
24	6	572.83	574.24	575.52	163643.	163809.	53366.
25	6	572.57	574.14	575.51	169666.	168925.	55360.
26	6	572.65	574.14	575.48	147499.	167890.	53930.
27	6	572.78	574.21	575.50	164375.	164630.	53441.
28	6	572.76	574.20	575.40	164359.	164220.	53631.
29	6	572.77	574.21	575.51	164876.	164963.	53688.
30	6	572.77E	574.21	575.51E	164836.	164810.	53740.
AVE		572.83	574.24	575.50	162684.	162673.	53184.

Table A.6. Detroit River Model June Output (continued)

DAY	MON	QTW	QWY	Q4P	QE	WYM	DEV
1	6	53240.	215239.	215545.	214827.	574.32	.05
2	6	52961.	213289.	213393.	213180.	574.33	.07
3	6	52670.	211823.	211864.	211709.	574.37	.05
4	6	52923.	212774.	212567.	213140.	574.32	.06
5	6	52995.	213915.	213733.	214153.	574.29	.03
6	6	53485.	216511.	216326.	216916.	574.20	.05
7	6	5316.3.	'16030.	215948.	215990.	574.17	.05
8	6	"3341.	216661.	216613.	216829.	574.14	.06
9	6	52927.	215269.	215.377.	215090.	574.15	.06
10	6	53333	212488.	212249.	212657.	574.1;	.06
11	6	53947.	219671.	219567.	220400.	574.64	.06
12	6	50397.	205525.	206574.	202818.	574.40	-.00
13	6	52543.	209775.	208776.	212144.	574.18	.05
14	6	51899.	211884.	211784.	211508.	574.09	.04
15	6	52079.	211799.	211620.	212245.	574.06	.03
16	6	E-3871.	220258.	220472.	220524.	574.03	.04
17	6	53108.	217434.	217897.	216386.	574.17	.03
18	6	52433.	212451.	212345.	212492.	574.21	.03
19	6	53838.	218300.	218576.	218432.	574.21	.04
20	6	54229.	220454.	220400.	220502.	574.22	.03
21	6	53519.	217'104.	217579.	216942.	574.25	.05
22	6	52824.	213592.	213438.	213636.	574.26	.04
23	6	53513.	216630.	216472.	217115.	574.20	.04
24	6	53427.	217236.	217327.	217000.	574.27	-.03
25	6	55085.	274009.	223694.	225026.	574.07	.07
26	6	54075.	221964.	221982.	221429.	574.10	.04
27	6	53536.	218165.	218397.	217Plt.	574.17	.04
28	6	53579.	217800.	217675.	217990.	574.16	.04
29	6	53720.	218684.	218806.	218564.	574.16	.05
30	6	53730.	218540.	218504.	218576.	574.16E	.05
AVE		53160.	215852.	215844.	215868.	574.1"	.04

APPENDIX B. St. Clair River Transient Model, Input, and Output, 1959-1961, 720.00-hr Increments

Starting elevations:	Fort Gratiot	= 575.94
	MBR	= 575.71
	St. Clair	= 574.43

```
      PROGRAM  SCRFLO    (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C****  UPPER  ST. CLAIR  RIVER  UNSTEADY  FLOU  MODEL  **********************
C      FRANK  H. QUINN  PROGRAMMER
C      REVISED  NOVEMBER  1976    JOHN  HAGMAN
      DIMENSION B(3),WS(25,4),Q(25,3),YVECT(4),C(4),XMTRX(4,4)
      DIMENSION  T(2),X(2),AN(2),A(2),U(3),R(2),QA(2),XMV(4,4),CORR(3)
      MX=5
      NX=6
      WRITE( NX,3000)
      NVAR   =  4
C****  READ  TIME  INCREMENT,  BEGINNING  YEAR  AND  COMMENT  IN  65-80 . *****
    1  READ  (MX,1010) ANC,IYRB,(B(I),I=1,3)
C****  READ  GAGE  CORRECTIONS  IF  NEEDED  *******************************
      READ  (MX,1002)(CORR(I),I=1,3)
C****  DEFINE  CALIBRATED  ROUGHNESS  FOR  LOWER  REACH   . ****************
      TH=.75
      TH1=.25
      AN(1)= .0205
      IYR=IYRB
      MM=-12
C****  READ  UATERLEVELS  FIRST  DOUNXTREAM,  THEN  UPSTREAM    . ********t*
C****  ST. CLAIR  IS  DOWNSTREAM  AND  FORT  GRATIOT  IS  UPSTREAM  GAGE  *****
    4 DO  5  I=1,3,2
      M=13
      KA=24
      READ( MX,1015)ICODE,(WS(J,I),J=M,KA)
    2 DO  6  J=M,KA
    6 WS(J,I)=WS(J,I)+CORR(I)
    7 M  =  KA  +1
    5  KA  =  M  +11
      KA  =  KA  -12
C****  READ  THE  MIDSTREAM  GAGE  LEVEL  AT  MBR    ***********************
      READ( MX,1015)ICODE,(WS(J,4),J=13,24)
      CO  9  J=13,24
    9 WS(J,4)=WS(J,4)+CORR(2)
      DO  8 I=1,12
      WS(I,1)=WS(13,1)
      WS(I,4)=WS(13,4)
    8 WS(I,3)=WS(13,3)
      WS(1,2)=WS(1,4)
C****  PRINT  TITLES  AND  HEADINGS        ********************************
   10  WRITE( NX,1020)(B(I),I=1,3)
      WRITE( NX,1021)ANC
      WRITE( NX,1025)WS(1,3),WS(1,2),WS(1,1)
      WRITE( NX,1026)
      DT=ANC*3600.
C****  INITIALIZE  MATRIX    *********************************************
      DO  20  I  = 1,NVAR
      DO  20  J  = 1,NVAR
   20   XHTRX  (I,J) =  0.
C****  DEFINE  CONSTANT  CHANNEL  PARAMETERS    ****************************
C****  DEFINE  CHANNEL  WIDTHS      ***************************************
      T(1)=1930.
```

