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Techniques of Water-Resources Investigations
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Chapter C3

A MODEL FOR SIMULATION OF FLOW IN SINGULAR AND INTERCONNECTED CHANNELS

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Book 7

AUTOMATED DATA PROCESSING AND COMPUTATIONS

A sample card deck setup to execute the branch-network flow model of the Detroit River is shown in figure 35. This figure is included to illustrate the relative ease and operational simplicity with which a complete flow simulation model may be initiated by the model user. In this particular execution setup, cross-sectional geometry, as well as boundary-value data, are retrieved from computer files. Cross-sectional geometry tables are retrieved from a computer file established by the cross-sectional geometry program, whereas boundary-value data are retrieved from a data base of time-dependent data. The initial conditions for the simulation depicted in figure 35 were computed and subsequently punched from a previous simulation. The model is set up to execute on a 15-minute time step using a value of 0.6 for θ and χ as defined in the section Finite-difference formulation.

The sample deck setup illustrated in figure 35 is intended to produce a line-printer plot of computed versus measured water-surface elevations. The model-generated graph, plotted via a Tektronix interactive terminal and illustrated in figure 36, was derived from a similar deck setup. This output represents a plot of the computed versus measured water-surface elevations at the Wyandotte gage location (fig. 33). In general, the agreement between computed and measured stages appears to be satisfactory; however, additional calibration and verification of this particular model are required. More conclusive tests of the model must await collection of synoptic sets of measured discharges, wind-vector data, and, of course, boundary-value water-level data for various flow and meteorological conditions. Computed discharges were within 3.5 percent of the measured discharges for one such set of synoptic data collected near the Fort Wayne gage location. Consequently, the Detroit River schematization appears to be appropriate for the flow model implementation and simulation; however, additional flow simulations are necessary to verify this assumption.

Summary

The branch-network flow model has been successfully used to simulate flow in singular reaches and in networks of interconnected open channels. The results of several applications illustrate the flexibility and accuracy of the flow model in simulating a wide range of flow conditions. The various model implementations were efficiently carried out using a computer program for analyzing channel cross-sectional geometry, a computerized system for editing, transcribing, storing, and retrieving time-dependent boundary-value data, and specific model-generated graphical outputs for evaluating computed results. These capabilities, which significantly hasten the model calibration and verification operations, also constitute an operational system for implementing and using the branch-network flow model.

The branch-network flow equations include wind shear on the water surface as a forcing function and are formulated to account for nonuniform velocity distributions through the momentum or Boussinesq coefficient. The four-point, finite-difference technique, with weighting factors for function values and their spatial derivatives in the flow equations, provides a high degree of flexibility in simulating diverse flow conditions in channels of variable cross-sectional properties. A unique branch-transformation technique is utilized in the model, resulting in a significant savings in computational time and computer storage. The implicit solution technique employed permits computations at large time steps. The subdivision of branches into segments of equal or unequal lengths is possible, thereby providing for the computation of water-surface elevations and flow discharges at any desired location.

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APPENDIXES I–IV

Appendix I, Program Control-Card Format

There are nine basic card types used for input to the branch-network flow model. The order of card input is illustrated in figure 15. The functional purpose of each card is given as follows:

Network-name card identifies the network being simulated.

Computation-control card defines the network dimensions, assigns the computation time increment, specifies the iteration and convergence criteria, signifies the choice of input/output units, assigns various constants and coefficients, and selects the type of output desired.

Branch-identity card identifies each branch by name and number and indicates the positive flow direction, as well as the number of cross sections to be input to define the channel segments and their geometry (one such card for each branch in the network).

Initial-condition cards (two cards for each of the cross sections in the identified branch) assign the segment lengths, water tempterature, flow-resistance coefficients, wind direction, and momentum coefficient, in addition to the initial values of stage and discharge.

Cross-sectional geometry cards constitute a set of data cards (preceded by one card identifying the number of data cards to input) defining the particular cross-sectional geometry relationships (one set for each cross section in the identified branch).

Nodal-flow card(s) assigns the external inflows (outflows, if negative) at each internal junction.

List-index card controls identification of data stored in the time-dependent data base, and thereby available as boundary-value data.

Boundary-value data cards consist of one card identifying the boundary-value data (required at each external junction) by type, station number, external junction number, recording frequency, and beginning and ending dates and times and are optionally followed by one card (containing functional boundary-condition coefficients) or by multiple cards (containing actual boundary-value data, if such data are to be input manually from cards).

Measured data cards consist of an initial card identifying the measured data (used for plotting versus computed results) by type, station number, junction or branch and cross-section numbers, recording frequency, and beginning and ending dates and times and are optionally followed by cards containing the measured values.

