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GATE STROKING

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Gate stroking consists of a series of continuous or discontinuous gate motions which produce a desired water surface profile in a canal. The first obvious application of gate stroking within the Bureau was on the Granite Reef Aqueduct, Central Arizona Project. The mathematical development of the technique is outlined and methods for treating the unique conditions found on Bureau aqueducts are presented. Sufficient computer documentation is provided to permit application of the program to other aqueducts. The technique can be applied either to the entire aqueduct or to the component reaches. If applied to the aqueduct, the output consists of both gate and pump schedules. When applied to reaches only, the set of gate schedules is produced.

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Division of Data Processing
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Denver, Colorado

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INTRODUCTION

The change from one discharge to another in open-channel flow always creates a disturbance in the water-surface elevation. The magnitude of the disturbance is related to the manner in which the change is accomplished. In some cases, the disturbances persist for long periods with large amplitudes. In 1969, Wylie [1]* developed a method to control the disturbances within certain limits. The objective of the method was to produce a predetermined variation in the water-surface elevation at one location in a canal pool by properly varying the boundary conditions at each end of the pool.

Since pool boundaries are usually gates, the technique of water-surface control is called "gate stroking." The term comes from a similar procedure used in closed conduits known as "valve stroking." Although the term "stroking" as used in this context cannot be found in the dictionary, its definition can be implied from the several meanings commonly listed. Thus, stroking is "any of a series of continuous or discontinuous efforts to do, produce, or accomplish something, especially a successful result." Based upon its usage and the general meaning of stroking, gate stroking can be defined as, *"a continuous or series of discontinuous gate motions which produce a predetermined water-surface variation in a canal."*

Since the original paper by Wylie, the number of gate stroking applications has been minimal. O'Loughlin [2] and Gientke [3] are two of the few who have referred to application of gate stroking for specific installations. Perhaps one of the reasons there are not more applications is that gate stroking requires a scheduled type of operation with centralized control. The number of systems meeting this requirement is rather limited.

The first obvious application of gate stroking within the Bureau was on the Granite Reef Aqueduct, Central Arizona Project. This aqueduct consists of several canal reaches separated by pumping stations. The aqueduct is intended to be controlled by a computer-assisted remote-control system. It anticipated that all delivery schedules can be reasonably estimated several days in advance of the actual need for the water. In addition, the aqueduct is designed without any wasteways or reregulating reservoirs. When put into operation, the canal is to be operated at nearly the design capacity. Thus, there is very little margin for errors and the control of transients is a significant factor. These considerations coupled with a desire to minimize onpeak pumping costs led to the development of the gate stroking technique within the Bureau.

Wylie's original concept was followed very closely in the development which follows; however, provision had to be made to include structures like turnouts, siphons, and free flowing tunnels in the Bureau's computer program. In addition, a technique had to be developed in which the initial conditions were not always at steady state.

The purpose of this report is to outline the mathematical development; present the methods used in handling the unique conditions found on Bureau aqueducts; illustrate how the gate stroking is utilized; and provide sufficient documentation for the computer program, appendix A, so that it can be applied to other aqueducts.

SUMMARY AND CONCLUSIONS

Gate stroking is a series of continuous or discontinuous gate motions which produce a desired water-surface profile in a canal. The first obvious application of gate stroking within the Bureau was on the Granite Reef Aqueduct, Central Arizona Project.

The mathematical development of the technique is outlined and methods for treating the unique conditions found on Bureau aqueducts are presented. Sufficient computer documentation is provided to permit application of the program to other aqueducts.

The technique can be applied either to the entire aqueduct or to the component reaches. If applied to the aqueduct, the output consists of both gate and pump schedules. When applied to reaches only the set of gate schedules is produced.

The most nebulous relationship in the technique is the gate discharge equation. Additional research to better define the gate discharge coefficients is required.

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* Numbers in brackets refer to literature cited in the bibliography.

ANALYTICAL DEVELOPMENT

Basic Equations

Any computational scheme which calculates the unsteady water-surface profiles can be used with the concept of gate stroking. The method chosen by Wylie is the method of characteristics. Two computational schemes are used with the method of characteristics. These are (a) the grid of characteristics and (b) the method of specified time increments. The grid of characteristics method was chosen for use in the computer program. This method is more accurate because interpolation at the interior of the grid is avoided. Since the computations for each segment are performed independently of the other segments, the grid does not have to intersect specified points on the boundary. Thus, the usual problem of joining computations at a boundary, when using the grid of characteristics, does not arise in the gate stroking application.

The equations of motion and continuity in an open channel can be expressed as four particular total differential equations. These are:

$$\left.\begin{aligned} &\sqrt{\frac{gT}{A}}\,\frac{dy}{dt}+\frac{1}{A}\,\frac{dQ}{dt}+g\,(S-S_0)=0 && (1)\\ &\frac{dx}{dt}=\frac{Q}{A}+\sqrt{\frac{gA}{T}} && (2)\end{aligned}\right\}C+$$

$$\left.\begin{aligned} -&\sqrt{\frac{gT}{A}}\,\frac{dy}{dt}+\frac{1}{A}\,\frac{dQ}{dt}+g\,(S-S_0)=0 && (3)\\ &\frac{dx}{dt}=\frac{Q}{A}-\sqrt{\frac{gA}{T}} && (4)\end{aligned}\right\}C-$$

where g = acceleration of gravity
T = top width of water prism
A = cross-sectional area of water prism
y = flow depth
t = time
Q = discharge at section
S = friction slope
S_0 = bottom slope
x = horizontal distance

The first two equations are valid along the positive characteristic $C+$, figure 1. The last two are valid along the negative characteristic.

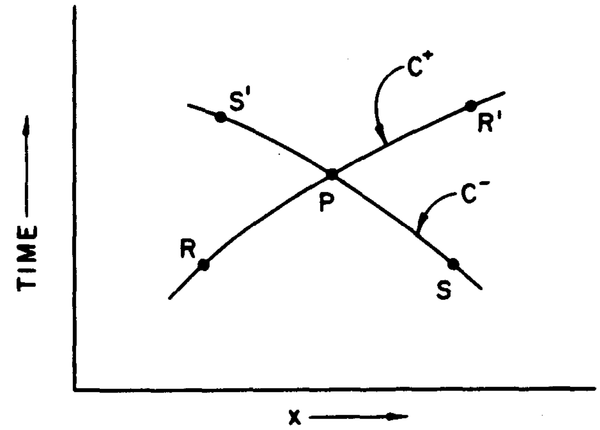


Figure 1.-Characteristic lines.

Using the notation of Wylie, the intersection point P presents a location at which the solution of the variables x, y, Q, and t is theoretically possible. If conditions are known simultaneously at either of the R and at either of the S points, then a numerical integration of the four characteristic equations will result in a solution of the variables at P.

Several computational schemes are used in the computer program. Each of these is dependent upon which combination of points R and S is known. The schemes can be related to specific regions in the x-t plane, figure 2.

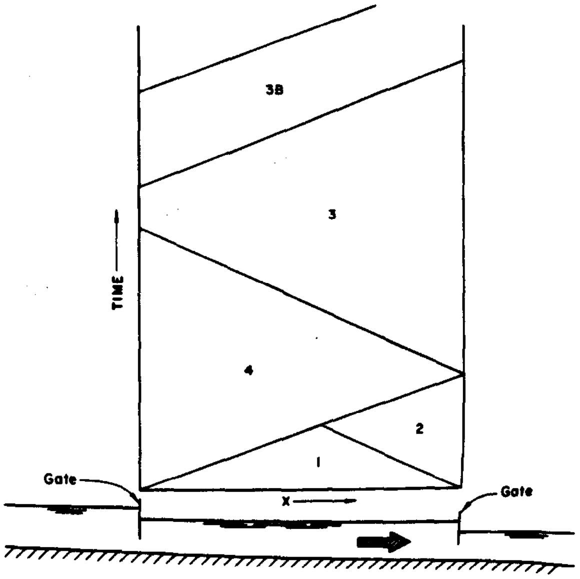


Figure 2.-Computational regions.

Each of the computational regions requires specific information from at least one of its borders. Each computational scheme then conveys information to the other borders. In general, borders occur along any time-distance line which borders a region, such as *A-B, B-C, C-A,* figure 3. Certain borders, however, have special significance. These occur at specific locations where depth variations are known or desired, and are known as boundaries. The canal segment between boundaries is called a "pool." The pool boundaries may or may not coincide with hydraulic barriers, such as gates. The canal segment between boundaries at which discharges are specified, is known as a "reach." Several pools may be contained within a reach.

The sequence of the computations for each of the regions which comprise a pool is described in the following paragraphs.

Region 1, *figure 3.—The initial conditions, that is,* depths and velocities along the entire length of the pool, must be defined at time equal zero. The variables at all points within the region can be determined by successively extending the grid forward in time. This region is also known as the domain of dependence since conditions within the region are uniquely determined by the conditions specified on one boundary. When the computations are completed, the value of the four variables will have been determined along the border A-B-C.

Region 2, figure 4.—In this region, conditions are known along the border *A-B.* At the point *P,* the value of the variable *x* is also known. However, to solve for the conditions at *P* using the positive characteristic, one additional variable must be specified. If the downstream boundary is a pump or a delivery point, the discharge will be specified. As will be seen later, if the boundary is a gate, the discharge will also be specified to maintain continuity. Therefore, along the boundary *A-C,* the discharge must be specified, whereas, time and depth will be determined. Interior points P_1 are computed from known values of R_1 and S_1 as was done in region 1. Upon completion of the computations, the values of all variables are known along the border *B-C-A.*

Region 3, figure 5.—This region is also a domain of dependence since the point *P* is determined from conditions given at the downstream boundary. Thus, along the boundary *A-D,* it is necessary to specify all four of the variables. To be compatible with the solution from region 2, the values of the four variables at point *A* must be indentical with those at point *C* in region 2. The other boundary values along the line *A-D* are determined from the prescribed discharge and

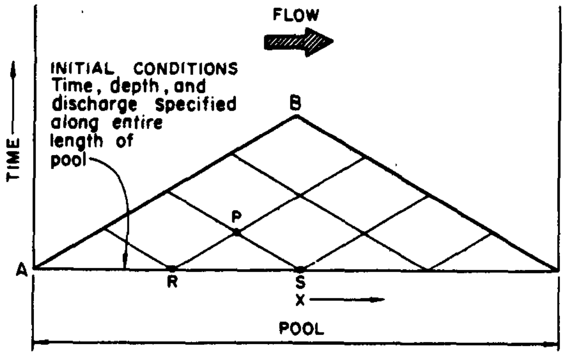


Figure 3.-Region 1.

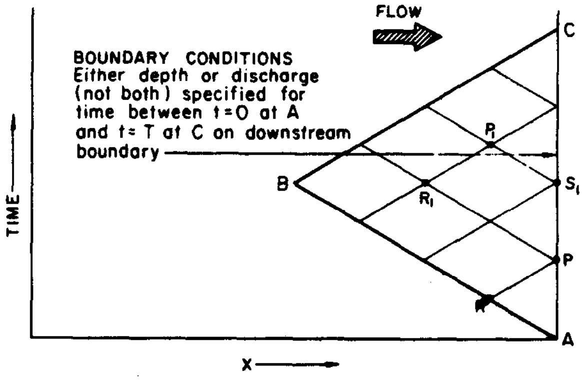


Figure 4.-Region 2.

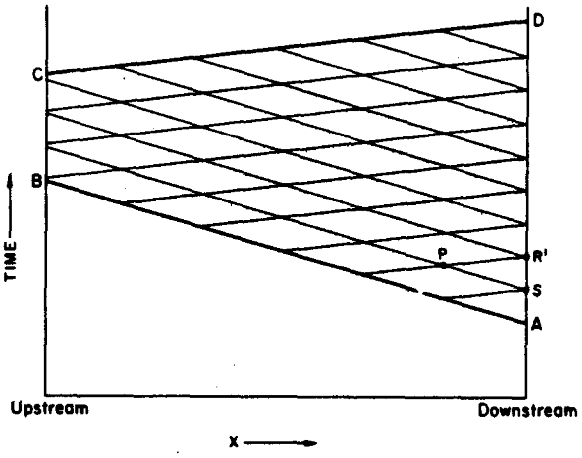


Figure 5.-Region 3.

water level schedules. When the computations are finished, the conditions are known along the borders *A-B* and *C-D.* To determine the conditions along *B-C* an interpolation is necessary. The interpolation scheme used involves a linear interpolation between points on the positive characteristics which cross the boundary (*A* to *B,* fig. 6). This is different than the scheme used by Wylie [1] who interpolated between the points of the diamond shape formed by the grid which crossed the boundary (*C* to *D,* fig. 6). Neither method seems to have any particular advantage over the other.

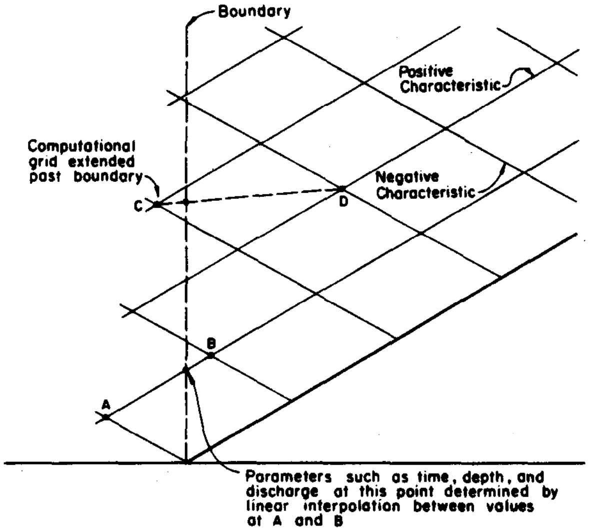


Figure 6.-Interpolation scheme.

The computations are extended in time, as required, (region 3B), by the same computational scheme used in region 3, figure 2. Region 3B has no theoretical significance. It is merely a device for extending the computations forward to an arbitrary time *t* without requiring additional computer memory when *t* is large.

Region 4, figure 7.—According to Wylie [1], this region is known as the domain of influence since it is influenced by the values of the conditions at point A. The computations proceed from known values on the borders *A-B* and *C-A,* when the computations have been completed, conditions along the boundary *C-B* will have been determined.

If the discharge at the upstream end of the most upstream pool is specified, then the depth in that pool cannot be specified. In this case, a fifth computational procedure has been provided, figure 8.

Region 5, figure 8.—In this region, the discharge is specified along boundaries *A-D* and *B-C.* The computations proceed in a fashion similar to those in region 3. However, at the downstream boundary *B-C,* distance and discharge as a function of time are known. This computational procedure is required only when the upstream boundary discharge is scheduled.

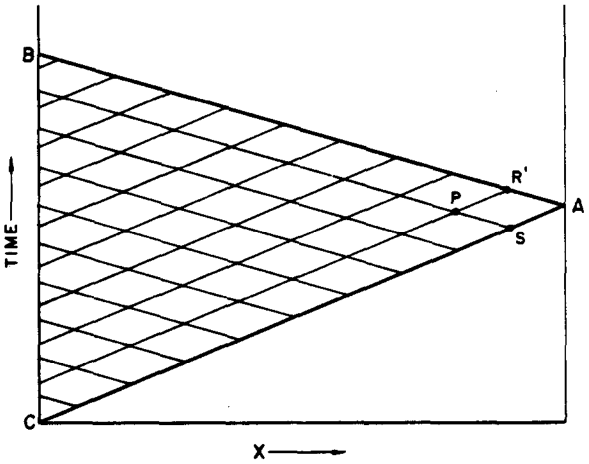


Figure 7.-Region 4.

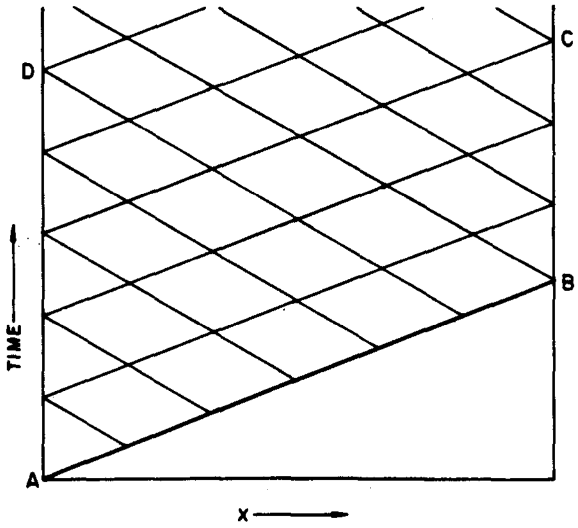


Figure 8.-Region 5.

Numerical Method

The four characteristic equations were integrated using the trapezoidal rule. The trapezoidal rule is given by

$$\int_{x_0}^{x_n} Y\,dX = \frac{h}{2}\,(Y_0 + 2Y_1 + 2Y_2 + \ldots 2Y_{n-1} + Y_n) \qquad (5)$$

where $h = X = X_1 - X_0$

If $n = 1$, then

$$\int_{x_0}^{x_1} Y\,dX = \frac{h}{2}\,(Y_0 + Y_1) \qquad (6)$$

Applying this rule to the characteristic equations gives

$$\frac{g}{2}\left(\frac{1}{C_R} + \frac{1}{C_P}\right)(Y_P - Y_R) + (Y_P - V_R) + \frac{g}{2}\,(S_R + S_P - 2S_0)\,(t_P - t_R) = 0 \qquad (7)$$

$$(X_P - X_R) = \left(\frac{V_P + V_R}{2} + \frac{C_R + C_P}{2}\right)(t_P - t_R) \qquad (8)$$

$$-\frac{g}{2}\left(\frac{1}{C_S} + \frac{1}{C_P}\right)(Y_P - Y_S) + (V_P - V_S) + \frac{g}{2}\,(S_S + S_P - 2S_0)\,(t_P - t_S) = 0 \qquad (9)$$

$$(X_P - X_S) = \left(\frac{V_P + V_S}{2} - \frac{C_P + C_S}{2}\right)(t_P - t_S) \qquad (10)$$

In these equations

$$C = \sqrt{\frac{gA}{T}} \qquad (11)$$

BOUNDARY CONDITIONS

Reach Versus Aqueduct Computation

The Granite Reef Aqueduct consists of several reaches separated by pumping stations. Each reach consists of several pools which are separated by control gates. Two methods of applying the gate stroking technique are possible. For one, the water level variations over an operating cycle within each reach are specified. In addition, the operation at each pumping station is specified. The other technique involves specifying water level changes at each pool in the entire aqueduct. Pumps are treated like gates having dead bands, figure 9. This type of operation could properly be called "pump stroking."