Figure B.2. St. Clair River model.

```
      T(2)=1550.0
      X(1)=60410.0
      X(2)=12560.0
      M=1
C**** COMPUTE INITIAL CONDITIONS ************************************
      A(1)=51205.0  +T(1)*(.50*(WS(M,1)+WS(M,2))-574.5)
      A(2)=51140.0  +T(2)*(.50*(WS(M,3)+WS(M,2))-576.3)
      R(1)=A(1)/T(1)
      R(2)=A(2)/T(2)
C**** DEFINE CALIBRATED ROUGHNESS FOR UPPER REACH ******************
      AN(2)=.00057  *WS(M,3)-.294
      Q(1,1)        =1.486*A(1)*R(1)**(2./3.)*(WS(1,2)-WS(1,1))**.5/AN(1)
     1/X(1)**.5
      Q(1,2)=Q(1,1)
      Q(1,3)=        1.486*A(2)*R(2)**(2./3.)*(WS(1,3)-WS(1,2))**.5/AN(2)
     1/X(2)**.5
      WS( 2.2) = WS(1,2)
   36 DO 18 I=1,3
   la Q(2,I)=Q(1,I)
      KB=KA-1
      M=1
   23 CONTINUE
      N = M+l
      LL=1
   21 CONTINUE
      QA(1)=TH/2.*(Q(N,1)+Q(N,2))+TH1/2.*(G(M,1)+Q(M,2))
      QA(2)=TH/2.*(Q(N,2)+Q(N,3))+TH1/2.*(Q(M,2)+Q(M,3))
      U(1)=ABS (QA(1))
      U(2)=ABS (QA(2))
C**** COMPUTE AREAS AND HYDRAULIC RADIUS ***************************
     0A(1)=51205.0 +T(1)*(TH/2.*(WS(N,1)+WS(N,2))+TH1/2.*(WS(M,1)+WS
     1(M,2))-574.5)
     0A(2)=51140.0 +T(2)*(TH/2.*(WS(N,3)+WS(N,2))+TH1/2.*(WS(M,3)+WS
     1(M,2))-576.3)
C**** DEFINE CALIBRATED ROUGHNESS FOR UPPER REACH  • *********..tt*ttt
      AN(2)=.00057  • WS(Pr3,-.294
      DO 24 I=1,2
   24 R(I)=A(I)/T(I)
      A1=77800.+3080.*(TH*WS(N,1)+TH1*WS(M,1)-574.1)
      A2=76000.+2630.*(TH*WS(N,2)+TH1*WS(M,2)-575.9)
      A3=57500.+1800.*(TH*WS(N,3)+TH1*WS(M,3)-576.8)
C**** COMPUTE Y VECTORS * ******************************************
C     CONTINUITY EQUATIONS          REACH 1 THEN REACH 2
C
     0YVECT(2)=-((WS(N,1)+WS(N,2)-WS(M,1)-WS(M,2))/(2.*DT)+(TH*(Q(N,1)-Q
     1(N,2))+TH1*(Q(M,1)-Q(M,2)))/(T(1)*X(1)))
     0YVECT(4)=-((WS(N,2)+WS(N,3)-WS(M,2)-WS(M,3))/(2.*DT)+(TH*(Q(N,2)-Q
     1(N,3))+TH1*(Q(M,2)-Q(M,3)))/(T(2)*X(2)))
C
C     EQUATIONS OF MOTION          REACH 1 AND THEN REACH 2
C
     0Z42=-QA(2)*T(2)*(WS(N,3)+WS(N,2)-WS(M,3)-WS(M,2))/(2.*DT*A(2)**2.)
     1*2.
```