As indicated the first eight card types are required with measured data cards being optionally required. All available parameter defaults can be taken simply by having the appropriate card column(s) blank. If all parameters on a particular card have acceptable defaults, the defaults can be exercised by inserting a blank card. As is identified in the following table, both metric and inch-pound equivalent default parameter values are available.

Variable	Columns	Format	Default	Definition
Network-name card (one required per execution)				
NETNAM	1-80	20A4	blanks	Name of the network of open channels.
Computation-control card (one required per execution)				
IUNIT	1- 2	A2	EN	System of units of input data (EN: in/lbs; ME: metric).
NBCH	3- 4	I2	(None)	Total number of branches in the network (0<NBCH<16).
NJNC	5- 6	I2	(None)	Total number of junctions (both internal and external) in the network (1<NJNC<16).
NBND	7- 8	I2	(None)	Number of external boundary conditions, and internal station locations if any, to be user defined (1<NBND<6).
NSTEPS[1]	9-12	I4	--------	Number of time steps to be computed.
OUNIT	13-14	A2	EN	System of units of output results (EN: in/lbs; ME: metric).
LUGEOM	15-16	I2	5	Logical unit number of the device containing the cross-sectional geometry data (5: card reader; 10: other).
NIT[2]	17-18	I2	5	Maximum number of iterations permitted per time step (usually $3 \leq NIT \leq 5$).
IOTOPT	19	I1	0	Output option (0: print results at every time step; 1: print results at every iteration; 2: print daily summary of results; 3: plot results at every time step; 4: print monthly flow-volume summaries).
IPLOPT[3]	20	I1	0	Plot option (0: do not plot; 1: plot computed discharge; 2: plot computed stage; 3: plot measured versus computed discharge; 4: plot measured versus computed stage).
IPLDEV[3 4]	21	I1	0	Plotter device (0: line printer; 1: Tektronix; 2: CalComp; 3: FR80).

See footnotes at end of table.

Variable	Columns	Format	Default	Definition
Computation-control card (one required per execution)—Continued				
IPRMSG	22	I1	0	Option to permit the time-dependent-data storage-and-retrieval system to print messages (0: do not print message; 1: print message).
IPLMSG	23	I1	0	Option to permit the plotter software to print messages (0: do not print messages; 1: print messages).
IEXOPT	24	I1	0	Option to extrapolate initial values for unknowns from present time step values (0: do not extrapolate; 1: extrapolate).
TYPETA	25	I1	1	Type of functional flow-resistance relationship, (1: constant; 2: temperature; 3: depth; 4: discharge; 5: Froude number; 6: Reynolds number).
INHR[5]	26–27	I2		Hour of initial-value data.
INMN[5]	28–29	I2		Minute of initial-value data.
IDTM[6]	30–33	I4		Simulation time increment in minutes.
THETA	34–36	F3.2	1.0	Finite-difference weighting factor (θ) for the spatial derivatives (usually $0.6 \leq \text{THETA} \leq 1.0$)
QQTOL[7]	37–41	F5.1		Discharge convergence criterion.
ZZTOL	42–46	F5.3	0.01/0.003048	Stage convergence criterion in feet or meters.
WSPEED	47–51	F5.2	0.0	Wind speed in miles or kilometers per hour.
WSDRAG	52–56	F5.4	0.0026	Water-surface drag coefficient.
H2ODEN	57–61	F5.4	1.9617/1.011	Water density in slugs/ft^3 or g/cm^3.
CHI[8]	62–64	F3.2	1.0	Weighting factor (χ) for function values in the flow equations (usually $0.5 \leq \text{CHI} \leq 1.0$).
IPUNIN	65	I1	0	Option to punch out initial condition cards at the end of the simulation (0: do not punch; 1: punch).
Branch-identification cards (one required per branch)				
IJF	1– 2	I2	(None)	Junction number identifying the source of positive flow for the branch ($0 < \text{IJF} \leq \text{NJNC}$).
IJT	3– 4	I2	(None)	Junction number identifying the outlet of positive flow for the branch ($0 < \text{IJT} \leq \text{NJNC}$).
NSEC[9]	5– 6	I2	(None)	Number of cross sections input to define the geometry of the branch.
NAME	7–46	10A4	Blanks	Name of branch.
Initial-condition cards (two required per cross section)				
First initial-condition card for cross section:				
Z[10]	1–10	F10.3	(None)	Initial stage value.
Q	11–20	F10.3	(None)	Initial discharge value.
DX	31–40	F10.2	(None)	Segment length.
T	41–50	F10.2	59.0/15.0	Water temperature, in degrees Fahrenheit or Celsius.
RN	51–80	3E10.4	(None)	Coefficients of flow-resistance relationship, i.e., $\eta(x) = \text{RN}(1) + \text{RN}(2)*x + \text{RN}(3)*x**2$.
Second initial-condition card for cross section:				
WANGLE	1–10	F10.3	0.0	Wind direction measured from the positive x-axis which lies along the centerline of the channel.
BETVEL	11–20	F10.3	1.0	Momentum coefficient.