The difference between reach and aqueduct computations is mainly one of operating philosophy. If a pump and water level schedule are both specified, then the water level in at least one pool in a reach cannot be specified. That is, the

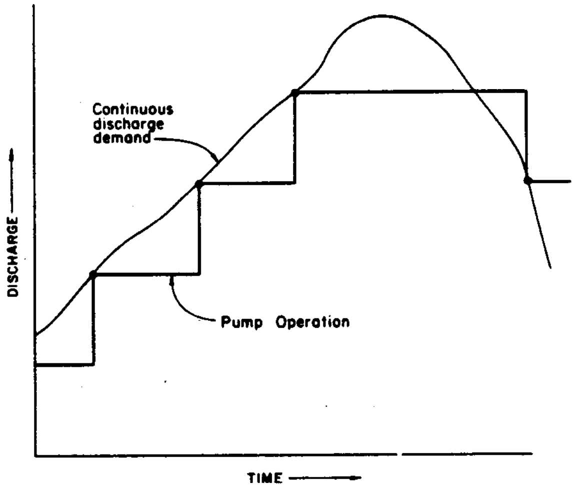


Figure 9.-Dead-band operation with a pump.

level in one pool must be allowed to seek its own level or "float." On the other hand, if only the water level variations and delivery schedules are specified, then the necessary pump schedules to achieve this can be uniquely determined. For the first case, the pump schedules are of primary importance and water level fluctuations in at least one pool must be tolerated. In the second case, water level fluctuations are controlled everywhere and the pumping schedule is the flexible component.

For a floating water level, the computations pass from a predictive to an analysis stage. The discharges at each end of the pool are specified and the water levels at the boundaries are calculated, figure 8. This computer program fails when there is a very small flow into the pool. As the water level drops, the wave celerity approaches zero. Since the reciprocal of the celerity is used in the method of characteristics, the range of permissible values for the variable may be exceeded in the computer with small flow depths.

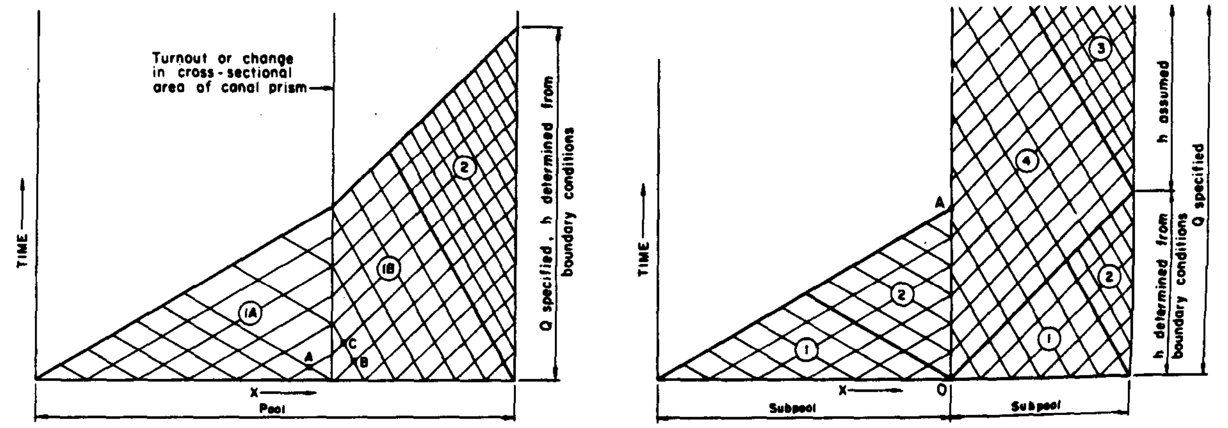
Changes in Prism Cross Section

In the derivation of the characteristics method, it was assumed that the section was prismoidal in each pool. This assumption does not hold true if a change in cross-sectional shape occurs in the pool. For large changes in shape, the characteristic line which crosses the change can deviate greatly from a straight line (point *A* to point *C*, fig. 10A).

The exact solution of this case requires two additional equations for the characteristic which crosses the change in section. These are (1) an equation which defines the distance between the known point (*A* or *B*) and the change in section, and (2) an energy equation across the change in section. This requires that every step in the computational matrix of pools with changes in section be checked to determine whether a crossing has occurred. If one has occurred, then a set of six simultaneous equations must be solved using an iterative scheme. The iterations are necessary since the area, top width, and hydraulic radius at the unknown point *C* are functions of the unknown depth at that point.

If the cross-sectional changes are not too abrupt, the differences in the slopes of the characteristic at the change can be ignored. This approximation requires the solution of five simultaneous equations. Studies have not been performed to determine what constitutes a large change in section.

As an alternate approach, the pool can be divided into subpools. The computations in each subpool proceed as if each were a pool. The computations begin at the downstream subpool in which the depth must be assumed along the region 3 boundary, (fig. 10B). As a consequence, both the depth and discharge are determined just downstream of the change in cross section. If continuity of flow across the change is maintained, then application of the energy equation will yield the depths on the upstream side of the



A. Actual Characteristic Grid

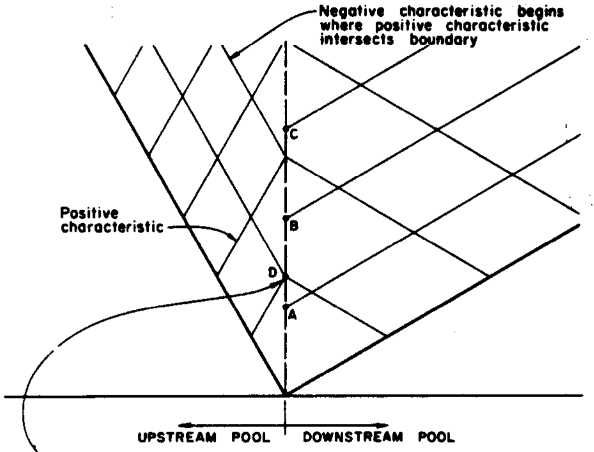
B. Simplified Computational Scheme

Figure 10.-Turnouts and change of cross-sectional area.

transition. These depths can be compared with the depths resulting from the upstream subpool computations of region 2. If the differences between the two are within acceptable limits, the depth variation assumed at the downstream pool boundary is acceptable. If the two are outside of acceptable limits, the downstream pool boundary depths must be respecified. Generally, rapid changes in water depths do not occur; therefore, iteration has not proven to be necessary.

The largest errors with this procedure develop at the last computation in region 2 of the upstream subpool, (fig. 10B). The effect of errors along the timeline *O-A* can be minimized by a relatively simple procedure. Using continuity of flow at the intermediate boundary, the flow depths are determined in the upstream subpool region 2. Then, using the energy equation across the intermediate boundary with known values of flow and depth from region 4 (and in some cases, region 3) a slightly different upstream flow depth is determined at the intermediate boundary in region 2. This depth based on energy considerations is substituted for that based on continuity considerations. A linear interpolation is required at the transition, (fig. 11), since the grid points from the downstream subpool regions 3 and 4 do not match with those from the upstream subpool region 2.

With the present program it has been assumed that the flow passes from one cross section to the other with no loss of energy. However, the energy equation could include a transition loss if desired.



Parameters such as time, depth, and discharge at this point determined by linear interpolation between values at A and B. The constant energy equation is applied at turnouts and changes in cross-sectional area. The gate equation is applied at control structures.

Figure 11.-Computational method across pool boundaries.

Turnouts

The concepts developed for changes in cross section also apply to turnouts. In this case, the continuity of flow also includes the proper accounting for the turnout discharge. Theory and experiment indicate that the turnout flow does not affect the energy head [4]. Therefore, energy is assumed constant across the turnout.

Gates

The general form of the equation for flow under a free flowing radial (Tainter) gate can be obtained from Bernoulli's equation [5]. It is expressed as:

$$Q = C_c bB \sqrt{2g\,(\Delta y + V_1^2/2g)} \qquad (12)$$

where C_c = Contraction coefficient
b = gate opening
B = gate width
Δy = difference between upstream and downstream water depths
V_1 = upstream mean velocity
g = acceleration of gravity

If the downstream depth exceeds the gate opening, the flow is said to be submerged. For this case, the equation must be modified to include losses that occur on the downstream side of the gate. It has been argued that the parameters C_c and $V_1^2/2g$ are governed by several linear terms which are characterized by the flow pattern [6]. Thus, it is possible to express the discharge as

$$Q = C_d bB \sqrt{2gy_1} \qquad (13)$$

where C_d = Discharge coefficient
y_1 = Upstream depth

The discharge coefficient is a function of the submergence y_2/b, trunnion height a/b, and upstream depth y_1/b ratios, (figs. 12 and 13).

The Corps of Engineers (7) uses the following form of the equation for submerged flow

$$Q = C_s B\, y_2 \sqrt{2g\,(\Delta y + V_1^2/2g)} \qquad (14)$$

where C_s = Submerged discharge coefficient.

With this equation, the discharge coefficient varies linearly on a log-log scale from a value of 0.04 at $y_2/b = 20$ to 0.35 at $y_2/b = 2.5$. The effect of the radius of curvature of the sector

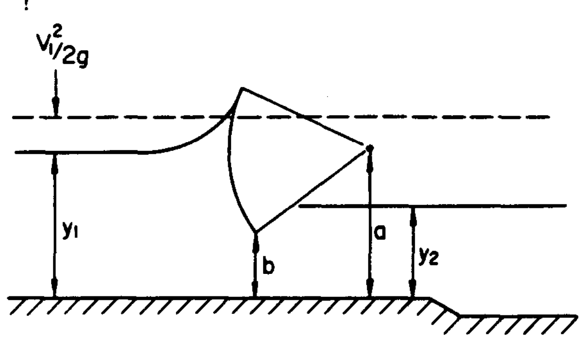


Figure 12.-Gate definition sketch.

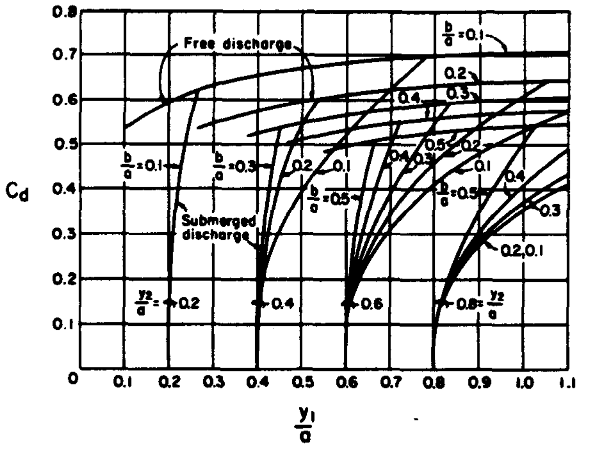


Figure 13.-Coefficient of free and submerged radial gate discharge for *r/a* = 1.5

which forms the gate and the trunnion height has not been systematically investigated for this form of the equation.

The equation used in the computer program is based upon the equation from the Corps of Engineers, using the gate opening instead of the downstream depth.

$$Q = CBb \sqrt{2g(\Delta y + V_1^2/2g)} \qquad (15)$$

where C = discharge coefficient

$= C_s y_2/b$

Since the spread in the data is so large (fig. 14) detailed model studies of the specific structures are recommended. With detailed studies, the simpler form of the discharge relationship given by equation (13) should be used.

In current practice, it is impractical for a gate to follow the timewise change in openings that are specified by the gate stroking technique. Instead, a dead-band type of operation is preferred. With this, a gate movement is initiated when the gate stroking predicts excursions which exceed the dead band. If this occurs, the time at which the gate motion should have started is calculated. This time is a function of the gate speed, (fig. 15). Future gate structure installations may include multi- and variable-speed gate motors. With these features the gates could follow the openings specified by the gate stroking technique more closely.

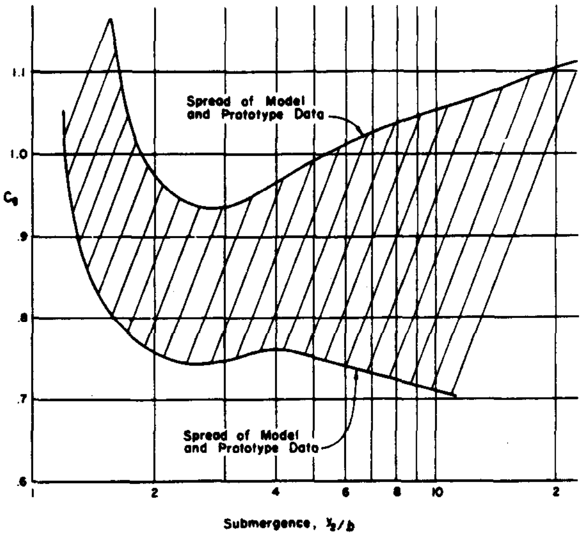


Figure 14.-Discharge coefficient as a function of submergence.

Siphons

Normally, siphons are located at the upstream end of a pool with a control gate located on the upstream end of the siphon, (fig. 16).

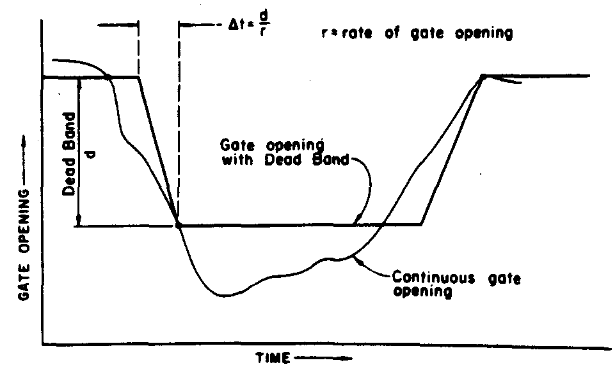


Figure 15.-Dead-band operation of gates.

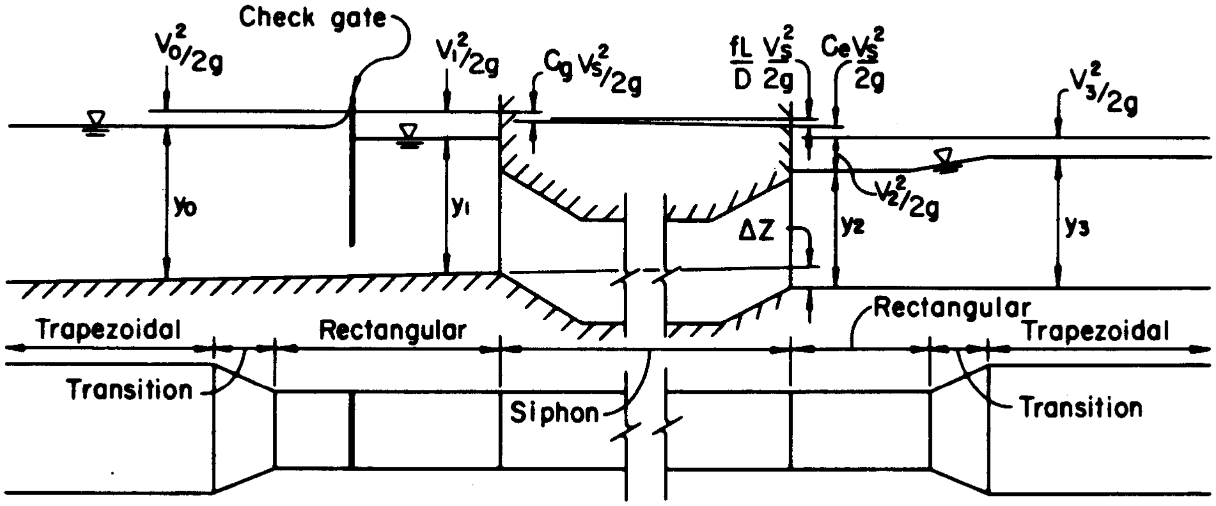


Figure 16.-Typical siphon layout.

The passage of a pressure wave through the siphon actually requires a finite length of time. However, if the wave travel time is small relative to the time steps used in the open channel portion, the siphon can be approximated with a lumped parameter. That is, it is only necessary to treat the siphon as an isolated loss which occurs with no time delays. The lumped parameter approximation is valid when

$$\frac{L}{a} < \Delta T$$

where L = siphon length
a = wave velocity
ΔT = computational time increment in open channel portion of conduit.

Normally, siphons are shorter than 2 km and wave speeds are of the order of 1000 m/s. These values indicate that the lumped parameter approximation is good for computational time increments exceeding 20 seconds in which ΔT exceeds the L/a ratio by an order of magnitude.