Figure B.2. St. Clair River model (continued).

```
     0Z41=-QA(1)*T(1)*(WS(N,2)+WS(N,1)-WS(M,2)-WS(M,1))/(2.*DT*A(1)**2.)
     1*2.
      Z61=(Q(N,1)+Q(N,2)-Q(M,1)-Q(M,2))/(2.*DT*A(1))
      Z62=(Q(N,2)+Q(N,3)-Q(M,2)-Q(M,3))/(2.*DT*A(2))
      Z11=32.2*AN(1)**2.*QA(1)*U(1)/(2.2082*A(1)**2.*R(1)**(4./3.))
      Z12=32.2*AN(2)**2.*QA(2)*U(2)/(2.2082*A(2)**2.*R(2)**(4./3.))
      Z21=32.2*(TH*(WS(N,1)-WS(N,2))+TH1*(WS(M,1)-WS(M,2)))/X(1)
      Z22=32.2*(TH*(WS(N,2)-WS(N,3))+TH1*(WS(M,2)-WS(M,3)))/X(2)
      Z31=-(QA(1)**2.*(A1-A2)/(A(1)**3.*X(1)))
      Z32=-(QA(2)**2.*(A2-A3)/(A(2)**3.*X(2)))
      YVECT(1)=-(Z11+Z21+Z31+Z41+Z61)
      YVECT(3)=-(Z12+Z22+Z32+Z42+Z62)
C**** COMPUTE  MATRIX    ***********************************************
C**** NOTE.   PRIMARY  DIAGONAL  VALUES  MUST  BE  NON  ZERO     . *+**********
      XMTRX(4,1)=1./(2.*DT)
      XMTRX(2,1)=1./(2.*DT)
      XMTRX(2,3)=-TH/(T(1)*X(1))
      XMTRX(4,4)=-TH/(T(2)*X(2))
      XMTRX(2,2)=-XMTRX(2,3)
      XMTRX(4,3)=-XMTRX(4, 4)
     0XMTRX(1,1)=-(32.2-QA(1)**2.*2180. /(A(1)**3.))/X(1)*TH -QA(1)*T(1)
     1/(DT*A(1)**2.)
     0XMTRX(3,1)= (32.2-QA(2)**2.*2180. /(A(2)**3.))/ X(2)*TH-QA(2)*T(2)
     1/(DT*A(2)**2.)
      ZZZ1=ABS(QA(1))
     0P1=32.2*AN(1)**2.*ZZZ1 *TH/(2.2082*A(1)**2.*R(1)**(4./3.))-QA(1)
     1      /A(1)**3.*(                        A1-A2                    )*TH/X(
     21)-TH*T(1)*(WS(N,1)+WS(N,2)-WS(M,1)-WS(M,2))/(2.*DT*A(1)**2.)
      ZZZ2=ABS(QA(2))
     0P3=32.2*AN(2)**2.*ZZZ2 *TH/(2.2082*A(2)**2.*R(2)**(4./3.))-QA(2)
     1      /A(2)**3.*(                        A2-A3                    )*TH/X(
     22)-TH*T(2)*(WS(N,2)+WS(N,3)-WS(M,2)-WS(M,3))/(2.*DT*A(2)**2.)
      XMTRX(1,2)=1./(2.*A(1)*DT)+P1
      XMTRX(3,3)=1./(2.*A(2)*DT)+P3
      XMTRX(1,3)=XMTRX(1,2)
      XMTRX(3,4)=XMTRX(3,3)
C**** INVERT  MATRIX     **********************************************
      DO  201  I=1,NVAR
      DO  201  J=1,NVAR
  201 XMV(I,J) = XMTRX(I,J)
      DO  214  K=1,NVAR
      DIV  = XMV(K,K)
      XMV(K,K) =  1.00
      DO  211  J=1,NVAR
  211 XMV(K,J) = XMV(K,J)/DIV
      DO  214  I=1,NVAR
      IF  (I-K) 212,214,212
  212 DIV  = XMV(I,K)
      XMV(I,K) =  0.00
      DO  213  J=1,NVAR
  213 XMV(I,J) = XMV(I,J)-DIV*XMV(K,J)
  214 CONTINUE
C**** COMPUTE   COEFFICIENTS     ******************************************
```