See footnotes at end of table

Variable	Columns	Format	Default	Definition
Cross-sectional geometry cards (one set required per cross section)				
First card of cross-sectional geometry identifies the number of input data cards:				
IPT	1- 2	I2	(None)	Number of cross-sectional geometry data cards ($1<\text{IPT}\leq 20$).
IPT number of cross-sectional geometry data cards:				
ZA[11]	1-10	F10.3	(None)	Stage at which corresponding area and top width were measured.
AA	11-20	F10.3	(None)	Cross-sectional area at specified stage.
BB	21-30	F10.3	(None)	Top width of cross section at specified stage.
Nodal-flow card(s) (one value per junction; 10 junctions per card)				
W[12]	1-80	10F8.2	0.0	External inflow (or outflow) at junction (constant nodal flow for duration of simulation assumed).
List-index card for time-dependent data base (one required per execution)				
DATYPE[13]	1- 4	I4	3330	Type of magnetic disk used to hold time-dependent data base (usually 2314 or 3330).
LISTB	38-39	I2	0	Option to list the time-dependent data base index before computation (1: print only the directory list; −1: print the directory list and the chronological summary; 0: do not print).
LISTA	46-47	I2	0	Option to list the time-dependent data base index after computation (1: print only the directory list; −1: print the directory list and the chronological summary; 0: do not print).
Boundary-value data cards (one set required per external boundary condition)				
First card of each boundary-value data set is a data-definition card:				
ITYPE[14]	1- 2	A2	' Z'	Type of boundary-value data specified (' Z': stage, ' Q': discharge).
IBJNC	3- 4	I2	(None)	Junction number of external boundary location ($0<\text{IBJNC}\leq\text{NJNC}$).
NDATA	5- 7	I3	0	Number of boundary-value data input (0: implies data are to be retrieved from the time-dependent data base; 1: boundary condition is specified by an equation; >1: identifies the number of boundary-value data cards to be read).
DTT[15]	8- 9	F2.0	(None)	Recording interval of boundary-value data in minutes.
ISTATN	10-17	I8	(None)	Station identification number of boundary-value data specified.
ITIME	25-39	5(I2,1X)	(None)	Beginning data and time of boundary-value data (YR/MO/DY HR:MN).
NTIME	45-59	5(I2,1X)	(None)	Ending data and time of boundary-value data (YR/MO/DY HR:MN).
IDREAD[15]	62-65	I4	(None)	Number of boundary-value data recorded per day.
DATUM[16]	66-72	F7.3	0.0	Datum correction for stage boundary-value data.
IDONLY[17]	80	I1	(None)	Flag to indicate whether or not the boundary-value data-definition card is input to describe boundary-value data or only to identify station information (0: implies inclusion for data input; 1: implies inclusion for station identification only).
NDATA number of boundary-value data cards if data are input via cards:				
ZQ	1-10	F10.3	(None)	Stage or discharge boundary value.
One card containing coefficients if boundary condition is specified by an equation:				
ZQBVCO	1-40	4E10.4	0.0	Coefficients of the boundary-value equation, i.e., $Z(Q)=\text{ZQBVCO}(1)+\text{ZQBVCO}(2)*Q+\text{ZQBVCO}(3)*Q**2+\text{ZQBVCO}(4)*Q**3$.

See footnotes at end of table

Variable	Columns	Format	Default	Definition
Measured-data cards (one set optionally required when plotting computed versus measured data):				
First card of each measured-data set is a data-definition card:				
MTYPE[18]	1- 2	A2	' Z'	Type of measured data supplied (' Z': stage; ' Q': discharge).
MJNC[19]	3- 4	I2	________	Junction number of measured data location (0<MJNC ≤NJNC).
MDATA	5- 7	I3	0	Number of measured data input (0: implies data are to be retrieved from the time-dependent data base; >1: identifies the number of measured-data cards to be read).
CDTT[15]	8- 9	F2.0	(None)	Input interval of measured data in minutes.
MSTATN	10-17	I8	(None)	Station identification number of measured data specified.
MITIME[20]	25-39	5(I2,1X)	(None)	Beginning date and time of measured data (YR/MO/DY HR:MN).
MNTIME[20]	45-59	5(I2,1X)	(None)	Ending date and time of measured data (YR/MO/DY HR:MN).
MDREAD[15 21]	62-65	I4	(None)	Number of measured data input per day.
CDATUM	66-72	F7.3	0.0	Adjustment factor for measured data.
MBCH[19]	78-79	I2	________	Branch number of measured data location (0<MBCH ≤NBCH).
MSEC[19]	80	I1	________	Cross-section number of measured data location (0<MSEC≤NSEC).
MDATA number of measured-data cards if data are input via cards:				
ZQMEAS	1-10	F10.3	(None)	Measured stage or discharge value.