Ignoring inertial effects, the equation of motion for flow in the siphon is given by

$$\frac{V_1^2}{2g} + y_1 + z_1 = \frac{V_2^2}{2g} + y_2 + z_2 + KQ^2 \tag{16}$$

where V = velocity
y = flow
z = distance from datum
g = local acceleration of gravity
K = loss coefficient

The subscripts 1 and 2 refer to locations in the canal immediately upstream and downstream of the siphon, respectively. The loss coefficient includes all singular and frictional effects. It can be approximated by

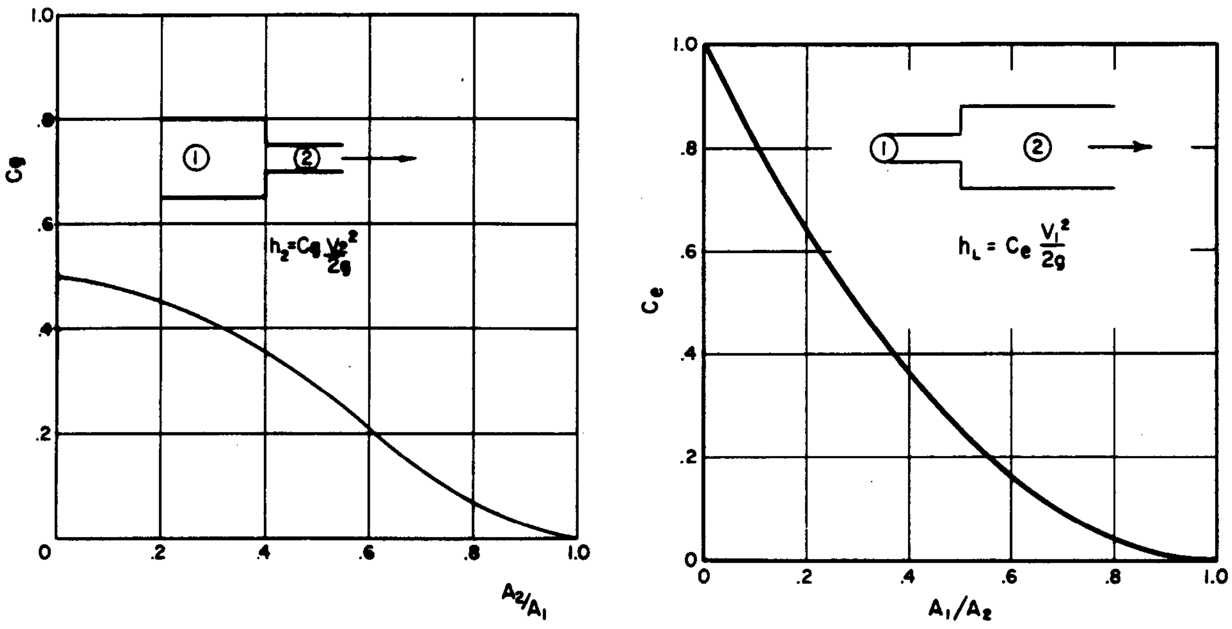
$$K = \frac{1}{2gA^2}\left(\frac{fL}{D} + C_g + C_e\right) \tag{17}$$

where A = cross-sectional area of siphon
f = Darcy-Weisbach friction factor
L = siphon length
D = equivalent hydraulic diameter of siphon = four times hydraulic radius
C_g = contraction coefficient of entrant flow
C_e = expansion coefficient of exit flow

The contraction and expansion coefficients can be accurately estimated from the ratio of the siphon area to the cross-sectional area of the respective water prisms using figure 17.

Specifications Constraints

With gate stroking, two boundary conditions are unknown (not specified) in each pool. These two unknowns are reduced to one, at boundaries that require a continuity of discharge. Based upon these two premises, it is possible to construct a series of general rules or constraints which define the computational procedures to be followed with gate stroking in canal reaches.



A. Contraction Coefficient

B. Expansion Coefficient

Figure 17.-Loss coefficients.

These are as follows:

1. In a reach there must exist at least one pool in which two conditions are specified (depth and discharge). This pool is defined as the pivot pool.

2. The computations start at a pivot pool and progress in both directions (upstream and downstream) away from the pivot pool. If the pivot pool is at the end of a reach, the computations progress in one direction only. The present program does not handle the condition of a pivot pool located other than at the end of a reach.

3. More than one pivot pool can exist in a reach; however, for the entire reach, exactly *N*+1 conditions must be specified, where *N* = number of pools.

4. A region 5 computation (fig. 8) must be performed when the specified condition is at the far end of the pool from the direction in which the computations are proceeding.

METHOD OF UTILIZATION

The Gate Stroking Model is intended to be interfaced with two other types of programs. The first of these is a scheduling program which determines the desirable water-surface elevations and pumping schedules for the daily operation of an aqueduct. Two types of scheduling programs have been developed for the Central Arizona Project. These are the Constant Volume Model and the Water Power Optimization Model. The Constant Volume Model assumes that some target storage value can be maintained in each aqueduct pool during both onpeak and offpeak periods. The Water Power Optimization Model on the other hand varies the storage value in each pool to optimize the onpeak and offpeak pumping schedules.

The second type of program with which the Gate Stroking Model was intended to interface is an analysis program. The analysis program actually simulates the canal flow. For that reason, it is called the Aqueduct Simulation Model.

Since the Aqueduct Simulation Model contains detailed flow data concerning the aqueduct at any point in time, it is used to obtain initial conditions for the Gate Stroking Model. Then a schedule of operations is developed for a subsequent time interval based on either the Constant Volume or the Water Power Optimization Model. This schedule of operations consists of changes in deliveries, possible pump operations, and specified water level fluctuations within the pools. Using this information, the Gate Stroking Model determines the gate and, in some cases, the pump schedules for the time interval under consideration. These schedules include both the gate openings and timing for the operation of the gates and pumps. Basically, the changes in flow rates through the pumps and gates should be continuous functions. However, in current practice, all of these changes actually take place in discrete amounts at discrete times. Therefore, it is necessary to determine the effects of the discrete operations through application of the Aqueduct Simulation Model to the time interval being considered. At the end of the interval the entire process is repeated. The scheduled time interval is one day in the case of the Granite Reef Aqueduct.

VALIDITY OF THE PROGRAM

As a check on the validity of the gate stroking program, the program was restructured to act as an analysis-type program. Several comparisons were made between the Aqueduct Simulation Model and the restructured Gate Stroking Model. It was found that the restructured Gate Stroking Model, using the grid of characteristics, converges to the steady-state conditions determined by the standard step method. Conversely, the method of specified time increments, as used by Shand [8], allows the water surface to drift rather than reach steady state. Depth differences from several tenths to over 0.3 m were found in the various comparisons.

The technique for restructuring the Gate Stroking Model was to make an initial estimate of depths downstream of gates, calculate the state variables in the pool upstream of the gate using that estimate, calculate the state variables in the pool downstream of the gate using the upstream values just calculated, recalculate the upstream pool using the new downstream values, etc. This process was continued until the water surface along the length of the canal stayed within some convergence limits from one iteration to the next. The technique is stable and generally requires from two to five iterations for convergence, depending upon the length of time modeled and the number and magnitude of gate movements. Unfortunately, for a canal of any length and for time periods of the order of a day, computer resource use can be significant. Investigations are being continued in an effort to improve the convergence of the technique.

PROGRAM DESCRIPTION

Background

The program (listed in appendix) determines the gate stroking schedules for a series of pools in a canal reach. If pools are separated by pumps, the pump schedules may either be determined or specified. The program is of a general nature and may be used to generate gate and, if desired, pump schedules for virtually any canal. Modifications were made to the program for the purpose of expediting a series of operations studies on Granite Reef and Salt-Gila Aqueducts, and separate versions of the program were used for those studies. The program description below pertains to the general version of the program.

The purpose of the program is to determine gate schedules which will produce desired boundary conditions (that is, depths and discharges) in a canal. The differential equations describing the flow apply to free surface flow in a prismatic canal section. Following Wylie [1], the method of characteristics is used to solve the equations within the interior of a computational segment. Abbott [9] gives an excellent description of the significance of characteristic functions as they pertain to the equations of state of water conveyance systems.

Problem Formulation

The present gate stroking technique has been formulated such that:

1. The computations proceed from one pool to another in an upstream direction.
2. Initial conditions along the entire length of the aqueduct must be specified.
3. At the downstream end of the most downstream pool:
    a. The discharge must be specified for all time.
    b. The depth must be specified for all time greater than one wave travel time in the pool.

4. At intermediate pools, the depth must be specified for time greater than one wave travel time in the pool.
5. To obtain a gate schedule for all pools it is necessary to project the most downstream pool depth and discharge schedules at least one wave travel time for the reach into the future. If pump stroking is involved, the most downstream pool schedules must be projected at least one wave travel for the entire length of the aqueduct.
6. The discharge at all intermediate pools is a dependent variable; that is, the discharge cannot be specified.

Initial Conditions

The state of the system must be described completely at some specific time, usually at a zero time reference. The system may be in a steady-state condition (all time derivatives equal to zero) or in an unsteady, or transient, condition. The program will accept initial conditions in any of three formats, individually for each pool. The formats differ only in the number of points at which the initial conditions are specified. The state variables, x (position along the length of the pool), y (water depth), and Q (water discharge quantity), may be specified at zero time at up to 40 equally spaced locations along the length of the pool.

If $N = 1$, the state variables must be specified at either end of the pool. A backwater calculation is then performed by the program to determine the state variables at 11 equally spaced points in the pool.

If $2 \leq N \leq 10$, linear interpolations of the state variables using the values at x_1 and x_n only are calculated at 11 equally spaced points in the pool.

If $11 \leq N \leq 40$, the values of the state variables provided by the user are accepted as the initial condition.

No checks are made at boundaries for consistency across boundaries.

Boundary Conditions

Depth schedules.—must be provided for the downstream boundaries of all pools. The program will accept schedules for a 48-hour period. If a depth schedule is not appropriate for a particular pool, that is, the most upstream pool in the reach or a pool with no control structure at its downstream end, the schedule will be ignored by the program. However, schedules must be provided for each and every pool. Depths are to be provided on the hour, and transitions from one depth to another are made linearly by the program. The specific format for input is described in subroutine READIT, which may be altered to suit the needs of the user.

Discharge schedules.—must be provided for the downstream boundaries of all pools. The discharge schedule at the upstream boundary of the most upstream pool must also be furnished to provide consistency with the input/output formats of the Constant Volume and Aqueduct Simulation Models. The program will ignore all but the most upstream and downstream schedules and will maintain discharge continuity throughout the length of the reach. Provision is made in the program to stroke the pumps at the upstream end of the reach or to stroke the gate which connects the reach to a reservoir. In these cases, the appropriate upstream discharge schedules will be ignored. Discharges are to be specified on the hour, and transitions from one discharge to another are made in one step at the time of change.

Turnout schedules.—must be provided for all turnouts. Turnouts are considered to be at the downstream ends of pools. They may occur separately or in conjunction with a control structure such as a check gate or siphon. The pool number, time of change of discharge (on the hour), and the change in discharge (positive discharge is outflow from the canal) are input for up to 48 discharge changes for each turnout. The initial turnout discharge is assumed zero, and the specified values are added to the current discharge at the specified times. No energy losses are considered at turnouts.

Pumps.—at the downstream end of the reach are treated as scheduled discharge devices. At the upstream end of the reach, pumps are treated as scheduled discharge devices if pump stroking is not employed.

With pump stroking, start and stop times for pumps within the reach are calculated using a dead band for discharge. That is, pumps will be started or shut down when the discharge change calculated by the program equals or exceeds the incremental discharge change specified for the pump in the physical descriptors for the pumps.

Gate positions.—are determined using the gate equation which is

$$Q = C_d \, b \, B \sqrt{2g(y_1 - y_2) + V_1^2/2g}$$

where C_d = discharge coefficient
b = gate opening
B = gate width
V_1 = mean velocity in the rectangular section upstream of the gate
y_1 = depth in the rectangular section upstream of the gate
y_2 = depth in the rectangular section downstream of the gate

Gate movements are performed only when the calculated gate position has changed from the previous position by an amount equal to or exceeding the dead-band value for that gate. Gate structures are treated as having one gate. The width of the rectangular gate section is specified in the variable BOTGATE. Independent operation of multiple gates within a structure is not a feature of the program. This type of operation can be simulated, however, by modifying the discharge coefficient. The modified coefficient for single gate operation within a structure having multiple gates is given by

$$C_d^{\prime} = \frac{C_d B_g}{B}$$

where B_g = bottom width of a single gate

Inverted siphons.—with or without control gates at the upstream end of the siphons are treated as zero length friction effects. The invert drop from the gate structure or siphon inlet to the siphon outlet and the friction loss factor are specified for each siphon.

Boundaries where no control structure is present.—(that is, changes in cross section, or turnouts) are treated as points at which no energy losses occur. Depths upstream of these boundaries are calculated using the energy equation.

Physical Descriptors

The constant descriptors of the reach, that is, stationing at pool ends, cross-section parameters, gate parameters, roughness, and siphon parameters, are set in DATA statements in the main program. Comment cards in the program describe the various parameters.

Modular Construction

The program has been constructed in a modular fashion. It is anticipated that expanded cap abilities will be easily accomplished by this approach. For example, circular sections were added by defining a circular pool type and adding the appropriate code in the area, top width, and wetted perimeter function routines.

Output

The output file is formated to be compatible for use as input to the Aqueduct Simulation Model.

Development and Structure of the Program

The gate stroking program was developed within rather severe time constraints to perform real-time operation studies for the Granite Reef and Salt-Gila Aqueducts. Previously published material dealt almost exclusively with techniques for the solution of the flow equations within a few computational segments. The equations of state and their solution for a system of pools present a challenge which is an order of magnitude greater than the problem of solving the open channel equations in a single segment. Some comments are appropriate concerning the general structure and the evolution of the present program.

The program is written in FORTRAN and is implemented on a CDC CYBER 74 computer system. Comment cards within the program explain the computational procedures. The assumption is made that anyone using the program will have a good understanding of free surface flow; an understanding of the various mathematical techniques encountered in the solution of the equations of state of the system; and a reasonable, but not expert, understanding of digital computing techniques. Within this framework, the program may be utilized to assist in the investigation of flow characteristics of virtually any canal configuration.

The program does not contain coding to accommodate all possible structures found in all canals. It also does not handle all possible canal cross sections. However, the modular structure of the program enables the user to add new structure types and pool types in a straightforward fashion. Likewise, from the multitude of possible operational philosophies for a canal, one was chosen as appropriate for the Granite Reef

Aqueduct, and that one was implemented in the program. The philosophy chosen is that pump schedules are predetermined at both ends of the reach and the most upstream pool in the reach will be uncontrolled with respect to depth variations. The same computational techniques can be used to "float" the downstream pool by calculating in a downstream direction or to pivot on an interior pool and calculate both upstream and downstream of that pool. The modular construction of the program allows the user to implement these schemes in a relatively straightforward fashion. Provision was also made for stroking the most upstream control structures. The input and output for the program are contained in the routines READIT and WRITEIT and may be modified easily to suit the user.

Various techniques were investigated for the treatment of the system at control structures and turnouts. The generalized program evolved out of experience gained with these various techniques. Some observations relative to the evolution may be beneficial.

Since turnouts generally divert only a small portion of the total discharge, the program used for the Granite Reef study merely adjusted the discharge within a computational segment when a characteristic crossed the turnout location. This treatment appears adequate when the turnout diversion is small and when the turnout is not near the control structures at the ends of the pool. The advantage of this technique is that depth continuity is maintained at a turnout location for all time. If the turnout discharge were a large percentage of the total discharge, a simultaneous depth correction could be made at the turnout using the energy equation. Difficulties in making the proper discharge correction were encountered when the turnout fell between a boundary and the grid point upstream or downstream of the boundary. Since the method of characteristics is stable for rather large time increments and, consequently, the *x* spacing of grid points can be rather large, the chance for a turnout between a boundary and the next grid point is fairly high. Thus, for the Salt-Gila study and the general program, turnouts are treated as boundaries. The disadvantage of this approach is that depths at the turnout for one wave-travel time in the upstream pool are not calculated identically in the upstream and downstream pools. Apparently, serious discrepancies do not occur for normal operation schemes. The energy equation is used to calculate a corrected depth across the turnout so the effect of large diversions is minimized.

As was discussed earlier, various equations have been used to describe the state of a canal system at gate structures. Mathematically, flows through the gates can be very sensitive to small differences in depths on the upstream and downstream sides of the gates. Accordingly, convergence criteria for the various iterative schemes in the program should be examined using the gate parameters particular to the system under investigation. An adequate compromise between program run times and long-term stability of the solution must be reached. For self-consistency, identical methods of computing the discharge through gates should be used in both the gate stroking and the Aqueduct Simulation Model programs. For this reason, equations more closely approximating the equations in Shand's [8] program were used in the Granite Reef and Salt-Gila versions of the gate stroking program. Due to the finite number of gate movements and different computational techniques, differences will occur between the predicted and "actual" water surfaces and discharges, even with identical physical parameters and gate equations. These differences should, however, be small. Large differences if they occur, can be attributed to interpolation errors in one or both of the programs.

Program Details

The equations upon which the coding is based are described in the preceding sections. The friction slope is computed using English customary units. The conversion to SI metric units can be accomplished by deleting the constant 1.49 in Subprogram S and by changing the value of the gravitational constant GGRAV to metric units.

The purposes of the subroutines and function subprograms are as follows:

PROGRAM GSM - Main calling program. Canal parameters are input through DATA statements located in this program

SUBROUTINE READIT - Routine to read in discharges, depths, turnout schedules, and initial conditions

SUBROUTINE STROKER - Routine to solve gate stroking problem for free surface flow

SUBROUTINE SOLVER - Routine to solve for x, t, Q and y at point P using values at point R on positive characteristic and values at point S on negative characteristic

FUNCTION C - Function to calculate wave celerity

FUNCTION R - Function to calculate hydraulic radius

FUNCTION A - function to calculate cross-sectional area in trapezoidal, horseshoe, or circular channels

FUNCTION TW - Function to calculate top width in trapezoidal, horseshoe, or circular channels

FUNCTION S - Function to calculate energy slope using Manning's equation

FUNCTION P - Function to calculate wetted perimeter in horseshoe, trapezoidal, or circular channels

SUBROUTINE BOUNDARY - Calculates *t*, *Q*, and *y* at an upstream boundary and *t* and *y* at a downstream boundary

FUNCTION HDN - Function to determine downstream boundary depth

FUNCTION QDN - Function to determine discharge boundary condition at downstream end of pools

FUNCTION QUPST - Function to specify discharge at upstream end of most upstream pool

SUBROUTINE TRNOUT - Routine to specify turnout discharge

SUBROUTINE GATEMO - Routine to calculate gate openings and pump schedules

SUBROUTINE GATEY - Routine to calculate depth in gate section from channel depth

FUNCTION CD - Routine to calculate discharge coefficient as a function of gate opening to upstream depth ratio

SUBROUTINE FOLOWER - Routine to follow stroking motions to determine start times and final positions of gates and pump schedules

SUBROUTINE WRITEIT - Routine to merge turnout, gate, and pump schedules into input file for unsteady model

BIBLIOGRAPHY

[1] Wylie, E. B., "Control of Transient Free-Surface Flow," Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 95, No. HY1, p. 347-361, January 1969.