Figure B.2. St. Clair River model (continued).

```
  241 DO 251 I=1,NVAR
      C(I) = 0.00
      DO 251 J=1,NVAR
  2 5 1 C(I)=C(I)+XMV(I,J)*YVECT(J)
C**** ADJUST COMPUTED VALUES BY CORRECTION COEFFICIENTS   . ***********
  2 5 3 WS(N,2)= WS(N,2) +C(1)
  2 6 0 Q(N,1)=Q(N,1)+C(2)
  2 6 5 Q(N,2)= Q(N,2) +C(3)
      Q(N,3) = Q(N,3) + C(4)
      LL=LL+1
      IF(LL-5)21,21,50
   50 CONTINUE
      JB=N+1
      WS(JB,2)=2.*WS(N,2)-WS(M,2)
   5 1 Q(JB,3)=2.*Q(N,3)-Q(M,3)
C**** COMPUTE DEVIATION BETYEEN COMPUTED AND MEASURED LEVEL AT HID GAGE*
      DEV=WS(N,2)-WS(N,4)
      MM=MM+1
C**** THE FIRST TUELVE ITERATIONS ARE TO LET THE MODEL STAEILIZE   . ****
      I F(MM)252,5 4 1 5 5 3
  553 CONTINUE
C**** CHECK FOR  END OF PAGE ROOM AND PRINT TITLES ON NEY PAGE .  *****'*
      IF((MM/24)*24-MM)53,52,53
   5 2 WRITE(NX,3000)
      WRITE( NX,1020)(B(I),I=1,3)
      WRITE( NX,1021)ANC
      WRITE(NX.1026)
C**** ALLOY PRINTOUT TO SKIP THE FIRST TUELVE ITERATIONS ************
   5 3 I F(M-12)55,55,54
   5 4 MON=M-11
      IF(MON-1)254,254,255
  2 5 4 WRITE(NX,1046)IYR,WS(N,1),WS(N,2),WS(N,3),Q(N,1),Q(N,2),Q(N,3),
     1WS(N,4),DEV
      GO TO 252
  255 CONTINUE
      URITECNX,1045)MON,WS(N,1),WS(N,2),WS(N,3),G(N,1),Q(N,2),Q(N,3),
     1WS(N,4),DEV
      GO TO 252
   55 CONTINUE
      IF(M-1)554,554,555
  5 5 4 WRITE(NX,1046)IYR,WS(N,1),WS(N,2),WS(N,3),G(N,1),Q(N,2),Q(N,3),
     1WS(N,4),DEV
      GO TO 252
  555 CONTINUE
      URITECNX,1045)M,WS(N,1),WS(N,2),WS(N,3),Q(N,1),Q(N,2),Q(N,3),
     1WS(N,4),DEV
  252 CONTINUE
      C O58I=1,3
   5 8 Q(JB,I)=2.*Q(N,I)-Q(M,I)
      M=M+1
C**** CHECK FOR COMPLETION OF FLOU CALCULATION FOR ENTIRE YEAR .  *****'
      IF(M-KB)23,23,59
   59 CONTINUE
```

Figure B.2. *St. Clair River model (continued).*

```
      DO 63 I=1,3
      Q(1,I)=Q(N,I)
   63 Q(2,I)=Q(JB,I)
      WS(1,1)=WS(N,1)
      WS(1,2)=WS(N,2)
      WS(2,2)=WS(JB,2)
      WS(1,3)=WS(N,3)
C**** IF ICODE IS A GAGE NUMBER THE PROGRAM WILL CONTINUE . ****t*.***
C**** NEGATIVE IN FIRST FOUR COLUMNS RECYCLES PROGRAW . *******.**t**
C**** IF ICODE IS ZERO THEN END RUN ********************************
      READ( MX,1015)ICODE,(WS(J,1),J=2,13)
      IF(ICODE)62,60,61
   62 WRITE( NX,3000)
      GO TO 1
   61 READ( MX,1015)ICODE,(WS(J,3),J=2,13)
      READ( MX,1015)ICODE,(WS(J,4),J=2,13)
      IYR=IYR+1
      DO 71 J=2,13
      WS(J,1)=WS(J,1)+CORR(1)
      WS(J,3)=WS(J,3)+CORR(3)
      WS(J,4)=WS(J,4)+CORR(2)
   71 CONTINUE
      M = 1
      KB=12
      GO TO 23
   60 WRITE(NX,1050)
      WRITE( NX,3000)
      STOP
C**** FORMAT STATEMENTS * ********************************************
 1002 FORMATC3F5.2)
 1010 FORMAT ( F10.0,5X,I5,45X,3A5)
 1015 FORMAT(I5,15X,12F5.2)
 1020 FORMAT(////37X,30HST.CLAIR RIVER TRANSIENT MODEL//45X,3A5//)
 1021 FORMAT(39X,F5.1,1X,20HHOUR TIME INCREMENTS//1
 1025 FORMAT(24X,19HSTARTING ELEVATIONS,2X,15HFORT GRATIOT = ,F6.2,
     1/54X,6HMBR = F6.2,/48X,12HST. CLAIR = ,F6.2//)
 1026 0FORMAT (7X,≠ YEAR≠,4X,3HMON,4X,3HWS1,4X,4HWS2C,5X,3HWS3,5X,2HQ1,7X
     1,2HQ2,7X,2HQ3,6X,4HWS2M,6X,≠ DEV≠/)
 1045 FORMAT(16X,I3,3(2X,F6.2),3(2X,F7.0),2(2X,F6.2))
 1046 FORMAT(/7X,I5,5X,≠ 1≠,3(2X,F6.2),3(2X,F7.0),2(2X,F6.2))
 1050 FORMAT(11H END OF RUN)
 3000 FORMAT(1H1)
      END
```