[1] If not specified, the number of time steps to be computed is determined from the time span specified on the *first* boundary-value data definition card.
[2] The computation is permitted to continue using the previous computed values whenever the maximum number of iterations is exceeded A message is printed, however, identifying the maximum stage and discharge deviations and the location(s) of their occurrence.
[3] These variables are only applicable for IOTOPT=3
[4] Tektronix, CalComp, and FR80 plots are produced in auxiliary operations from files of plotter instructions generated during the simulation.
[5] If not specified, the time of initial-value data is taken as the time of the first boundary-value datum.
[6] If not specified, the simulation time step is set to the data recording interval on the *first* boundary-value data definition card
[7] The default discharge convergence criterion is taken as 0 5 percent of the minimum (absolute value greater than zero) initial-value discharge. If all initial discharges are zero the default discharge convergence criterion is set to one
[8] If not specified, the weighting factor χ is set equal to the weighting factor for the spatial derivatives, θ.
[9] The total number of cross sections used to define the geometry of all branches composing the network must not exceed the maximum number of cross sections allocated (NBSEC ≥ Σ NSEC(I); I=1,NBCH) for the particular version of the model program (see section Program restrictions). In general, it is recommended not to exceed the maximum number of cross sections allocated per branch, which is 4 in this model-program version
[10] Initial values at external boundary locations default to the first boundary-value datum input
[11] Stage-area-width relationships must be input in sequence starting with the values at the lowest stage.
[12] Code nodal-flow values in sequence according to the junction numbering scheme.
[13] Other direct-access devices can be accommodated as required.
[14] If boundary-value data sets are input from both disk and cards, put disk boundary-value data definition cards first beginning with the boundary-value data recorded at the greatest frequency (smallest time interval.)
[15] The data interval and the number of data per day need not both be specified, either is sufficient.
[16] Appropriate uses of the DATUM adjustment factor are to change datum references or to correct for known or suspected recorder elevation shifts.
[17] The IDONLY flag permits the accumulation and compilation of flow volumes at internal station locations of the network. The station identification number must be provided to accommodate filing flow volumes at a particular location.
[18] Only one set of measured data can be input per branch of the network.
[19] The location of measured data may be defined either by junction number or by branch and cross-sectional numbers.
[20] All sets of measured data must begin and end at a common date and time in the same calendar day. This data and time must be within the time span of the simulation.
[21] All measured data must be supplied at the computation time step frequency

Appendix II, Definition of MAIN Program Variables and Arrays

The ability to relate program variables and arrays to the mathematical formulation of the flow equations may be necessary or desirable on occasion. The following table defining the program variables and arrays in the MAIN program is provided for this purpose. It may also be useful if it is necessary to modify the program to accommodate large network systems or other unique flow conditions. Variables and arrays used similarly in the subprograms of the model are also defined accordingly. However, no commonality of definitions is intended or should be inferred between the model source code, as presented herein, and the time-dependent-data storage-and-retrieval or the graphical display software systems as utilized.