[2] O'Loughlin, E. M., "Application of Unsteady Flow Analysis to Operation Decisions in Long Aqueducts," International Commission on Irrigation and Drainage, Eighth Congress, Bulgaria, R. 16, p. 28.2.207-28.2.223 1972.

[3] Gientke, F. J., "Transient Control in Lower Sacramento River," Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 100, No. HY3, p. 405-424, March 1974.

[4] Chow, V. T., *Open-Channel Hydraulics,* McGraw-Hill, p. 328, 1959.

[5] Ippen, A. T., "Channel Transitions and Controls," *Engineering Hydraulics,* edited by H. Rouse, p. 536, 1950.

[6] Metzler, D. E., "A Model Study of Tainter-Gate Operation," M.S. Thesis, Iowa State University, Ames, 1948.

[7] U.S. Army Engineer Waterway Experiment Station, "Hydraulic Design Criteria," Chart 320-8, 1959.

[8] Shand, M. J., "Final Report - Automatic Downstream Control Systems for Irrigation Canals," Hydraulic Engineering Laboratory, College of Engineering, University of California, Berkeley, Report HEL-8-4, August 1971.

[9] Abbott, M. B., *An Introduction to the Method of Characteristics,* American Elsevier, New York, 1966.

APPENDIX

Gate Stroking Computer Program Listing

```
      PROGRAM GSM(INPUT=64,OUTPUT=64,TAPE1=64,TAPE2=64,TAPE3=64,
       TAPE4=64,TAPE5=64,TAPE6=64,TAPE8=64,TAPE9=64)
C GENERALIZED GATE-STROKING PROGRAM
C
C THE GATE-STROKING TECHNIQUE IS TAKEN FROM BEN WYLIES
C  PAPER  CONTROL OF TRANSIENT FREE-SURFACE FLOW  IN
C  JAN., 1969, PROC OF ASCE, JOURNAL OF THE HYDRAULICS
C  DIVISION
C
C THIS PROGRAM IS IN ENGLISH UNITS
C  THE GRAVITATIONAL CONSTANT, GGRAV, AND THE FACTOR
C  1.49 IN MANNINGS N IN SUBPROGRAM S ARE THE ONLY
C  CHANGES REQUIRED FOR METRIC CONVERSION
C  SOME INTERMEDIATE OUTPUTS MAY BE AFFECTED BY A
C  METRIC CONVERSION, AS FORMAT F10.3 IS GENERALLY
C  USED, SO IT WOULD PAY TO CHECK AND SEE THAT NO
C  SIGNIFICANCE WAS LOST IN ROUNDING
C
C THE PROGRAM IS SET UP TO INPUT PUMP SCHEDULES AND
C  DEPTH SCHEDULES AT 0, 0700 AND 2300 HOURS.
C  THE INPUT IS IN ROUTINE READIT, AND MAY HAVE TO BE
C  CHANGED.  THE OUTPUT IS IN ROUTINE WRITEIT, AND MAY
C  HAVE TO BE CHANGED TO SUIT THE USERS REQUIREMENTS.
C
C TAPE1 IS INTERMEDIATE T,Q AND Y FILE AT POOL BOUNDARIES
C TAPE2 IS INTERMEDIATE T AND GATE OPENING FILE
C TAPE3 IS INPUT FILE CONTAINING PUMP, DEPTH AND TURNOUT SCHEDULES
C TAPE4 IS SCRATCH FILE USED TO OVERLAY COMMON
C TAPE5 IS INTERMEDIATE START TIME AND GATE POSITION FILE
C TAPE6 IS OUTPUT FILE CONTAINING PROGRAM MESSAGES TO USER
C TAPE8 IS INPUT FILE CONTAINING INITIAL CONDITIONS
C      IN UNSTEADY MODEL FORMAT
C TAPE9 IS OUTPUT FILE IN UNSTEADY MODEL FORMAT FOR INPUT
C      TO UNSTEADY MODEL
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     .  NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     .  MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     .  (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     .  TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     .  STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     .  UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51)
     .  TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C SCRATCH AREA TO BE OVERLAID IN THE VARIOUS SUBROUTINES
C TO KEEP MEMORY WITHIN SOME SORT OF REASONABLE BOUND
      COMMON /SCRATCH/
     .   NDX(50),XSTART(40,50),YSTART(40,50),QSTART(40,50),
     .  HSCHED(48,50),XINIT(40),YINIT(40),QINIT(40),H(48),
     .  DUMMY1(7169)
      DIMENSION SCRATCH(15787)
```

```
      EQUIVALENCE (SCRATCH(1),NDX(1))
C
C STUDY TELLS THE PROGRAM IF THE MOST UPSTREAM
C  STRUCTURE, EITHER A PUMP OR A GATE, IS TO BE
C  STROKED OR NOT
C   STUDY=1 IS NO STROKING (Q IS SCHEDULED)
C   STUDY=2 IS STROKING
      DATA (STUDY=2)
C
C
C POOLS ARE NUMBERED FROM DOWNSTREAM TO UPSTREAM IN THE REACH
C ARRAYS ARE DIMENSIONED FOR 50 POOLS
C ARRAYS ARE DIMENSIONED FOR 40 GRID POINTS PER POOL
C
C SET MAX TIME FOR THE REACH
C MAX TIME MUST BE AT LEAST STUDY TIME (USUALLY 24 HOURS)
C  PLUS WAVE TRAVEL TIME FOR THE REACH
C  TIME IS IN SECONDS
      DATA (TMAXI=19600.)
C STATIONING AT UPSTREAM ENDS OF POOLS
C ARRAY IS UPSTA(POOL)
      DATA (UPSTA=270494.4,234854.4,198105.6,162148.8,134270.4
     .  ,45*0.0)
C STATIONING AT DOWNSTREAM ENDS OF POOLS
C ARRAY IS DWNSTA(POOL)
      DATA (DWNSTA=304972.8,270494.4,234854.4,198105.6,162148.8
     .  ,45*0.0)
C NUMBER OF POOLS IN THE REACH
      DATA (NOPOOLS=5)
C TYPES OF POOLS
C     POOLTYP=0  THIS POOL NOT USED
C     POOLTYP=1  TRAPEZOIDAL CHANNEL
C     POOLTYP=2  HORSESHOE TUNNEL
C     POOLTYP=3  CIRCULAR TUNNEL
C ARRAY IS POOLTYP(POOL)
      DATA (POOLTYP=5*1,45*0)
C MANNINGS N
C  ARRAY IS MANN(POOL)
      DATA (MANN=5*0.016,45*0.0)
C BOTTOM SLOPE - S0
C  ARRAY IS BOTGRAD(POOL)
      DATA (BOTGRAD=5*0.00008,45*0.0)
C STRUCTURE TYPES AT UPSTREAM ENDS OF POOLS
C     ARRAY IS STRTYPE(POOL)
C     STRTYPE(51) IS MOST DOWNSTREAM STRUCTURE
C         STRTYPE=0  POOL NOT USED
C         STRTYPE=1  PUMP
C         STRTYPE=2  NORMAL CHECK GATE
C         STRTYPE=3  SYPHON WITH CHECK GATE
C         STRTYPE=4  SYPHON WITH NO CONTROL STRUCTURF
C         STRTYPE=5  NO CONTROL STRUCTURE
      DATA (STRTYPE=3*2,3,2,45*0,2)
C TRAPEZOIDAL CHANNEL PROPERTIES - BOTTOM WIDTH AND SIDESLOPE
C  SIDESLOPE=0.0 GIVES A RECTANGULAR SECTION
C
      DATA (BOTTOM=5*24.0,45*0.0)
      DATA (SIDSLOP=5*1.5,45*0.0)
```

```
      C CHECK GATE PROPERTIES
      C POOL NUMBERING IS D/S TO U/S
      C GATE IS AT U/S END OF POOL
      C  PARAMETERS FOR GATE AT D/S END OF REACH IN ARRAY(51)
      C
      C SET UPSTREAM AND DOWNSTREAM CONSTANT LEVEL
      C  RESERVOIR DEPTHS IF GATES AT U/S OR D/S ENDS OF REACH
            DATA (USRES=16.0),(DSRES=14.0)
      C
      C CHECK GATE BOTTOM WIDTH
            DATA (BOTGATE=5*36.0,45*0.0,36.0)
      C GATE MOTOR SPEED
            DATA (SPEED=5*0.75,45*0.0,0.75)
      C GATE MOTION DEADBAND
            DATA (DEDBAND=5*0.5,45*0.0,0.5)
      C INVERT DROP FROM GATE SECTION TO CHANNEL ON D/S SIDE OF GATE
      C  IF SYPHON, LUMP INVERT DROPS ON D/S SIDE IN SYFONDY BELOW
      C   IF GATE AT D/S END OF REACH, DEPTH IN DSRES IS IN
      C    GATE SECTION - NO D/S INVERT DROP OR SYPHON PARAMETERS ARE
      C    INPUT FOR THAT GATE
            DATA (DSINVT=3*0.1,0.0,0.1,45*0.0)
      C INVERT DROP FROM CHANNEL TO GATE SECTION ON U/S SIDE OF GATE
      C  IF GATE AT U/S END OF REACH, DEPTH IN USRES IS IN
      C   GATE SECTION - NO U/S INVERT DROP IS INPUT FOR THAT GATE
      C   U/S INVERT DROP IS ALLOWED FOR GATE AT D/S END
      C   OF REACH, IF ANY
            DATA (USINVT=50*0.0,0.0)
      C GATE COEFFICIENTS
      C  ARRAY IS GATECO(1-11,POOL)
      C  SEE ROUTINE GATEMO FOR THEIR USE IN GATE EQUATION
            DATA (GATECO=
           .  .71,.688,.67,.655,.645,.644,.659,.693.
           .  .756,.862,1.019
           .  ,.71,.688,.67,.655,.645,.644,.659,.693,
           .  .756,.862,1.019
           .  ,.71,.688,.67,.655,.645,.644,.659,.693,
           .  .756,.862,1.019
           .  ,.71,.688,.67,.655,.645,.644,.659,.693,
           .  .756,.862,1.019
           .  ,.71,.688,.67,.655,.645,.644,.659,.693,
           .  .756,.862,1.019
           .  ,495*0.0
           .  ,.71,.688,.67,.655,.645,.644,.659,.693,
           .  .756..862,1.019)
      C PUMP PARAMETERS
      C  PUMPDQ(POOL) IS DISCHARGE INCREMENT FOR PUMPS AT U/S END OF POOL
      C  USED IN ROUTINE FOLOWER TO DETERMINE PUMP SCHEDULES
      C  PUMPDQ(51) IS AT D/S END OF REACH
            DATA (PUMPDQ=4*0.0,125.,45*0.0,125.)
      C
      C TUNNEL PROPERTIES
      C RADIUS IS HEIGHT OF TUNNEL, INVERT TO CREST, FOR HORSESHOE TUNNEL
      C RADIUS IS RADIUS OF TUNNEL FOR CIRCULAR TUNNEL
      C  ARRAY IS RADIUS(POOL)
            DATA (RADIUS=50*0.0)
      C
      C SYPHON PARAMETERS
```

```
C  ARRAYS ARE SYFONDY(POOL) AND SYFNLOS(POOL)
C INVERT DROP IN SYPHON
       DATA (SYFONDY=3*0.0,3.24,0.0,45*0.0)
C SYPHON LOSSES
       DATA (SYFNLOS=3*0.0,3.21E-7,0.0,45*0.0)
C TURNOUTS
C  TURNOUTS CAN BE AT D/S END OF ANY POOL
C  NUMBER OF TURNOUTS IN THE REACH
       DATA (NUMTRNS=0)
C
       DATA (GGRAV=32.2),(PI=3.1415927)
C
       REWIND 6
       REWIND 1
       REWIND 2
       REWIND 3
       REWIND 4
       REWIND 5
       REWIND 8
       REWIND 9
C
C READ IN FLOWS, DEPTHS AND TURNOUT SCHEDULES
C  AND INITIAL CONDITIONS
       CALL READIT
C
C SET TIME INCREMENT FOR CALCULATIONS AT BOUNDARIES (IN SECONDS)
C 5 MIN X 30 HOURS STAYS IN ARRAY LIMITS
C
       TINC=300.
C SET NUMBER OF POOLS IN THIS REACH
       NPOOLS=NOPOOLS
C SET BEGINNING AND ENDING STATIONING FOR POOLS
       DO 10 I=1,NPOOLS
       STABEG(I)=UPSTA(I)
       STAEND(I)=DWNSTA(I)
 10    CONTINUE
C SET MAXIMUM CALCULATION TIME FOR THE REACH -
C  MODEL TIME, NOT COMPUTE TIME
       TMAX=TMAXI
C SOLVE FOR EACH POOL
C CALCULATIONS PROCEED IN UPSTREAM DIRECTION
       DO 100 I=1,NPOOLS
       IPOOL=I
C SET POOL LENGTH AND TYPE
       XEND=STAEND(IPOOL)-STABEG(IPOOL)
       TYPPOOL=POOLTYP(IPOOL)
C SET INITIAL CONDITIONS FOR THIS POOL
C HSCHED IS D/S DEPTH SCHEDULE
C HSCHED WAS READ IN BY READIT
C SCHEDULE IS FOR 48 HOURS
       DO 20 J=1,48
       H(J)=HSCHED(J,IPOOL)
 20    CONTINUE
C SET NUMBER OF INCREMENTS ALONG LENGTH OF POOL
C CALCULATE BACKWATER CURVE IF ONLY ONE POINT IS GIVEN -
C  THE NON-ZERO VALUE FOR Y MAY BE AT EITHER END OF POOL
C  AND THE BACKWATER CURVE WILL BE CALCULATED TO THE OTHER END
```

```
      NXINC=NDX(IPOOL)
C CALCULATE BACKWATER CURVE, IF DESIRED, FOR 11 POINTS IN POOL
      IF(NXINC.EQ.2.AND.YSTART(1,IPOOL).EQ.0.0) CALL BAKWATR(1)
      IF(NXINC.EQ.2.AND.YSTART(2,IPOOL).EQ.0.0) CALL BAKWATR(2)
C LINEAR WATER SURFACE IF LESS THAN 11 POINTS
C  IF BAKWATR WAS CALLED, NXINC WAS SET TO 11
      IF(NXINC.GE.11) GO TO 40
      WRITE(6,9000)
      DELX=XSTART(NXINC,IPOOL)-XSTART(1,IPOOL)
      DELY=YSTART(NXINC,IPOOL)-YSTART(1,IPOOL)
      DELQ=QSTART(NXINC,IPOOL)-QSTART(1,IPOOL)
C LINEAR INTERPOLATION FROM ZERO TO XEND IN 10 EQUAL STEPS
      DO 30 L=2,11
      FL=L-1
      XSTART(L,IPOOL)=XSTART(1,IPOOL)+FL*DELX/10.0
      YSTART(L,IPOOL)=YSTART(1,IPOOL)+FL*DELY/10.0
      QSTART(L,IPOOL)=QSTART(1,IPOOL)+FL*DELQ/10.0
 30   CONTINUE
      NXINC=11
      NDX(IPOOL)=11
 40   CONTINUE
C CHECK THAT ARRAYS ARE NOT OVERRUN
      WRITE(6,9010) NXINC
      IF(NXINC.GT.40) STOP
C MEASURE X FROM ZERO AT UPSTREAM END OF POOL
      DO 50 L=1,NXINC
      XINIT(L)=XSTART(L,IPOOL)-STABEG(IPOOL)
      YINIT(L)=YSTART(L,IPOOL)
      QINIT(L)=QSTART(L,IPOOL)
 50   CONTINUE
      WRITE(6,9040) XINIT(1),XINIT(NXINC)
      XINIT(1)=0.0
      XINIT(NXINC)=XEND
C SAVE COMMON ON TAPE4
      WRITE(4,9030) (SCRATCH(ISCR),ISCR=1,845
      REWIND 4
C SOLVE THIS POOL
      CALL STROKER
C RETRIEVE COMMON FOR NEXT POOL
      READ(4,9030) (SCRATCH(ISCR),ISCR=1,8450)
      REWIND 4
      WRITE(6,9020) IPOOL
 100  CONTINUE
      REWIND 1
C CALCULATE GATE OPENINGS AND PUMP DISCHARGES FOR 24 HOUR PERIOD
      CALL GATEMO
C CALCULATE GATE MOVEMENTS FROM GATE OPENINGS AND CALCULATE PUMP SCHEDULES
      CALL FOLOWER
C OUTPUT CALCULATED DATA FOR UNSTEADY MODEL INPUT
      CALL WRITEIT
      WRITE(6,9050)
      REWIND 6
      REWIND 9
      STOP
C FORMATS
 9000 FORMAT(1X,43HINTERPOLATING WATER SURFACE FROM END POINTS)
 9010 FORMAT(1X,6HNXINC=,I10,19H  MAX ALLOWED IS 40 )
```

```
            9020  FORMAT(1X,8HEND POOL,I5/)
            9030  FORMAT(5O20)
            9040  FORMAT(1X,6HXINIT=,2F10.2)
            9050  FORMAT(1X,18HNORMAL TERMINATION )
290               END
```

```
      SUBROUTINE BAKWATR(ICHOOSE)
C ROUTINE TO CALCULATE INITIAL BACKWATER CURVES
C GIVEN DOWNSTREAM Y AND Q (ICHOOSE=1)
C OR UPSTREAM Y AND Q (ICHOOSE=2)
C SECOND ORDER RUNGA-KUTTA METHOD ON
C     DY/DX=(SO-S)/(1-Q**2*T/A**3*G)
      DIMENSION X(40)
      COMMON /ALL/
C PHYSICAL PARAMETERS
     .  NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51).
     .  MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     .  (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     .  TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     .  STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     .  UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     .  TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C SCRATCH AREA TO BE OVERLAID IN THE VARIOUS SUBROUTINES