Figure B.2. St. Clair River model (continued).

Table B.1. St. Clair River Model Output

YEAR	MON	WS1	WS2C	WS3	Q1	Q2	Q3	WS2M	DEV
1959	1	514.43	575.50	515.94	144404.	144404.	144404.	575.71	-.21
	2	574.35	575.40	515.83	142156.	142150.	142149.	575.57	-.17
	3	514.12	575.30	575.88	154268.	154263.	154263.	515.35	.03
	4	574.43	515.18	516.32	163137.	163162.	163166.	575.79	-.01
	5	574.14	576.12	576.68	168129.	168141.	168143.	516.09	.03
	b	514.91	576.33	576.92	172854.	172861.	112863.	516.32	.01
	1	514.93	516.34	576.93	112360.	172358.	172358.	516.33	.01
	8	514.91	576.34	576.93	113163.	113163.	173163.	516.35	-.01
	9	574.19	516.26	576.81	114722.	174716.	174716.	576.29	-.03
	10	514.13	516.20	576.80	173711.	173715.	173715.	516.14	.06
	11	574.69	576.19	576.81	175685.	175684.	115684.	576.22	-.03
	12	574.68	576.23	516.86	178283.	178284.	178285.	576.21	.02
1960	1	515.31	576.56	577.09	165811.	165839.	165842.	576.54	.02
	?	575.81	576.11	511.19	140574.	148586.	148586.	516.79	-.02
	3	515.19	516.41	577.01	166350.	166319.	166316.	576.50	-.03
	4	575.22	516.66	577.26	111206.	111223.	177226.	576.11	-.05
	5	515.16	577.35	578.02	193113.	193144.	193150.	577.36	-.01
	b	576.23	517.82	578.52	198727.	198745.	198748.	511.86	-.04
	1	516.49	518.13	570.86	205058.	205069.	205071.	578.14	-.01
	8	516.59	578.25	579.00	207113.	201116.	207716.	578.25	.00
	9	516.42	578.09	578.84	206118.	206107.	206105.	518.11	-.02
	10	516.13	517.81	51b.56	203555.	203542.	203539.	E.11.84	-.03
	11	575.77	571.42	518.14	197011.	196993.	196990.	511.46	-.04
	12	575.85	517.38	578.05	190496.	190503.	190504.	511.42	-.04
1961	1	575.90	571.25	511.85	118141.	118736.	118735.	517.25	.00
	2	575.34	516.90	577.56	186265.	186239.	186237.	516.85	.05
	3	575.21	516.92	571.63	194193.	194199.	194200.	576.90	.02
	4	575.42	517.04	577.12	190811.	190879.	190880.	577.03	.01
	5	575.76	577.26	577.90	186978.	186992.	186944.	577.28	-.02
	6	515.80	517.29	577.93	186603.	186600.	186600.	511.29	-.00
	7	515.82	577.36	518.02	190254.	190258.	190258.	517.38	-.02
	8	575.80	511.34	578.01	190348.	190345.	190345.	571.31	-.03
	9	515.66	511.22	577.90	190312.	190305.	190304.	511.26	-.04
	10	575.40	577.04	511.74	192258.	192247.	192245.	577.10	-.06
	11	515.13	516.83	577.55	193045.	193035.	193033.	576.88	-.05
	12	574.91	516.59	511.29	lR9009.	188998.	188996.	576.63	-.04

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