Array (size) or Variable	Definition
A(60)	cross-sectional area at present time step.
AA(20,60)	cross-sectional area array of stage-area-width geometry tables.
AM(3600)	coefficient matrix of unknowns.
AP(60)	cross-sectional area at future time step.
AAVG	four-point weighted-average, cross-sectional area.
AQMAX(60)	cross-sectional area at time of maximum discharge for the day.
AQMIN(60)	cross-sectional area at time of minimum discharge for the day.
AAVGCU	cube of four-point weighted-average, cross-sectional area.
AAVGSQ	square of four-point weighted-average, cross-sectional area.
AIRDEN	air density, used to calculate the wind-resistance coefficient.
B(60)	cross-sectional top width at present time step.
BB(20,60)	cross-sectional top width array of stage-area-width geometry tables.
BP(60)	cross-sectional top width at future time step.
BU(30)	branch transformation vector.
BMX(60)	right-hand-side vector of unknowns.
BUU(60)	branch transformation matrix.
BAVG	four-point weighted-average, cross-sectional top width.
BIGQ	maximum difference in computed discharges over the time step.
BIGZ	maximum difference in computed stages over the time step.
BETCOR	average momentum coefficient for the segment.
BETVEL(60)	momentum coefficient for the cross section.
BRNAME(10,15)	name of branches in the network.
CN	conversion factor for the flow-resistance function.
CW	factor of wind forcing function.
C1	temporary branch transformation coefficient.
C2	Do.
C3	Do.
C4	Do.
CHI	finite-difference weighting factor for function values in the equation of motion.
CDTT	data recording frequency for measured data.
CDATUM	temporary variable used as adjustment factor for time-dependent data.
DC	units of temperature data.
DT	computational time step in seconds.
DX(60)	branch-segment length.
DET	inverse of coefficient matrix.
DTT(5)	data recording frequency for boundary-value data.
DCHI	form of the finite-difference weighting factor for function values.
DXIJ	length of the *J*th segment of the *I*th branch.
DATUM(5)	adjustment factor for stage boundary-value data.
DELTA	matrix coefficient.
DPERM(12)	number of days per month.
DTPRT	logical variable controlling printout at time step.
DTYPE	boundary-value data type.
DAYSUM	logical variable controlling daily summary printout.
DTHETA	form of the finite-difference weighting factor for spatial derivatives.
DTZERO	flow-volume interpolation variable.
EN	units identifier for inch-pound system.
ERROR	logical variable signalling an error in the initial values.
EPSLON	matrix coefficient.
FOUND	logical variable identifying missing initial values.
G	gravitational acceleration.
GAMMA	matrix coefficient.
GINDEX	logical unit variable for data-station reference file.
H2ODEN	water density used to calculate the wind-resistance coefficient.

Array (size) or Variable	Definition
I	DO-loop variable most frequently used as branch index.
II	total number of equations for the network.
IJ	cross-section index.
IS	flag signalling a singular matrix.
I2	branch transformation index.
I4	Do.
IAR	statement function for coefficient-matrix addressing.
ICT(15)	counter for number of branches at each junction.
IDA	beginning day of boundary-value data.
IDX(15,15)	list of branches at each junction.
IHR	beginning hour of boundary-value data.
IJF(15)	junction identifying flow source of branch.
IJT(15)	junction identifying flow outlet of branch.
IJ2	segment transformation index.
IJ4	Do.
IMN	beginning minute of boundary-value data.
IMO	beginning month of boundary-value data.
IPT(60)	number of stage-area-width relationships for cross section.
IYR	beginning year of boundary-value data.
IBCH	branch number.
IBLK	test variable for default, boundary-value data type.
ICHK	flag signalling matrix solver to check for maximum pivots.
IDTM	computation time step in minutes.
IISQ	square of the number of equations to be solved.
IJP1	cross-section index.
INHR	initial hour of simulation.
INMN	initial minute of simulation.
IREM	temporary variable used to hold the remainder in various arithmetic operations.
I2P1	branch transformation index.
I2P2	Do.
I4P1	Do.
I4P2	Do.
I4P3	Do.
I4P4	Do.
IBIGQ	branch with maximum difference in computed discharges.
IBIGZ	branch with maximum difference in computed stages.
IBJNC(5)	junction number of boundary-value data location.
IDETA(6)	letter indicating the type of "η" relationship specified.
IFVOL(8,31,5)	accumulated flow volume.
IJVKT(5)	number of flow reversals within the day.
IJVOL(5)	cross section at which flow volumes are accumulated.
IJ2P1	segment transformation index.
IJ2P2	Do.
IJ4P1	Do.
IJ4P2	Do.
IJ4P3	Do.
IJ4P4	Do.
INTER	data recording frequency.
ITVOL(8,31,5)	time of flow reversal.
ITYPE(5)	boundary-value data type.
IUNIT	units of measure of input data.
IDONLY(5)	flag indicating data definition is for station identification only.
IDTPDY	number of time steps per day.
IDTYPE	type of disk containing time-dependent data base.
IETIME	elapsed minutes in the calendar year to the beginning of boundary-value data.
IETIYR	total elapsed minutes in calendar year of boundary-value data.
IETJYR	total elapsed minutes in next consecutive calendar year of boundary-value data.
IEXOPT	option to extrapolate unknowns.
IITIME	time of first boundary-value data.
INDATA(360)	array of data retrieved from time-dependent data base.
IOTOPT	output option.
IPLDEV	type of device used for plotting.
IPLMSG	flag controlling the printout of messages generated by the plotter software.
IPLOPT	plot output option.
IPRMSG	flag controlling the printout of messages generated by the time-dependent-data storage-and-retrieval routine.
IPUNIN	option to punch initial condition cards.
IQDATA(360)	array of discharge boundary-value data.
IRDPDY	readings per day of boundary-value data.
ISTATN(5)	station identification number of boundary-value data.
ITQMAX(60)	time of maximum discharge for the day.
ITQMIN(60)	time of minimum discharge for the day.
IZDATA(720)	array of stage boundary-value data.
IZQBVE(5)	flag signalling that boundary condition is to be specified by an equation.
J	DO-loop variable used as segment, cross-section, and junction index.
JDA	beginning day of partial boundary-value data retrieval.
JHR	beginning hour of partial boundary-value data retrieval.
JMN	beginning minute of partial boundary-value data retrieval.
JMO	beginning month of partial boundary-value data retrieval.
JP1	segment index.
JYR	beginning year of partial boundary-value data retrieval.
JBIGQ	cross section with maximum difference in computed discharges.
JBIGZ	cross section with maximum difference in computed stages.
JDAYN	Julian day number.