C TO KEEP MEMORY WITHIN SOME SORT OF REASONABLE BOUND
      COMMON /SCRATCH/
     .    NDX(50),XSTART(40,50),YSTART(40,50),QSTART(40,50),
     .  HSCHED(48,50),XINIT(40),YINIT(40),QINIT(40),H(48),
     .  DUMMY1(7169)
      REAL K
      WRITE(6,70)
C DIVIDE POOL INTO (N-1)*10 SEGMENTS
C STORE ONLY EVERY TENTH VALUE OF XN AND YN
      XEND=XSTART(2,IPOOL)-XSTART(1,IPOOL)
      N=11
      SO=BOTGRAD(IPOOL)
      TYPPOOL=POOLTYP(IPOOL)
      NDX(IPOOL)=11
      NXINC=11
      IF(ICHOOSE.EQ.1) GO TO 5
C CALCULATE IN DOWNSTREAM DIRECTION
      QO=QSTART(1,IPOOL)
      YO=YSTART(1,IPOOL)
      FN=N-1
      DX=XEND/(FN*10.)
      X(1)=0.0
      L=0
      YN=YO
      DO 2 I=2,N
      L=L+1
      DO 1 J=1,10
      FJ=J
      XN=X(L)+FJ*DX
      A1=A(YN)
      TW1=TW(YN)
      IF(TW1.LE.0.) GO TO 60
      VC2=GGRAV*A1/TW1
      IF(VC2.LE.0.) GO TO 40
```

```
      V1=Q0/A1
      IF(ABS(V1**2-VC2).LT.0.001) GO TO 50
      R1=R(YN)
      S1=S(V1,R1)
      F1=(S0-S1)/(1.-Q0**2*TW1/(A1**3*GGRAV))
      Y2=YN+DX*F1
      A2=A(Y2)
      TW2=TW(Y2)
      IF(TW2.LE.0.) GO TO 60
      VC2=GGRAV*A2/TW2
      IF(VC2.LE.0.) GO TO 40
      V2=Q0/A2
      IF(ABS(V2**2-VC2).LT.0.001) GO TO 50
      R2=R(Y2)
      S2=S(V2,R2)
      F2=(S0-S2)/(1.-Q0**2*TW2/(A2**3*GGRAV))
      K=0.5*(F1+F2)
      YN=YN+DX*K
    1 CONTINUE
      X(L+1)=XN
      XSTART(L+1,IPOOL)=XN+STABEG(IPOOL)
      YSTART(L+1,IPOOL)=YN
      QSTART(L+1,IPOOL)=Q0
    2 CONTINUE
      XSTART(1,IPOOL)=STABEG(IPOOL)
      XSTART(N,IPOOL)=STAEND(IPOOL)
      RETURN
C CALCULATE IN UPSTREAM DIRECTION
    5 CONTINUE
      Q0=QSTART(2,IPOOL)
      Y0=YSTART(2,IPOOL)
      FN=N-1
      DX=-XEND/(FN*10.)
      X(N)=XEND
      L=N+1
      YN=Y0
      DO 20 I=2,N
      L=L-1
      DO 10 J=1,10
      FJ=J
      XN=X(L)+FJ*DX
      A1=A(YN)
      TW1=TW(YN)
      IF(TW1.LE.0.) GO TO 60
      VC2=GGRAV*A1/TW1
      IF(VC2.LE.0.) GO TO 40
      V1=Q0/A1
      IF(ABS(V1**2-VC2).LT.0.001) GO TO 50
      R1=R(YN)
      S1=S(V1,R1)
      F1=(S0-S1)/(1.-Q0**2*TW1/(A1**3*GGRAV))
      Y2=YN+DX*F1
      A2=A(Y2)
      TW2=TW(Y2)
      IF(TW2.LE.0.) GO TO 60
      VC2=GGRAV*A2/TW2
      IF(VC2.LE.0.) GO TO 40
```

```
              V2=Q0/A2
              IF(ABS(V2**2-VC2).LT.0.001) GO TO 50
              R2=R(Y2)
              S2=S(V2,R2)
              F2=(S0-S2)/(1.-Q0**2*TW2/(A2**3*GGRAV))
              K=0.5*(F1+F2)
              YN=YN+DX*K
      10      CONTINUE
              X(L-1)=XN
              XSTART(L-1,IPOOL)=XN+STABEG(IPOOL)
              YSTART(L-1,IPOOL)=YN
              QSTART(L-1,IPOOL)=Q0
      20      CONTINUE
              XSTART(1,IPOOL)=STABEG(IPOOL)
              XSTART(N,IPOOL)=STAEND(IPOOL)
              YSTART(N,IPOOL)=Y0
              QSTART(N,IPOOL)=Q0
              RETURN
      40      CONTINUE
              WRITE(6,45) YN,XN
      45      FORMAT(1X,22HZERO OR NEG V**2 AT Y=,F10.3,
               3H X=,F10.3,12H IN BAKWATER )
              STOP
      50      CONTINUE
              WRITE(6,55) YN,XN
      55      FORMAT(1X,14HCRITICAL DEPTH,F10.3,3H AT,F10.3,
             . 12H IN BAKWATER )
              STOP
      60      CONTINUE
              WRITE(6,65) YN,XN
      65      FORMAT(1X,32HZERO OR NEG TW IN BAKWATER AT Y=,F10.3,
             . 3H X=,F10.3)
      70      FORMAT(1X,41HCALCULATING BACKWATER CURVE FOR THIS POOL
              STOP
              END
```

```
       SUBROUTINE READIT
C ROUTINE TO READ IN FLOWS AND DEPTHS AND TURNOUT SCHEDULES
C
C
       COMMON /ALL/
C PHYSICAL PARAMETERS
     .  NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     .  MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     .  (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     .  TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     .  STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     .  UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     .  TMAXI,NUMTRNS,USRES,DSRES
C
       REAL NMANN,MANN
       INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
C SCRATCH AREA TO BE OVERLAID IN THE VARIOUS SUBROUTINES
C TO KEEP MEMORY WITHIN SOME SORT OF REASONABLE BOUND
       COMMON /SCRATCH/
     .  NDX(50),XSTART(40,50),YSTART(40,50),QSTART(40,50),
     .  HSCHED(48,50),
     .  XINIT(40),YINIT(40),QINIT(40),H(48),
     .  QD(48),QU(48),QT(48,50),
     .  DUMMY1(4673)
C
C TAPE 3 HAS UPSTREAM AND DOWNSTREAM Q SCHEDULES, DEPTH
C SCHEDULES AND TURNOUT SCHEDULES AT
C T=0, 0700 AND 2200
C SCHEDULES MUST BE SUPPLIED AT EVERY POOL BOUNDARY,
C  EVEN WHEN THEY CANNOT BE USED, E.G., AT POOL BOUNDARIES
C  WHERE NO CONTROL STRUCTURE IS PRESENT
C
       REWIND 3
C READ OVER 4 LINE HEADING
       READ(3,9000)
       MAX=NOPOOLS
C READ AT HOURS 0, 7, 22
C READ U/S PUMP SCHEDULE
C INDEX IS HOUR+1
       READ(3,9030) QU(1),QU(8),QU(23)
       BACKSPACE 3
C STORE IN D/S TO U/S ORDER
C  TAPE 3 IS IN U/S TO D/S ORDER
       INDX=MAX
       DO 30 I=1,MAX
       READ(3,9040) HSCHED(1,INDX),HSCHED(8,INDX),HSCHED(23,INDX)
       INDX=INDX-1
 30    CONTINUE
C READ D/S PUMP SCHEDULE
C READ AT HOURS 0, 0700 AND 2200
C INDEX IS HOUR+1
       READ(3,9050) QD(1),QD(8),QD(23)
C FILL IN REMAINING HOURS OF DAY
```

```
      DO 40 I=2,7
      QU(I)=QU(I-1)
      QD(I)=QD(I-1)
      DO 40 J=1,MAX
      HSCHED(I,J)=HSCHED(I-1,J)
 40   CONTINUE
      DO 50 I=9,22
      QU(I)=QU(I-1)
      QD(I)=QD(I-1)
      DO 50 J=1,MAX
      HSCHED(I,J)=HSCHED(I-1,J)
 50   CONTINUE
      QU(24)=QU(23)
      QD(24)=QD(23)
      DO 60 J=1,MAX
      HSCHED(24,J)=HSCHED(23,J)
 60   CONTINUE
C CONTINUE SCHEDULES FOR SECOND 24 HOURS
      DO 70 I=1,24
      QU(I+24)=QU(24)
      QD(I+24)=QD(24)
      DO 70 J=1,MAX
      HSCHED(I+24,J)=HSCHED(24,J)
 70   CONTINUE
C QT(HOUR,POOL) IS TURNOUT Q
C  TURNOUT IS AT D/S END OF POOL
      DO 80 I=1,50
      DO 80 J=1,48
      QT(J,I)=0.0
 80   CONTINUE
C ARE THERE ANY TURNOUTS IN THIS REACH
C NUMTRNS IS SET IN A DATA STATEMENT IN MAIN PROGRAM
      IF(NUMTRNS.EQ.0) GO TO 140
C READ TURNOUT SCHEDULES
C MAXTURN IS LAST INDEX IN THIS REACH
C READ OVER 3 LINE HEADING FOR SCHEDULE
      READ(3,9060)
      MAXTURN=NUMTRNS
      DO 130 INDX=1,MAXTURN
C READ NUMBER OF CHANGES AT THIS TURNOUT
      READ(3,9010) LPOOL,NCHANGE
C READ TIME OF CHANGE AND DELTA Q
C CHANGES MAY ONLY BE MADE ON THE HOUR FROM 0000 TO 2300 HOURS
      DO 120 I=1,NCHANGE
      READ(3,9070) NTIME,DELQ
C TIME INDEX IS HOUR+1
      ITIME=NTIME+1
      QT(ITIME,LPOOL)=QT(ITIME,LPOOL)+DELQ
      MIN=ITIME+1
      IF(MIN.GT.24) GO TO 100
C SET Q AT TURNOUT FOR THE REMAINDER OF THE DAY
      DO 90 J=MIN,24
      QT(J,LPOOL)=QT(J-1,LPOOL)
 90   CONTINUE
 100  CONTINUE
C CONTINUE SCHEDULE FOR SECOND 24 HOURS
      DO 110 J=1,24
```

```
      QT(J+24,LPOOL)=QT(24,LPOOL)
  110 CONTINUE
  120 CONTINUE
  130 CONTINUE
  140 CONTINUE
C TAPE 8 HAS INPUT FOR UNSTEADY MODEL
C READ INITIAL CONDITIONS FROM THIS FILE
C COPY TAPE 8 TO TAPE 9 FOR USE AS INPUT TO
C UNSTEADY MODEL WITH GATE SCHEDULES INSERTED
C AFTER THIS PROGRAM HAS CALCULATED THEM
C AND WITH TURNOUT SCHEDULES INSERTED
      REWIND 8
      REWIND 9
C READ 3 TITLE CARDS AND STUDY START TIME CARD
      DO 150 I=1,4
      READ(8,9080)
      WRITE(9,9080)
      WRITE(6,9080)
  150 CONTINUE
C READ INITIAL CONDITIONS
      KPOOL=NOPOOLS
C READING POOLS FROM UPSTREAM TO DOWNSTREAM
C STORING POOLS FROM D/S TO U/S
C X VALUES RUN FROM U/S TO D/S IN BOTH CASES
C MUST HAVE CARDS FOR U/S AND D/S ENDS OF ALL POOLS
C   IF ONLY U/S AND D/S POINTS ARE GIVEN, THEN
C    IF Y U/S = 0.0, CALCULATE BACKWATER CURVE FROM D/S END
C    IF Y D/S = 0.0, CALCULATE BACKWATER CURVE FROM U/S END
C    IF Y U/S AND Y D/S .NE. 0.0, LINEAR WATER SURFACE AND
C       LINEAR Q CHANGE BETWEEN ENDS OF POOL
C
  170 INDX=1
      READ(8,9110) YSTART(INDX,KPOOL),QSTART(INDX,KPOOL)
     . ,XSTART(INDX,KPOOL)
      WRITE(9,9110) YSTART(INDX,KPOOL),QSTART(INDX,KPOOL)
     . ,XSTART(INDX,KPOOL)
C SEARCH FOR END OF POOL
      XEND=DWNSTA(KPOOL)
  180 INDX=INDX+1
      READ(8,9110) YSTART(INDX,KPOOL),QSTART(INDX,KPOOL)
     . ,XSTART(INDX,KPOOL)
     WRITE(9,9110) YSTART(INDX,KPOOL),QSTART(INDX,KPOOL)
       ,XSTART(INDX,KPOOL)
      IF(XSTART(INDX,KPOOL).EQ.XEND) GO TO 190
      IF(XSTART(INDX,KPOOL).LT.XEND) GO TO 180
      WRITE(6,9120) XSTART(INDX,KPOOL),XEND
      STOP
  190 CONTINUE
C STORE THE NUMBER OF INITIAL CONDITION POINTS
      NDX(KPOOL)=INDX
C HAVE WE READ DOWN TO POOL 1, THE MOST D/S POOL IN THE REACH
      IF(KPOOL.EQ.1) RETURN
      KPOOL=KPOOL-1
C READ NEXT D/S POOL
      GO TO 170
C
C
```

```
C FORMATS
 9000  FORMAT(1X///1X)
 9010  FORMAT(I4,I5)
 9030  FORMAT(17X,F11.2,2F16.2 )
 9040  FORMAT(1X/17X,F11.2,2F16.2/1X)
 9050  FORMAT( 17X,F11.2,2F16.2 )
 9060  FORMAT(1X//1X)
 9070  FORMAT(I9,3X,F10.2)
 9080  FORMAT(40H
     .  40H                                           )
 9090  FORMAT(I10)
 9100  FORMAT(10H          ,I10,20H
     .  40H                                          )
 9110  FORMAT(F10.3,10H          ,F10.3,
     .  30H                               ,F10.2)
 9120  FORMAT(1X,13HFOUND STATION,F10.3,
     .  21H BEFORE FINDING XEND=,F10.3,10H IN READIT )
       END
```

```
      SUBROUTINE STROKER
C ROUTINE TO SOLVE GATE STROKING PROBLEM FOR OPEN
C CHANNEL FLOW AS PER WYLIE
C THIS PROGRAM IS SET UP FOR Q AND Y
C
      COMMON /SOLV/  XP,YP,TP,QP,XR,YR,TR,QR,XS,YS,TS,QS
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     . NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     . MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     . (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     . TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     . STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     . UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     . TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
C SCRATCH AREA TO BE OVERLAID IN THE VARIOUS SUBROUTINES
C TO KEEP MEMORY WITHIN SOME SORT OF REASONABLE BOUND
      COMMON /SCRATCH/ XCP1(40),YCP1(40),TCP1(40),QCP1(40)
     . ,XCM1(40),YCM1(40),TCM1(40),QCM1(40)
     . ,XCP2(40),YCP2(40),TCP2(40),QCP2(40)
     . ,XDN2(40),YDN2(40),TDN2(40),QDN2(40)
     . ,XCP3(40),YCP3(40),TCP3(40),QCP3(40)
     . ,XCM3(40),YCM3(40),TCM3(40),QCM3(40)
     . ,XDN3(40),YDN3(40),TDN3(40),QDN3(40)
     . ,XUP3(40),YUP3(40),TUP3(40),QUP3(40)
     . ,XCP3B(40),YCP3B(40),TCP3B(40),QCP3B(40)
     . ,XDN3B(40),YDN3B(40),TDN3B(40),QDN3B(40)
     . ,XUP3B(40),YUP3B(40),TUP3B(40),QUP3B(40)
     . ,XCP4(81),YCP4(81),TCP4(81),QCP4(81)
     . ,XCM4(81),YCM4(81),TCM4(81),QCM4(81)
     . ,XUP4(81),YUP4(81),TUP4(81),QUP4(81)
     . ,XCP5(81),YCP5(81),TCP5(81),QCP5(81)
     . ,DUMMY1(5394),XINIT(40),YINIT(40),QINIT(40),DUMMY2(2544)
     . ,INDX(85),TINDX(85),KDWN,TDWN(500),QDWN(500),YDWN(500)
     . ,KUP,TUP(500),QUP(500),YUP(500)
     . ,KMAX,SAVETUP(500),SAVEYUP(500),SAVEQUP(500)
      DIMENSION ISEQNCE(5,2),X(85),Y(85),T(85),Q(85)
C ISEQNCE IS SEQUENCE TO CALCULATE SOLUTION REGIONS
C
C MAP OF SOLUTION REGIONS FOR ALL BUT MOST U/S POOL
C REGION 3B IS REPEATED AS NECESSARY TO GET TO TMAX
C Q AND Y ARE GIVEN AT D/S BOUNDARY AND Q AND Y ARE
C CALCULATED AT U/S BOUNDARY
C *                                         *
C *                                   *     *
C *                               *         *
C *                          *              *
C *                     *                   *
C *                *                        *
```

```
C *           *                             *
C *      *                                  *
C * *                38                     *
C *                                         *
C *                                   *     *
C *                               *         *
C *                          *              *
C *                     *                   *
C *                *                        *
C *           *                             *
C *      *                                  *
C * *                3                      *
C *      *                                  *
C *           *                             *
C *                *                        *
C *                     *                   *
C *                          *              *
C *                               *         *
C *                                    *    *
C *             4                           *
C *                                    *    *
C *                               *         *
C *                          *              *
C *                     *         2         *
C *                *         *              *
C *           *                   *         *
C *      *             1               *    *
C * *                                       *
C *******************************************
C
C MAP OF SOLUTION REGIONS FOR MOST U/S POOL
C IF Q INTO POOL IS SCHEDULED (STUDY=1)
C
C Q IS GIVEN AT BOTH BOUNDARIES AND Y IS CALCULATED
C FOR BOTH BOUNDARIES
C
C *                                         *
C *                                         *
C *                                         *
C *                                         *
C *                                         *
C *                                         *
C *                                         *
C *                                         *
C *                                         *
C *                                         *
C *                                         *
C *             5                           *
C *                                    *    *
C *                               *         *
C *                          *              *
C *                     *         2         *
C *                *         *              *
C *           *                   *         *
C *      *             1               *    *
C * *                                       *
C *******************************************
```

```
C
C
C ISEQNCE=8 EXITS THE COMPUTATION LOOP
      DATA (ISEQNCE=1,2,3,4,8,1,2,5,8,8)
C LAST=2 FOR MOST UPSTREAM POOL
C IF Q IS SCHEDULED FOR U/S END OF THAT POOL
C FLOAT DEPTH FOR MOST UPSTREAM POOL
C IF Q IS SCHEDULED
      LAST=1
C IPOOL IS THE POOL BEING CALCULATED
C NPOOLS IS THE NUMBER OF THE MOST U/S POOL
      IF(IPOOL.EQ.NPOOLS.AND.STUDY.EQ.1) LAST=2
C TIMINC IS THE TIME INCREMENT USED FOR CALCULATIONS
C IT MAY BE INCREASED IF 40 POINTS IN REGION 3 WONT GET
C THE SOLUTION TO X=0
C OR DECREASED IF POOL IS VERY SHORT
      TIMINC=TINC
C SET THE NUMBER OF COMPUTATION POINTS FOR EACH REGION
      N1=NXINC
      N2=N1
      N4=N1+N2-1
      N5=N4
C KUP IS UPSTREAM INDEX FOR STORING T, Q AND Y
      KUP=N4
      IF(LAST.EQ.2) KUP=1
C KDWN IS DOWNSTREAM INDEX FOR STORING T, Q AND Y
      KDWN=0
      DO 800 IPASS=1,5
      ISEQ=ISEQNCE(IPASS,LAST)
      GO TO(100,200,300,400,500,900,900,900),ISEQ
C X, Y, T AND Q ARE WORKING ARRAYS
C ...CPJ AND ...CMJ ARRAYS ARE X, Y, T AND Q VALUES
C ALONG + AND - CHARACTERISTICS IN REGION J
C
C REGION 1 - INITIAL CONDITIONS
  100 CONTINUE
C XINIT, ETC., ARE INITIAL CONDITIONS AT TIME = 0
      DO 110 I=1,N1
      X(I)=XINIT(I)
      Y(I)=YINIT(I)
      T(I)=0.
      Q(I)=QINIT(I)
  110 CONTINUE
      X(N1)=XEND
      XCP1(1)=X(1)
      YCP1(1)=Y(1)
      TCP1(1)=T(1)
      QCP1(1)=Q(1)
      XCM1(1)=X(N1)
      YCM1(1)=Y(N1)
      TCM1(1)=T(N1)
      QCM1(1)=Q(N1)
      M=N1-1
      DO 160 I=2,N1
      DO 150 J=1,M
C IP, IR AND IS ARE P, R AND S POINT INDICES IN X, Y, T
C AND Q WHERE P IS POINT TO BE SOLVED FOR,
```

```
C R IS KNOWN POINT ON + CHARACTERISTIC AND
C S IS KNOWN POINT ON - CHARACTERISTIC
C P, R, S NOTATION FOLLOWS WYLIE
      IP=J
      IR=J
      IS=J+1
C SET R AND S POINT VALUES
      XR=X(IR)
      YR=Y(IR)
      TR=T(IR)
      QR=Q(IR)
      XS=X(IS)
      YS=Y(IS)
      TS=T(IS)
      QS=Q(IS)
C SOLVE FOR POINT P
      CALL SOLVER
C STORE NEW VALUES
      X(IP)=XP
      Y(IP)=YP
      T(IP)=TP
      Q(IP)=QP
C STORE END POINTS IN REGION 1 BOUNDING CHARACTERISTICS
      IF(J.EQ.1) GO TO 130
 120  IF(J.EQ.M) GO TO 140
      GO TO 150
C STORE IN + CHARACTERISTIC
 130  CONTINUE
      XCP1(I)=XP
      YCP1(I)=YP
      TCP1(I)=TP
      QCP1(I)=QP
C LAST POINT IS ALSO ON - CHARACTERISTIC
C CHECK FOR THIS SITUATION
      GO TO 120
C STORE IN - CHARACTERISTIC
 140  CONTINUE
      XCM1(I)=XP
      YCM1(I)=YP
      TCM1(I)=TP
      QCM1(I)=QP
 150  CONTINUE
      M=M-1
 160  CONTINUE
      WRITE(6,9000)ISEQ
      GO TO 800
C REGION 2 -  Q SPECIFIED D/S
 200  CONTINUE
      XDN2(1)=XCM1(1)
      YDN2(1)=YCM1(1)
      TDN2(1)=TCM1(1)
      QDN2(1)=QCM1(1)
      DO 230 I=2,N2
      X(1)=XCM1(I)
      Y(1)=YCM1(I)
      T(1)=TCM1(I)
      Q(1)=QCM1(I)
```

```
               M=I
               DO 210 J=2,M
               IR=J-1
               IS=J
               IP=J
        C SET R AND S POINT VALUES
               XR=X(IR)
               YR=Y(IR)
               TR=T(IR)
               QR=Q(IR)
        C CHECK FOR BOUNDARY
               IF(J.EQ.M) GO TO 220
               XS=X(IS)
               YS=Y(IS)
               TS=T(IS)
               QS=Q(IS)
        C SOLVE FOR POINT P
               CALL SOLVER
        C STORE NEW VALUES
               X(IP)=XP
               Y(IP)=YP
               T(IP)=TP
               Q(IP)=QP
          210  CONTINUE
          220  XP=XEND
        C BNDRY(1) IS D/S BOUNDARY - Q SPECIFIED, C+ CHARACTERISTIC
               CALL BNDRY(1)
        C STORE BOUNDARY VALUES
               X(IP)=XP
               Y(IP)=YP
               T(IP)=TP
               Q(IP)=QP
        C STORE IN D/S ARRAY
               XDN2(I)=XP
               YDN2(I)=YP
               TDN2(I)=TP
               QDN2(I)=QP
          230  CONTINUE
        C STORE IN REGION 2 BOUNDING CHARACTERISTIC
               DO 240 I=1,N2
               XCP2(I)=X(I)
               YCP2(I)=Y(I)
               TCP2(I)=T(I)
               QCP2(I)=Q(I)
          240  CONTINUE
        C STORE IN TDWN,QDWN,YDWN FOR GATE MOTION CALCULATIONS LATER
               DO 250 I=1,N2
               TDWN(I)=TDN2(I)
               QDWN(I)=QDN2(I)
               YDWN(I)=YDN2(I)
          250  CONTINUE
        C UPDATE D/S INDEX FOR SAVING T, Q AND Y
               KDWN=N2
        C STORE ENDING TIME AND DEPTH FOR INTERPOLATION
        C IN POOL 2 AND FOLLOWING
               T1=TDN2(N2)
               Y1=YDN2(N2)
```

```
      WRITE(6,9000)ISEQ
      GO TO 800
C REGION 3 - H AND Q SPECIFIED D/S
 300  CONTINUE
C SET T PREVIOUS FOR STORING BOUNDARY VALUES ONLY
C EVERY TINC TIME ADVANCE
      TUPPREV=0.
      TDNPREV=0.
C COMPARE WAVE TRAVEL TIME WITH TIMINC TO SEE IF
C POOL IS TOO SHORT TO USE TIMINC
      YCHECK=YDN2(N2)
      CELERTY=C(YCHECK)
      FN=N1-1
      DXCHECK=XEND/FN
      DX3=CELERTY*TIMINC
      IF(DX3/DXCHECK.GT.2.) TIMINC=DXCHECK/CELERTY*2.
      IF(DX3/DXCHECK.GT.2.) WRITE(6,9040) TIMINC
C IF TIMINC TOO SHORT, TREAT AS ZERO LENGTH POOL
      IF(TIMINC.LT.0.5*TINC) GO TO 810
C NUMBER OF POINTS IN 3B REGION
      N3B=0
C NCROSS CHECKS THAT REGION 3 CROSSES X=0
      NCROSS=0
C MATCH WITH REGION 2 END POINT ON D/S BOUNDARY
      XDN3(1)=XEND
      TDN3(1)=TDN2(N2)
      YDN3(1)=YDN2(N2)
      QDN3(1)=QDN2(N2)
      DO 304 I=2,40
      N3=I
      XDN3(I)=XEND
      TDN3(I)=TDN3(I-1)+TIMINC
      IF(TDN3(I).GE.TMAX) GO TO 302
      YDN3(I)=HDN(TDN3(I))
      QDN3(I)=QDN(TDN3(I))
      GO TO 304
  302 TDN3(I)=TMAX
      YDN3(I)=HDN(TMAX)
      QDN3(I)=QDN(TMAX)
      GO TO 306
  304 CONTINUE
      N3B=1
  306 CONTINUE
      WRITE(6,9010) N3
      IF(TDN3(1).GE.TDN3(N3)) WRITE(6,9020)TDN3(1),TDN3(N3)
      IF(TDN3(1).GE.TDN3(N3)) STOP
      XCP3(1)=XDN3(N3)
      YCP3(1)=YDN3(N3)
      TCP3(1)=TDN3(N3)
      QCP3(1)=QDN3(N3)
      XCM3(1)=XDN3(1)
      YCM3(1)=YDN3(1)
      TCM3(1)=TDN3(1)
      QCM3(1)=QDN3(1)
      DO 308 I=1,N3
      X(I)=XDN3(I)
      Y(I)=YDN3(I)
```

```
      T(I)=TDN3(I)
      Q(I)=QDN3(I)
 308  CONTINUE
C K=UPSTREAM X=0 INTERSECT INDEX
      K=1
      M=N3-1
      N=M
      DO 322 I=1,M
C NALLX CHECKS THAT ALL XP ARE LESS THAN ZERO
      NALLX=0
      DO 320 J=1,N
      IP=J
      IS=J
      IR=J+1
C SET R AND S POINT VALUES
      XR=X(IR)
      YR=Y(IR)
      TR=T(IR)
      QR=Q(IR)
      XS=X(IS)
      YS=Y(IS)
      TS=T(IS)
      QS=Q(IS)
C SOLVE FOR POINT P
      CALL SOLVER
C SET NALLX IF ANY XP HAS NOT CROSSED X=0
      IF(XP.GE.0.0) NALLX=1
C CHECK FOR CROSSING X=0
      IF(XP.LT.0.0.AND.XS.GE.0.0) GO TO 318
 310  CONTINUE
C STORE NEW VALUES
      X(IP)=XP
      Y(IP)=YP
      T(IP)=TP
      Q(IP)=QP
C CHECK FOR END POINTS
      IF(J.EQ.1) GO TO 314
 312  IF(J.EQ.N) GO TO 316
      GO TO 320
C STORE IN C-
 314  CONTINUE
      XCM3(I+1)=XP
      YCM3(I+1)=YP
      TCM3(I+1)=TP
      QCM3(I+1)=QP
C LAST POINT MAY ALSO BE ON + CHARACTERISTIC
C CHECK FOR THIS SITUATION
      GO TO 312
C STORE IN C+
 316  CONTINUE
      XCP3(I+1)=XP
      YCP3(I+1)=YP
      TCP3(I+1)=TP
      QCP3(I+1)=QP
      GO TO 320
C INTERPOLATE UPSTREAM VALUES
C AT X=0
```

```
  318 CONTINUE
C SET NCROSS TO SHOW THAT X=0 WAS CROSSED
      NCROSS=1
      DELX=XP-XS
      DX=XP
      RATIO=DX/DELX
      XUP3(K)=0.0
      YUP3(K)=YP-RATIO*(YP-YS)
      TUP3(K)=TP-RATIO*(TP-TS)
      QUP3(K)=QP-RATIO*(QP-QS)
      K=K+1
      GO TO 310
  320 CONTINUE
C HAVE ALL POINTS CROSSED X=0 - IF SO STOP CALCULATING
      IF(NALLX.EQ.0) GO TO 324
      N=N-1
  322 CONTINUE
  324 CONTINUE
C IF DID NOT CROSS X=0, STOP
      IF(NCROSS.EQ.0) GO TO 346
C FIND C+ X=0 INTERCEPT
      DO 326 I=2,N3
      IF(XCP3(I).GT.0.0) GO TO 326
      DELX=XCP3(I)-XCP3(I-1)
      DX=XCP3(I)
      RATIO=DX/DELX
      XUP3(K)=0.0
      YUP3(K)=YCP3(I)-RATIO*(YCP3(I)-YCP3(I-1))
      TUP3(K)=TCP3(I)-RATIO*(TCP3(I)-TCP3(I-1))
      QUP3(K)=QCP3(I)-RATIO*(QCP3(I)-QCP3(I-1))
      GO TO 328
  326 CONTINUE
  328 CONTINUE
C SORT UPSTREAM BOUNDARY ON T
      DO 330 I=1,K
      T(I)=TUP3(I)
      TINDX(I)=1.
  330 INDX(I)=0
      ILOW=1
      TLOW=T(1)
      DO 336 J=1,K
      DO 332 I=1,K
      IF(TINDX(I).LT.0.0) GO TO 332
      IF(T(I).GE.TLOW) GO TO 332
      ILOW=I
      TLOW=T(I)
  332 CONTINUE
      INDX(J)=ILOW
      TINDX(ILOW)=-1.
      DO 334 L=1,K
      IF(TINDX(L).LT.0.0) GO TO 334
      ILOW=L
      TLOW=T(L)
      GO TO 336
  334 CONTINUE
  336 CONTINUE
      DO 338 I=1,K
```

```
      X(I)=XUP3(I)
      Y(I)=YUP3(I)
      T(I)=TUP3(I)
      Q(I)=QUP3(I)
 338  CONTINUE
      DO 340 I=1,K
      J=INDX(I)
      XUP3(I)=X(J)
      YUP3(I)=Y(J)
      TUP3(I)=T(J)
      QUP3(I)=Q(J)
 340  CONTINUE
C STORE IN TDWN,QDWN,YDWN FOR GATE MOTION CALCULATIONS LATER
      DO 342 I=1,N3
C UPDATE D/S INDEX TO SAVE T, Q AND Y
      KDWN=KDWN+1
      J=KDWN
      TDWN(J)=TDN3(I)
      QDWN(J)=QDN3(I)
      YDWN(J)=YDN3(I)
      IF(I.EQ.1) GO TO 342
C SAVE ONLY AFTER TINC TIME ADVANCE
      IF(TDN3(I).GE.TDNPREV+TINC) GO TO 341
      KDWN=KDWN-1
      GO TO 342
C UPDATE TDNPREV (T PREVIOUS)
 341  TDNPREV=TDN3(I)-0.01
 342  CONTINUE
      WRITE(6,9000)ISEQ
C STORE IN TUP, QUP AND YUP FOR FUNCTIONS QDN AND HDN FOR NEXT POOL
      DO 344 I=1,K
C UPDATE U/S INDEX TO SAVE T, Q AND Y
      KUP=KUP+1
      N=KUP
      TUP(N)=TUP3(I)
      QUP(N)=QUP3(I)
      YUP(N)=YUP3(I)
      IF(I.EQ.1) GO TO 344
C SAVE ONLY AFTER TINC TIME ADVANCE
      IF(TUP3(I).GE.TUPPREV+TINC) GO TO 343
      KUP=KUP-1
      GO TO 344
C UPDATE TUPPREV (T PREVIOUS)
 343  TUPPREV=TUP3(I)-0.01
 344  CONTINUE
C CHECK TO SEE IF 3B REGION MUST BE USED TO GET TO TMAX
      IF(N3B.EQ.0) GO TO 800
C INITIALIZE FOR 3B REGION
      XDN3B(1)=XEND
      TDN3B(1)=TDN3(N3)
      YDN3B(1)=YDN3(N3)
      QDN3B(1)=QDN3(N3)
C START CALCULATIONS IN 3B REGION
      GO TO 350
 346  CONTINUE
      WRITE(6,9030) IPOOL
C INCREASE TIME INCREMENT TO GET ACROSS POOL IN 40 POINTS
```

```
      TIMINC=TIMINC+TINC
      IF(N3.LT.40) STOP
      WRITE(6,9040)TIMINC
      GO TO 300
C CALCULATE 3B REGION
  350 CONTINUE
      NALLX=0
      DO 354 I=2,40
      N3B=I
      XDN3B(I)=XEND
      TDN3B(I)=TDN3B(I-1)+TIMINC
      IF(TDN3B(I).GE.TMAX) GO TO 352