Array (size) or Variable	Definition
JETIME	elapsed minutes in the calendar year to the beginning of boundary-value data retrieved.
JITIME	time of first boundary-value data retrieved.
K	DO-loop variable used for various indexing.
KT	time-step counter.
KDA	day at current time step.
KHR	hour at current time step.
KMN	minute at current time step.
KMO	month at current time step.
KYR	year at current time step.
KETIME	elapsed minutes in the calendar year to current time step.
KTMATS	matrix solution counter.
KTMEAS	measured data set counter.
L	DO-loop variable used as boundary-value and measured data index.
LASTN	iterations required for last time step.
LISTA	option to list time-dependent data base index after simulation.
LISTB	option to list time-dependent data base index before simulation.
LAMBDA	matrix coefficient.
LEAPDY	leap-day indicator.
LETIME	elapsed minutes in the calendar year to time of last plot.
LUGEOM	logical unit variable for cross-sectional geometry data file.
M	DO-loop variable for time step.
ME	units identifier for metric system.
MM	coefficient matrix index.
MT	units of metric data.
MU	matrix coefficient.
M0	coefficient matrix index.
MDA	ending day of partial boundary-value data retrieval.
MDT	data recording frequency for measured data.
MHR	ending hour of partial boundary-value data retrieval.
MMN	ending minute of partial boundary-value data retrieval.
MMO	ending month of partial boundary-value data retrieval.
MYR	ending year of partial boundary-value data retrieval.
MAXS	maximum number of cross sections accommodated in the network.
MBCH(5)	branch identifying measured data location.
MIDA	beginning day of measured data.
MIHR	beginning hour of measured data.
MIMN	beginning minute of measured data.
MIMO	beginning month of measured data.
MIYR	beginning year of measured data.

Array (size) or Variable	Definition
MJNC	junction identifying measured data location.
MKDA	ending day of measured data.
MKHR	ending hour of measured data.
MKMN	ending minute of measured data.
MKMO	ending month of measured data.
MKYR	ending year of measured data.
MSEC(5)	cross section identifying measured data location.
MXBH	maximum number of branches accommodated in the network.
MXBY	maximum number of external boundary and flow-volume locations accommodated in the network.
MXJN	maximum number of junctions accommodated in the network.
MXMD	maximum number of measured data locations accommodated in the network.
MXPT	maximum number of stage-area-width relationships accommodated per cross section.
MAXBD	maximum number of boundary-value data accommodated per retrieval.
MDATA(5)	number of measured data input.
MTYPE(5)	measured data type.
MAXCZQ	maximum number of computed results per day.
MAXMZQ	maximum number of measured data accommodated.
MAXQBD	maximum number of discharge boundary-value data accommodated per retrieval.
MAXZBD	maximum number of stage boundary-value data accommodated per retrieval.
MDREAD	readings per day of measured data.
MEITIM	elapsed minutes in the calendar year to the beginning of measured data.
MEKTIM	elapsed minutes in the calendar year to the end of measured data.
METIME	elapsed minutes in the calendar year to the end of boundary-value data retrieved.
MITIME	time of last boundary-value data retrieved.
MOREBD	logical variable signalling the need to retrieve additional boundary-value data.
MSTATN(5)	station identification number of measured data.
N	DO-loop variable for iteration.
ND	number of data.
NN	coefficient matrix index.
NS	number of cross sections.
NDA	ending day of boundary-value data.
NHR	ending hour of boundary-value data.
NIT	number of iterations permitted per time step.
NMN	ending minute of boundary-value data.
NMO	ending month of boundary-value data.
NNN	coefficient matrix index.
NYR	ending year of boundary-value data.