      YDN3B(I)=HDN(TDN3B(I))
      QDN3B(I)=QDN(TDN3B(I))
      GO TO 354
  352  TDN3B(I)=TMAX
      YDN3B(I)=HDN(TMAX)
      QDN3B(I)=QDN(TMAX)
      GO TO 356
  354 CONTINUE
  356 CONTINUE
      WRITE(6,9050)N3B
      IF(TDN3B(1).GE.TDN3B(N3B)) WRITE(6,9060)TDN3B(1),TDN3B(N3B)
      IF(TDN3B(1).GE.TDN3B(N3B)) STOP
      XCP3B(1)=XDN3B(N3B)
      YCP3B(1)=YDN3B(N3B)
      TCP3B(1)=TDN3B(N3B)
      QCP3B(1)=QDN3B(N3B)
      DO 358 I=1,N3B
      X(I)=XDN3B(I)
      Y(I)=YDN3B(I)
      T(I)=TDN3B(I)
      Q(I)=QDN3B(I)
  358 CONTINUE
C K=UPSTREAM X=0 INTERSECT INDEX
      K=1
      M=N3-1
      N=N3B-1
      DO 368 I=1,M
      NALLX=0
      L=N3B+1
      DO 366 J=1,N
      L=L-1
      IP=L
      IS=L-1
      IR=L
C SET R AND S POINT VALUES
      XR=X(IR)
      YR=Y(IR)
      TR=T(IR)
      QR=Q(IR)
      XS=X(IS)
      YS=Y(IS)
      TS=T(IS)
      QS=Q(IS)
C SOLVE FOR POINT P
      CALL SOLVER
```

```
C SET NALLX IF ANY XP HAS NOT CROSSED X=0
      IF(XP.GE.0.0) NALLX=1
C
C CHECK FOR CROSSING X=0
      IF(XP.LT.0.0.AND.XR.GE.0.0) GO TO 364
 360  CONTINUE
C STORE NEW VALUES
      X(IP)=XP
      Y(IP)=YP
      T(IP)=TP
      Q(IP)=QP
C CHECK FOR END POINTS
      IF(L.EQ.N3B) GO TO 362
      GO TO 366
C STORE IN C+
 362  CONTINUE
      XCP3B(I+1)=XP
      YCP3B(I+1)=YP
      TCP3B(I+1)=TP
      QCP3B(I+1)=QP
      GO TO 366
C INTERPOLATE UPSTREAM VALUES
C AT X=0
 364  CONTINUE
      DELX=XP-XR
      DX=XP
      RATIO=DX/DELX
      XUP3B(K)=0.0
      YUP3B(K)=YP-RATIO*(YP-YR)
      TUP3B(K)=TP-RATIO*(TP-TR)
      QUP3B(K)=QP-RATIO*(QP-QR)
      K=K+1
      GO TO 360
 366  CONTINUE
C HAVE ALL POINTS CROSSED X=0 - IF SO, STOP CALCULATIONS
      IF(NALLX.EQ.0) GO TO 370
      IF(I.GE.N3) N=N-1
      IF(I.GE.N3) GO TO 368
      X(1)=XCP3(I+1)
      Y(1)=YCP3(I+1)
      T(1)=TCP3(I+1)
      Q(1)=QCP3(I+1)
 368  CONTINUE
 370  CONTINUE
C SORT UPSTREAM BOUNDARY ON T
      K=K-1
      DO 372 I=1,K
      T(I)=TUP3B(I)
      TINDX(I)=1.
 372  INDX(I)=0
      ILOW=1
      TLOW=T(1)
      DO 378 J=1,K
      DO 374 I=1,K
      IF(TINDX(I).LT.0.0) GO TO 374
      IF(T(I).GE.TLOW) GO TO 374
      ILOW=I
```

```
      TLOW=T(I)
  374 CONTINUE
      INDX(J)=ILOW
      TINDX(ILOW)=-1.
      DO 376 L=1,K
      IF(TINDX(L).LT.0.0) GO TO 376
      ILOW=L
      TLOW=T(L)
      GO TO 378
  376 CONTINUE
  378 CONTINUE
      DO 380 I=1,K
      X(I)=XUP3B(I)
      Y(I)=YUP3B(I)
      T(I)=TUP3B(I)
      Q(I)=QUP3B(I)
  380 CONTINUE
      DO 382 I=1,K
      J=INDX(I)
      XUP3B(I)=X(J)
      YUP3B(I)=Y(J)
      TUP3B(I)=T(J)
      QUP3B(I)=Q(J)
  382 CONTINUE
C STORE IN TDWN,QDWN,YDWN FOR GATE MOTION CALCULATIONS LATER
      DO 384 I=1,N3B
C UPDATE D/S INDEX FOR SAVING T, Q AND Y
      KDWN=KDWN+1
      J=KDWN
      TDWN(J)=TDN3B(I)
      QDWN(J)=QDN3B(I)
      YDWN(J)=YDN3B(I)
      IF(I.EQ.1) GO TO 384
C SAVE ONLY AFTER TINC TIME ADVANCE
      IF(TDN3B(I).GE.TDNPREV+TINC) GO TO 383
      KDWN=KDWN-1
      GO TO 384
  383 TDNPREV=TDN3B(I)-0.01
  384 CONTINUE
      WRITE(6,9000)ISEQ
C STORE IN TUP, QUP AND YUP FOR FUNCTIONS QDN AND YDN FOR NEXT POOL
      DO 386 I=1,K
C UPDATE U/S INDEX FOR SAVING T, Q AND Y
      KUP=KUP+1
      N=KUP
      TUP(N)=TUP3B(I)
      QUP(N)=QUP3B(I)
      YUP(N)=YUP3B(I)
      IF(I.EQ.1) GO TO 386
C SAVE ONLY AFTER TINC TIME ADVANCE
      IF(TUP3B(I).GE.TUPPREV+TINC) GO TO 385
      KUP=KUP-1
      GO TO 386
  385 TUPPREV=TUP3B(I)-0.01
  386 CONTINUE
C SAVE TIME FOR TMAX FOR NEXT POOL
      SAVTIME=TUP(KUP)
```

```
C STORE IN C+3
      DO 388 I=1,N3
      XCP3(I)=XCP3B(I)
      YCP3(I)=YCP3B(I)
      TCP3(I)=TCP3B(I)
      QCP3(I)=QCP3B(I)
  388 CONTINUE
      IF(TCP3B(1).GE.TMAX) GO TO 800
C CLEAR FOR ANOTHER PASS THRU 3B BAND
      DO 390 I=1,40
      XUP3B(I)=0.
      YUP3B(I)=0.
      TUP3B(I)=0.
      QUP3B(I)=0.
      XDN3B(I)=0.
      YDN3B(I)=0.
      TDN3B(I)=0.
      QDN3B(I)=0.
  390 CONTINUE
      XDN3B(1)=XEND
      YDN3B(1)=YCP3B(1)
      TDN3B(1)=TCP3B(1)
      QDN3B(1)=QCP3B(1)
      GO TO 350
C REGION 4 - NO BOUNDARY CONDITIONS
  400 CONTINUE
C LOAD C+ FROM REGIONS 1 AND 2
      M=N2
      DO 410 I=1,M
      J=N2-I+1
      XCP4(I)=XCP2(J)
      YCP4(I)=YCP2(J)
      TCP4(I)=TCP2(J)
      QCP4(I)=QCP2(J)
  410 CONTINUE
      N=N4
      J=N1
      DO 420 I=M,N
      XCP4(I)=XCP1(J)
      YCP4(I)=YCP1(J)
      TCP4(I)=TCP1(J)
      QCP4(I)=QCP1(J)
      J=J-1
  420 CONTINUE
C INTERPOLATE C-AT SAME X AS C+
      XCM4(1)=XCP4(1)
      YCM4(1)=YCP4(1)
      TCM4(1)=TCP4(1)
      QCM4(1)=QCP4(1)
      DO 440 I=2,N
      DO 430 J=2,N3
      IF(XCM3(J).GT.XCP4(I)) GO TO 430
      DX=XCP4(I)-XCM3(J)
      DELX=XCM3(J-1)-XCM3(J)
      RATIO=DX/DELX
      XCM4(I)=XCP4(I)
      YCM4(I)=YCM3(J)+RATIO*(YCM3(J-1)-YCM3(J))
```

```
      TCM4(I)=TCM3(J)+RATIO*(TCM3(J-1)-TCM3(J))
      QCM4(I)=QCM3(J)+RATIO*(QCM3(J-1)-QCM3(J))
      GO TO 440
  430 CONTINUE
  440 CONTINUE
C K = INDEX FOR UPSTREAM BOUNDARY
      K=1
      DO 450 I=1,N4
      X(I)=XCP4(I)
      Y(I)=YCP4(I)
      T(I)=TCP4(I)
      Q(I)=QCP4(I)
  450 CONTINUE
C SET X=0, T=0 UPSTREAM
      XUP4(1)=0.0
      YUP4(1)=YCP4(N4)
      TUP4(1)=TCP4(N4)
      QUP4(1)=QCP4(N4)
      DO 480 I=2,N4
      X(1)=XCM4(I)
      Y(1)=YCM4(I)
      T(1)=TCM4(I)
      Q(1)=QCM4(I)
      DO 470 J=2,N4
      IP=J
      IR=J-1
      IS=J
C SET R AND S POINT VALUES
      XR=X(IR)
      YR=Y(IR)
      TR=T(IR)
      QR=Q(IR)
      XS=X(IS)
      YS=Y(IS)
      TS=T(IS)
      QS=Q(IS)
C SOLVE FOR POINT P
      CALL SOLVER
C STORE NEW VALUES
      X(IP)=XP
      Y(IP)=YP
      T(IP)=TP
      Q(IP)=QP
C CHECK FOR X=0 CROSSING
      IF(XP.LT.0.0.AND.XR.GE.0.0) GO TO 460
      GO TO 470
C INTERPOLATE AT X=0 ON C+
  460 CONTINUE
      K=K+1
      DX=0.0-XP
      DELX=XR-XP
      RATIO=DX/DELX
      XUP4(K)=0.0
      YUP4(K)=YP+RATIO*(YR-YP)
      TUP4(K)=TP+RATIO*(TR-TP)
      QUP4(K)=QP+RATIO*(QR-QP)
  470 CONTINUE
```

```
  480 CONTINUE
      WRITE(6,9000)ISEQ
C STORE IN TUP, QUP AND YUP FOR USE IN FUNCTIONS QDN AND HDN IN NEXT POOL
      DO 490 I=1,K
      TUP(I)=TUP4(I)
      QUP(I)=QUP4(I)
      YUP(I)=YUP4(I)
  490 CONTINUE
      GO TO 800
C REGION 5 - Q SPECIFIED ON BOTH BOUNDARIES
  500 CONTINUE
C SET TPREV FOR STORING BOUNDARY VALUES ONLY EVERY
C TINC TIME ADVANCE
      TPREV=-(TINC+0.01)
C LOAD C+ FROM REGIONS 1 AND 2
      DO 510 I=1,N1
      XCP5(I)=XCP1(I)
      YCP5(I)=YCP1(I)
      TCP5(I)=TCP1(I)
      QCP5(I)=QCP1(I)
  510 CONTINUE
      M=N1
      DO 520 I=1,N2
      XCP5(M)=XCP2(I)
      YCP5(M)=YCP2(I)
      TCP5(M)=TCP2(I)
      QCP5(M)=QCP2(I)
      M=M+1
  520 CONTINUE
      DO 530 I=1,N5
      X(I)=XCP5(I)
      Y(I)=YCP5(I)
      T(I)=TCP5(I)
      Q(I)=QCP5(I)
  530 CONTINUE
C STORE END POINTS
  540 CONTINUE
      YUP(KUP)=Y(1)
      TUP(KUP)=T(1)
      QUP(KUP)=Q(1)
      YDWN(KDWN)=Y(N5)
      TDWN(KDWN)=T(N5)
      QDWN(KDWN)=Q(N5)
C STOP AFTER TMAX
      IF(T(N5).GE.TMAX) GO TO 590
C STORE ONLY EVERY TIME T HAS ADVANCED BY TINC
C TO KEEP NUMBER OF POINTS IN YUP, YDWN, ETC.
C APPROXIMATELY THE SAME AS IN THE OTHER POOLS
      DELTAT= T(1)-TPREV
      IF(DELTAT.LT.TINC) GO TO 550
      TPREV=T(1)
      KUP=KUP+1
      KDWN=KDWN+1
  550 CONTINUE
      DO 580 I=1,N5
      IP=I
      IR=I-1
```

```
      IS=I+1
      IF(I.EQ.1) GO TO 560
      IF(I.EQ.N5) GO TO 570
C SET R AND S POINT VALUES
      XR=X(IR)
      YR=Y(IR)
      TR=T(IR)
      QR=Q(IR)
      XS=X(IS)
      YS=Y(IS)
      TS=T(IS)
      QS=Q(IS)
C SOLVE FOR POINT P
      CALL SOLVER
C STORE NEW VALUES
      X(IP)=XP
      Y(IP)=YP
      T(IP)=TP
      Q(IP)=QP
      GO TO 580
C UPSTREAM BOUNDARY
  560 XS=X(IS)
      YS=Y(IS)
      TS=T(IS)
      QS=Q(IS)
      XP=0.0
      CALL BNDRY(0)
C
C STORE NEW VALUES
      X(IP)=XP
      Y(IP)=YP
      T(IP)=TP
      Q(IP)=QP
      GO TO 580
C DOWNSTREAM BOUNDARY
  570 XR=X(IR)
      YR=Y(IR)
      TR=T(IR)
      QR=Q(IR)
      XP=XEND
      CALL BNDRY(1)
C
C STORE NEW VALUES
      X(IP)=XP
      Y(IP)=YP
      T(IP)=TP
      Q(IP)=QP
  580 CONTINUE
      GO TO 540
  590 CONTINUE
      WRITE(6,9000)ISEQ
  800 CONTINUE
      GO TO 900
C TIME INCREMENT FOR CALCULATIONS TOO SHORT
C FOR REALISTIC RUN TIMES, SO TREAT AS ZERO
C LENGTH POOL
  810 CONTINUE
```

```
      WRITE(6,9120)
C CALCULATE D/S VALUES AT TINC INTERVALS FROM END OF REGION 2
C TO TIME TMAX
      TP=TDN2(N2)-TINC
      DO 820 I=N2,500
      TP=TP+TINC
      IF(TP.GT.TMAX) TP=TMAX
      TDWN(I)=TP
      QDWN(I)=QDN(TP)
      YDWN(I)=HDN(TP)
      KSAVE=I
      IF(TP.GE.TMAX) GO TO 830
 820  CONTINUE
C SAVE SAME VALUES FOR U/S END OF POOL
 830  CONTINUE
      KMAX=KSAVE
      DO 840 I=1,KSAVE
      TUP(I)=TDWN(I)
      QUP(I)=QDWN(I)
      YUP(I)=YDWN(I)
 840  CONTINUE
      SAVTIME=TMAX
      KUP=KMAX
      KDWN=KMAX
 900  CONTINUE
C SAVE TMAX FOR NEXT POOL
      TMAX=SAVTIME
C SAVE KUP FOR USE IN FUNCTIONS QDN AND HDN IN NEXT POOL
      KMAX=KUP
C SAVE T, Q AND Y FOR MATCHING IN NEXT POOL
      MAXPT=KMAX
      DO 1000 I=1,MAXPT
      SAVETUP(I)=TUP(I)
      SAVEQUP(I)=QUP(I)
      SAVEYUP(I)=YUP(I)
 1000 CONTINUE
C
C
C WRITE OUT T, Q AND Y AT BOTH ENDS OF POOL
C FOR USE IN GATE OPENING CALCULATIONS
C STRTYPE IS TYPE OF CONTROL STRUCTURE
C DEPTHS ARE IN THE CHANNEL, NOT IN THE GATE SECTION
      WRITE(1,9070) IPOOL,KDWN
      WRITE(1,9080) (TDWN(I),I=1,KDWN)
      WRITE(1,9080) (QDWN(I),I=1,KDWN)
      WRITE(1,9080) (YDWN(I),I=1,KDWN)
      WRITE(6,9090)KDWN
      WRITE(6,9100)KUP
      WRITE(1,9110) IPOOL,KUP, STRTYPE(IPOOL)
      WRITE(1,9080) (TUP(I),I=1,KUP)
      WRITE(1,9080) (QUP(I),I=1,KUP)
      WRITE(1,9080) (YUP(I),I=1,KUP)
      RETURN
C FORMATS
 9000 FORMAT(11H END REGION,I5 )
 9010 FORMAT(5H N3= ,I10)
 9020 FORMAT(1X,45HTRANSIENT TRAVEL TIME EXCEEDS TIME AVAILABLE /
```

```
              .  28HTO TMAX. COMPUTATION HALTED.
              .  /1X,6HT2MAX=,F10.3,10X,5HTMAX=,F10.3//)
        9030  FORMAT(1X,32HTIME SPAN TOO SHORT TO CALCULATE,
              .  43H AT UPSTREAM BOUNDARY IN REGION 3 FOR POOL ,I5/)
        9040  FORMAT(1X,20HNEW TIME INCREMENT =,F10.1)
        9050  FORMAT(5H N3B= ,I10)
        9060  FORMAT(1X,17HSTOP IN 3B. TMIN=,F10.3,6H TMAX=,F10.3//)
        9070  FORMAT(1X,3I10,10X)
        9080  FORMAT(1X,10F10.3)
        9090  FORMAT(1X,5HKDWN=,I5//)
        9100  FORMAT(1X,5HKUP= ,I5//)
        9110  FORMAT(1X,4I10)
        9120  FORMAT(1X,28HTREATING AS ZERO LENGTH POOL  )
              END
```

```
      SUBROUTINE SOLVER
C ROUTINE TO SOLVE FOR X,T,Q AND Y AT POINT P
C USING VALUES AT POINT R ON + CHARACTERISTIC
C AND VALUES AT POINT S ON - CHARACTERISTIC
C METHOD AND NOTATION FOLLOW WYLIE
C
      COMMON /SOLV/  XP,YP,TP,QP,XR,YR,TR,QR,XS,YS,TS,QS
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     . NMANN,S0,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     . MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     . (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     . TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     . STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     . UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     . TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
      CR=C(YR)
      CS=C(YS)
      RR=R(YR)
      AR=A(YR)
      VR=QR/AR
      SR=S(VR,RR)
      RS=R(YS)
      AS=A(YS)
      VS=QS/AS
      SS=S(VS,RS)
      VP=(VR+VS)/2.
      VPPREV=VP
      YP=(YR+YS)/2.
      YPPREV=YP
      TP=((VR+CR)*TR-(VS-CS)*TS-XR+XS)/(VR+CR-VS+CS)
      XP=(VR+CR)*(TP-TR)+XR
      S0=BOTGRAD(IPOOL)
      AP=A(YP)
      QP=VP*AP
C ICOUNT STOPS LOOPING IF SOLUTION DOES NOT CONVERGE
      ICOUNT=1
 10   CONTINUE
      RP=R(YP)
      AP=A(YP)
      VP=QP/AP
      SP=S(VP,RP)
      CP=C(YP)
      TP=(2.*(XS-XR)+TR*(VP+CP+VR+CR)-TS*(VP-CP+VS-CS))/
     ( (VR+CR-(VS-CS)+2.*CP)
      C4=GGRAV/2.*(1./CR+1./CP)
      C3=VR+C4*YR-GGRAV/2.*(SR+SP-2.*S0)*(TP-TR)
      C2=GGRAV/2.*(1./CS+1./CP)
      C1=VS-C2*YS-GGRAV/2.*(SS+SP-2.*S0)*(TP-TS)
```

```
       YPPREV=YP
       YP=(C3-C1)/(C2+C4)
       VPPREV=VP
       VP=C3-C4*YP
       AP=A(YP)
       QP=VP*AP
       ICOUNT=ICOUNT+1