Array (size) or Variable	Definition
NBCH	number of branches in the network.
NBND	number of external boundary condition and flow-volume locations in the network.
NBPJ	number of branches joining at a junction.
NJNC	number of junctions in the network.
NSEC(15)	number of cross sections in the branch.
NSM1	number of segments in a branch.
NDATA(5)	number of boundary-value data input.
NDFIRT	total number of boundary-value data to be retrieved.
NDPART	number of data in partial boundary-value data retrieval.
NETIME	elapsed minutes in the calendar year to the end of boundary-value data.
NETNAM(20)	name of network.
NITIME	time of last boundary-value data.
NOCONV	logical variable signalling conversion of units.
NOEXTP	logical variable controlling extrapolation.
NOPRIT	logical variables controlling printout.
NSTEPS	total number of time steps to be computed.
OMEGA	matrix coefficient.
OUNIT	units of measure of output results.
ONECHI	form of the geometry finite-difference weighting factor.
OPLOTS	logical variable controlling plot generation.
PSI	matrix coefficient.
PTPLT	logical variable controlling printer-plot generation.
PUNCH	logical unit variable for card punch.
PRINTR	logical unit variable for line printer.
PRTMSG	logical variable controlling the printout of messages generated by the time-dependent-data storage-and-retrieval system.
Q(60)	discharge at present time step.
QP(60)	discharge at future time step.
QIJ	discharge at the *J*th cross section of the *I*th branch at present time step.
QAVG	four-point weighted-average discharge.
QMAX	maximum discharge for the day.
QMIN	minimum discharge for the day.
QSUM	cumulative discharge for the day.
QTOL	discharge difference for tolerance check.
QIJP1	discharge at the $J+1$st cross section of the *I*th branch at the present time step.
QQTOL	discharge convergence criterion.
QTEMP	temporary discharge variable.
QTYPE	code identifying discharge data.
QZCONV	discharge or stage conversion factor.
R(60)	hydraulic radius at present time step.
RN(4,60)	coefficients of flow-resistance equation.
RP(60)	hydraulic radius at future time step.
ROW(60)	pointers to rows containing maximum pivot elements.
RAVG	four-point weighted-average hydraulic radius.
RNIJ	flow-resistance coefficient of the *J*th segment of the *I*th branch.
READER	logical unit variable for card reader.
RTCODE	error code returned from time-dependent data storage-and-retrieval routine.
SIGMA	matrix coefficient.
STRIP	option to strip error codes from data retrieved from time-dependent data base.
STAGES	logical variable signalling the plotting of stages.
T(60)	water temperature.
TH	factor of parabolic interpolation for boundary-value data.
TWOG	twice the gravitational acceleration.
THETA	finite-difference weighting factor for the spatial derivatives.
THPSI	flow equation factor.
TUNIT	units identifier for temperature data.
TDDATA	logical unit variable for the time-dependent data base.
TWOCSQ	twice the square of the conversion factor for the flow-resistance function.
TYPETA	option identifying the type of flow-resistance relationship specified.
U(120)	segment transformation vector.
UU(240)	segment transformation matrix.
UNIT	units identifier for initial-value data.
UUIJP1	temporary variable used in branch transformation computation.
UUIJP2	Do.
UUIJP3	Do.
UUIJP4	Do.
W(15)	nodal flow at junction.
WANGLE(60)	angle of wind direction with respect to positive flow direction.
WSDRAG	water-surface drag coefficient.
WSPEED	wind speed.
XSKT(15)	cross-section counter.
Z(60)	stage at present time step.
ZA(20,60)	stage array of stage-area-width geometry tables.
ZP(60)	stage at future time step.
ZQ(720,5)	stage and (or) discharge boundary-value data.
ZIJ	stage at the *J*th cross section of the *I*th branch at present time step.
ZETA	matrix coefficient.
ZTOL	stage difference for tolerance check.

Array (size) or Variable	Definition
ZIJP1	stage at the $J+1$st cross section of the Ith branch at present time step.
ZQMAX(60)	stage at time of maximum discharge for the day.
ZQMIN(60)	stage at time of minimum discharge for the day.
ZQPIJ	stage or discharge at the Jth cross section of the Ith branch at future time step.
ZTEMP	temporary stage variable.
ZTMAX	maximum stage specified in stage-area-width geometry tables.
ZTMIN	minimum stage specified in stage-area-width geometry tables.
ZTYPE	code identifying stage data.
ZZTOL	stage convergence criterion.
ZDATUM	stage computation datum.
ZQBVCO(4,5)	coefficients of stage-discharge rating curves.
ZQCOMP (288,60)	computed stages or discharges for the day.
ZQMEAS (192,5)	measured stage or discharge data.

Appendix III, Adjustable Arrays

Object-time dimensioning of arrays is utilized in the branch-network flow model. This technique facilitates the expansion of arrays to accommodate networks with unique dimension requirements. This table identifies those arrays whose dimensions may require modification dependent upon the characteristics of the network being simulated. Because object-time dimensioning is employed, a change in the dimension of an array is directly accomplished by declaring its new dimension in the MAIN program only, with no modifications required in the subroutines. To facilitate the expansion of arrays, the following table identifies the variables controlling the dimensions, the current (default) dimensions, and the array type. Knowing the variables controlling the array dimensions and the array type it is a simple matter to expand the array capacities and to compute the model's new machine storage requirements. Dimension variables are defined in the table footnotes.

Array	Type	Variable dimension	Current dimension
A	REAL*4	(NBSEC)[1]	(60)
AP	do	do	(60)
AQMAX	do	do	(60)
AQMIN	do	do	(60)
B	do	do	(60)
BP	do	do	(60)
BETVEL	do	do	(60)
DX	do	do	(60)
IPT	INTEGER*2	do	(60)
ITQMAX	do	do	(60)
ITQMIN	do	do	(60)
Q	REAL*4	do	(60)
QP	do	do	(60)
QMAX	do	do	(60)
QMIN	do	do	(60)
QSUM	do	do	(60)
R	do	do	(60)
RP	do	do	(60)
T	do	do	(60)
WANGLE	do	do	(60)
Z	do	do	(60)
ZP	do	do	(60)
ZQMAX	do	do	(60)
ZQMIN	do	do	(60)
U	REAL*8	(2*NBSEC)	(120)
UU	do	(4*NBSEC)	(240)
RN	REAL*4	do	(4,60)
AA	do	(MXPT,NBSEC)[2]	(20,60)
BB	do	do	(20,60)
ZA	do	do	(20,60)
ZQCOMP	do	(MAXCZQ,NBSEC)[3]	(288,60)
IJF	INTEGER*2	(MXBH)[4]	(15)
IJT	do	do	(15)
NSEC	do	do	(15)
XSKT	do	do	(15)
BRNAME	INTEGER*4	(10,MXBH)	(10,15)
AM	REAL*4	((4*MXBH)**2)	(3600)
BU	REAL*8	(2*MXBH)	(30)
BMX	REAL*4	(4*MXBH)	(60)
BUU	REAL*8	do	(60)
ROW	INTEGER*2	do	(60)
W	REAL*4	(MXJN)[5]	(15)
ICT	INTEGER*2	do	(15)
IDX	do	(MXJN,MXBH)	(15,15)
DTT	REAL*4	(MXBY)[6]	(5)
DATUM	do	do	(5)
IBJNC	INTEGER*2	do	(5)
ITYPE	do	do	(5)
NDATA	do	do	(5)
ISTATN	INTEGER*4	do	(5)
IZQBVE	INTEGER*2	do	(5)
ZQBVCO	REAL*4	(4,MXBY)	(4,5)
ZQ	do	(MAXZBD,MXBY)[7]	(720,5)
IZDATA	INTEGER*2	(MAXZBD)	(720)
INDATA	INTEGER*4	(MAXZBD/2)	(360)
IQDATA	do	do	(360)
MBCH	INTEGER*2	(MXMD)[8]	(5)
MSEC	do	do	(5)
MDATA	do	do	(5)
MTYPE	do	do	(5)
MSTATN	INTEGER*4	do	(5)
ZQMEAS	REAL*4	(MAXMZQ,MXMD)[9]	(288,5)

[1] NBSEC is the total number of cross sections used to define the channel geometry of the network. (Computed results are produced at these locations.)

[2] MXPT is the maximum number of stage-area-width relationships used to define the channel geometry at a given cross section.

[3] MAXCZQ is the maximum number of daily computed results held in storage for plotting purposes.

[4] MXBH is the maximum number of branches accommodated within the network.

[5] MXJN is the maximum number of junctions accommodated within the network.

[6] MXBY is the maximum number of external boundary locations and internal flow-volume locations accommodated within the network.

[7] MAXZBD is the maximum number of boundary-value data held in storage for computation purposes. (The boundary-value data arrays are automatically refreshed with data from the time-dependent data base as required during the simulation.)

[8] MXMD is the maximum number of measured data locations accommodated within the network.

[9] MAXMZQ is the maximum number of measured data held in storage for plotting purposes.