        IF(ICOUNT.GT.50) WRITE(6,9000)
        IF(ICOUNT.GT.50) STOP
       IF(ABS(YPPREV-YP).GT.0.001) GO TO 10
       IF(ABS(VPPREV-VP).GT.0.001) GO TO 10
       XP=XR+((VP+VR)/2.+(CR+CP)/2.)*(TP-TR)
C CHECK THAT FLOW IS NOT SUPERCRITICAL
       CELRITY=C(YP)
       AREA=A(YP)
       IF(ABS(CELRITY*AREA/QP).LE.1.) WRITE(6,9010) XP,YP,TP,QP
       IF(ABS(CELRITY*AREA/QP).LE.1.) STOP
       RETURN
C FORMATS
 9000  FORMAT(1X,14HSTOP IN SOLVER)
 9010  FORMAT(1X,22HSUPERCRITICAL FLOW AT
    ..  /5X,3HX= ,F10.1/5X,3HY= ,F10.1/5X,
     .  3HT= ,F10.1/5X,3HQ= ,F10.1/)
       END
```

```
      FUNCTION C(Y)
C CELERITY
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     . NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     . MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     . (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     . TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     . STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     . UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     . TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
C A=AREA
C TW=TOP WIDTH
      C=SQRT(GGRAV*A(Y)/TW(Y))
      RETURN
      END
```

```
       FUNCTION R(Y)
C HYDRAULIC RADIUS
C A=AREA
C P=WETTED PERIMETER
       R=A(Y)/P(Y)
       RETURN
       END
```

```
      FUNCTION A(Y)
C CROSS SECTIONAL AREA
C POOL IS TRAPEZOIDAL CHANNEL - TYPPOOL=1
C OR HORSESHOE TUNNEL - TYPPOOL=2
C OR CIRCULAR TUNNEL - TYPPOOL=3
C
C BOTTOM WIDTH AND SIDESLOPE OF TRAPEZOIDAL CHANNEL
C ARE SPECIFIED IN BOTTOM(POOL) AND SIDSLOP(POOL)
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     . NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     . MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     . (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     . TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     . STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     . UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     . TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
      IF(Y.LE.0.0) WRITE(6,9001) IPOOL,Y
      IF(Y.LE.0.0) STOP
      IF(TYPPOOL.EQ.1) GO TO 50
      IF(TYPPOOL.EQ.3) GO TO 60
C IN HORSESHOE TUNNEL SECTION
C RAD IS INVERT TO CREST DISTANCE
      RAD=RADIUS(IPOOL)
C CHECK FOR LOWEST ARC
      Y1=RAD/4.*(3.-SQRT(7.))
      IF(Y.GT.Y1) GO TO 10
      A=(Y-RAD)*SQRT(RAD**2-(Y-RAD)**2)
       +RAD**2*ASIN((Y-RAD)/RAD)+PI*RAD**2/2.
      RETURN
C CHECK FOR AT SPRINGLINE
 10   IF(ABS(Y-RAD/2.).GT.0.00001) GO TO 20
      Y2=RAD/2.
      A=(Y1-RAD)*SQRT(RAD**2-(Y1-RAD)**2)
     . +RAD**2*ASIN((Y1-RAD)/RAD)+PI*RAD**2/2.
     . -(Y1-Y2)*SQRT(RAD**2-(Y1-Y2)**2)
     . -RAD**2*ASIN((Y1-Y2)/RAD)-RAD*(Y-Y1)
      RETURN
C
C CHECK FOR BELOW SPRINGLINE
 20   IF(Y.GT.RAD/2.) GO TO 30
      Y2=RAD/2.
      A=(Y1-RAD)*SQRT(RAD**2-(Y1-RAD)**2)
     . +RAD**2*ASIN((Y1-RAD)/RAD)+PI*RAD**2/2.
     . +(Y-Y2)*SQRT(RAD**2-(Y-Y2)**2)
     . +RAD**2*ASIN((Y-Y2)/RAD)
     . -(Y1-Y2)*SQRT(RAD**2-(Y1-Y2)**2)
     . -RAD**2*ASIN((Y1-Y2)/RAD)-RAD*(Y-Y1)
      RETURN
```

```
C CHECK FOR FILLED TUNNEL
 30    IF(Y.GT.RAD) GO TO 40
       Y2=RAD/2.
       A=(Y1-RAD)*SQRT(RAD**2-(Y1-RAD)**2)
     .  +RAD**2*ASIN((Y1-RAD)/RAD)+PI*RAD**2/2.
     .  -(Y1-Y2)*SQRT(RAD**2-(Y1-Y2)**2)
     .  -RAD**2*ASIN((Y1-Y2)/RAD)-RAD*(Y2-Y1)
     .  +(Y-Y2)*SQRT((RAD/2.)**2-(Y-Y2)**2)
     .  +(RAD/2.)**2*ASIN((Y-Y2)/(RAD/2.))
       RETURN
 40    WRITE(6,9000) Y,IPOOL
       STOP
C TRAPEZOIDAL CHANNEL SECTION
 50    CONTINUE
       A=(BOTTOM(IPOOL)+SIDSLOP(IPOOL)*Y)*Y
       RETURN
C CIRCULAR TUNNEL SECTION
 60    CONTINUE
       RAD=RADIUS(IPOOL)
       IF(ABS(Y-RAD).GT.0.00001) GO TO 70
C HALF-FULL
       A=PI*RAD**2/2.
       RETURN
 70    IF(Y.GT.RAD) GO TO 80
C LOWER HALF OF SECTION
       X=RAD-Y
       THETA=ACOS(X/RAD)
       A=THETA*RAD**2-X*RAD*SIN(THETA)
       RETURN
C UPPER HALF OF SECTION
 80    IF(Y.GT.2.*RAD) GO TO 90
       X=Y-RAD
       THETA=ACOS(X/RAD)
       A=(PI-THETA)*RAD**2+X*RAD*SIN(THETA)
       RETURN
 90    WRITE(6,9000) Y,IPOOL
       STOP
C FORMAT
 9000  FORMAT(1X,38HDEPTH GREATER THAN TUNNEL HEIGHT AT
     .   3H Y=,F10.2,9H IN POOL ,I5)
 9001  FORMAT(1X,13HDEPTH IN POOL,I5,2H =,F10.1/
     .  1X,20HSTOP IN AREA ROUTINE )
       END
```

```
      FUNCTION TW(Y)
C TOP WIDTH
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     . NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     . MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     . (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     . TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     . STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     . UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     . TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
C POOL IS TRAPEZOIDAL CHANNEL - TYPPOOL=1
C OR HORSESHOE TUNNEL - TYPPOOL=2
C OR CIRCULAR TUNNEL - TYPPOOL=3
C
C BOTTOM WIDTH AND SIDESLOPE OF TRAPEZOIDAL CHANNEL
C ARE SPECIFIED IN BOTTOM AND SIDSLOP
      IF(TYPPOOL.EQ.1) GO TO 50
      IF(TYPPOOL.EQ.3) GO TO 60
C IN HORSESHOE TUNNEL SECTION
C RAD IS INVERT TO CREST DISTANCE
      RAD=RADIUS(IPOOL)
C CHECK FOR LOWEST ARC
      Y1=RAD/4.*(3.-SQRT(7.))
      IF(Y.GT.Y1) GO TO 10
      TW=2.*SQRT(RAD**2-(RAD-Y)**2)
      RETURN
C CHECK FOR AT SPRINGLINE
 10   IF(ABS(Y-RAD/2.).GT.0.00001) GO TO 20
      TW=RAD
      RETURN
C CHECK FOR BELOW SPRINGLINE
 20   Y2=RAD/2.
      IF(Y.GT.Y2) GO TO 30
      THETA=ASIN((Y2-Y)/RAD)
      TW=RAD*(2.*COS(THETA)-1.)
      RETURN
C CHECK FOR FILLED TUNNEL
 30   IF(Y.GT.RAD) GO TO 40
      THETA=ASIN((Y-Y2)/(RAD/2.))
      TW=RAD*COS(THETA)
      RETURN
 40   WRITE(6,9000) Y,IPOOL
      STOP
C TRAPEZOIDAL CHANNEL
 50   CONTINUE
      TW=BOTTOM(IPOOL)+2.*SIDSLOP(IPOOL)*Y
      RETURN
C IN CIRCULAR TUNNEL
```

```
 60    CONTINUE
       RAD=RADIUS(IPOOL)
       IF(ABS(Y-RAD).GT.0.00001) GO TO 70
C HALF-FULL
       TW=2.*RAD
       RETURN
 70    IF(Y.GT.RAD) GO TO 80
C LOWER HALF OF SECTION
       X=RAD-Y
       THETA=ACOS(X/RAD)
       TW=2.*RAD*SIN(THETA)
       RETURN
C UPPER HALF OF SECTION
 80    IF(Y.GT.2.*RAD) GO TO 90
       X=Y-RAD
       THETA=ACOS(X/RAD)
       TW=2.*RAD*SIN(THETA)
       RETURN
 90    WRITE(6,9000) Y,IPOOL
       STOP
C FORMAT
 9000  FORMAT(1X,38HDEPTH GREATER THAN TUNNEL HEIGHT AT
         3H Y=,F10.2,9H IN POOL ,I5)
       END
```

```
      FUNCTION S(V,R)
C ENERGY GRADE
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     .  NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     .  MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     .  (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     .  TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     .  STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     .  UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     .  TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
C V IS VELOCITY
C R IS HYDRAULIC RADIUS
C GET MANNINGS N FOR THIS POOL
      NMANN=MANN(IPOOL)
      S=(V*NMANN/1.49)**2/R**(4./3.)
      RETURN
      END
```

```
      FUNCTION P(Y)
C WETTED PERIMETER
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     .  NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     .  MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     .  (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     .  TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     .  STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     .  UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     .  TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C POOL IS TRAPEZOIDAL CHANNEL - TYPPOOL=1
C OR HORSESHOE TUNNEL - TYPPOOL=2
C OR CIRCULAR TUNNEL - TYPPOOL=3
C
C BOTTOM WIDTH AND SIDESLOPE OF TRAPEZOIDAL CHANNEL
C ARE SPECIFIED IN BOTTOM(POOL) AND SIDSLOP(POOL)
      IF(TYPPOOL.EQ.1) GO TO 50
      IF(TYPPOOL.EQ.3) GO TO 60
C IN TUNNEL SECTION
C RAD IS INVERT TO CREST DISTANCE
      RAD=RADIUS(IPOOL)
C CHECK FOR LOWEST ARC
      Y1=RAD/4.*(3.-SQRT(7.))
      IF(Y.GT.Y1) GO TO 10
      P=2.*RAD*ACOS((RAD-Y)/RAD)
      RETURN
 10   IF(ABS(Y-RAD/2.).GT.0.00001) GO TO 20
      Y2=RAD/2.
      P=2.*RAD*(ACOS((RAD-Y1)/RAD)+PI/2.-ACOS((Y2-Y1)/RAD))
      RETURN
C CHECK FOR BELOW SPRINGLINE
 20   Y2=RAD/2.
      IF(Y.GT.Y2) GO TO 30
      P=2.*RAD*(ACOS((RAD-Y1)/RAD)+ACOS((Y2-Y)/RAD)
     .  -ACOS((Y2-Y1)/RAD))
      RETURN
C CHECK FOR FILLED TUNNEL
 30   IF(Y.GT.RAD) GO TO 40
      P=2.*RAD*(ACOS((RAD-Y1)/RAD)+PI/2.-ACOS((Y2-Y1)/RAD))
     .  +RAD*ASIN((Y-Y2)/(RAD/2.))
      RETURN
 40   WRITE(6,9000)Y,IPOOL
      STOP
C TRAPEZOIDAL CHANNEL
 50   CONTINUE
      P=BOTTOM(IPOOL)+Y*2.*SQRT(SIDSLOP(IPOOL)**2+1.)
      RETURN
C IN CIRCULAR TUNNEL
 60   CONTINUE
```

```
      RAD=RADIUS(IPOOL)
      IF(ABS(Y-RAD).GT.0.00001) GO TO 70
C HALF-FULL
      P=PI*RAD
      RETURN
   70 IF(Y.GT.RAD) GO TO 80
C LOWER HALF OF SECTION
      X=RAD-Y
      THETA=ACOS(X/RAD)
      P=2.*RAD*THETA
      RETURN
C UPPER HALF OF SECTION
   80 IF(Y.GT.2.*RAD) GO TO 90
      X=Y-RAD
      THETA=ACOS(X/RAD)
      P=2.*RAD*(PI-THETA)
      RETURN
   90 WRITE(6,9000) Y,IPOOL
      STOP
C FORMAT
 9000 FORMAT(1X,38HDEPTH GREATER THAN TUNNEL HEIGHT AT
     .  3H Y=,F10.2,9H IN POOL ,I5)
      END
```

```
      SUBROUTINE BNDRY(IUPRDWN)
C UPSTREAM OR DOWNSTREAM BOUNDARY
C IUPRDWN ZERO FOR UPSTREAM BOUNDARY
C IUPRDWN ONE FOR DOWNSTREAM BOUNDARY
C Q IS SPECIFIED IN FUNCTIONS QUPST AND QDN
C NOTATION FOLLOWS WYLIE
C
      COMMON /SOLV/  XP,YP,TP,QP,XR,YR,TR,QR,XS,YS,TS,QS
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     .  NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     .  MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     .  (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     .  TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     .  STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     .  UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     .  TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
      IF(IUPRDWN.EQ.0) GO TO 20
C DOWNSTREAM BOUNDARY
C INTERSECT C+ WITH BOUNDARY
      CR=C(YR)
      RR=R(YR)
      AR=A(YR)
      VR=QR/AR
      SR=S(VR,RR)
      V=VR
      T=TR+(XP-XR)/(VR+CR)
      TPREV=T
      Y=YR
      X=XEND
      SO=BOTGRAD(IPOOL)
      AP=A(Y)
      Q=QDN(T)
      V=Q/AP
      QPREV=Q
   10 CONTINUE
      YPREV=Y
      RP=R(Y)
      SP=S(V,RP)
      CP=C(Y)
      Y=YR+(2.*(VR-V)/GGRAV-(SR+SP-2.*SO)*(T-TR))
     .  /(1./CR+1./CP)
      RP=R(Y)
      SP=S(V,RP)
      CP=C(Y)
      AP=A(Y)
      V=VR-GGRAV/2.*(SR+SP-2.*SO)*(T-TR)
     .  -GGRAV/2.*(1./CR+1./CP)*(Y-YR)
      TPREV=T
```

```
      T=2.*(XP-XR)/(V+VR+CR+CP)+TR
      QPREV=Q
      Q=QDN(T)
      V=Q/AP
      IF(ABS(QPREV-Q).GT.0.001) GO TO 10
      IF(ABS(TPREV-T).GT.0.001) GO TO 10
      IF(ABS(YPREV-Y).GT.0.001) GO TO 10
      VP=V
      TP=T
      YP=Y
      QP=Q
C CORRECT FOR CHANGE IN CHANNEL CROSS SECTION AT NO GATE D/S BOUNDARY
      IF(IPOOL.EQ.1) RETURN
C YBEFORE IS D/S Y CALCULATED FROM INITIAL CONDITIONS
C AND CONTINUITY OF Q
C YAFTER IS D/S Y CALCULATED FROM ENERGY BALANCE
C YBEFORE AND YAFTER SHOULD BE NEARLY EQUAL FOR
C A VALID SOLUTION ACROSS THE CHANGE IN SECTION
      IF(STRTYPE(IPOOL-1).EQ.4) WRITE(6,9000) YP
      IF(STRTYPE(IPOOL-1).EQ.4) YP=HDN(T)
      IF(STRTYPE(IPOOL-1).EQ.4) WRITE(6,9010) YP
      IF(STRTYPE(IPOOL-1).EQ.5) WRITE(6,9000) YP
      IF(STRTYPE(IPOOL-1).EQ.5) YP=HDN(T)
      IF(STRTYPE(IPOOL-1).EQ.5) WRITE(6,9010) YP
      RETURN
C UPSTREAM BOUNDARY
C INTERSECT C- WITH BOUNDARY
 20   CONTINUE
      CS=C(YS)
      RS=R(YS)
      AS=A(YS)
      VS=QS/AS
      SS=S(VS,RS)
      V=VS
      T=TS+(XP-XS)/(VS-CS)
      TPREV=T
      Y=YS
      X=0.
      SO=BOTGRAD(IPOOL)
      AP=A(Y)
      Q=QUPST(T)
      V=Q/AP
      QPREV=Q
 30   CONTINUE
      YPREV=Y
      RP=R(Y)
      SP=S(V,RP)
      CP=C(Y)
      Y=YS-(2.*(VS-V)/GGRAV-(SS+SP-2.*SO)*(T-TS))
       /(1./CS+1./CP)
      RP=R(Y)
      SP=S(V,RP)
      CP=C(Y)
      AP=A(Y)
      V=VS-GGRAV/2.*(SS+SP-2.*SO)*(T-TS)
       +GGRAV/2.*(1./CS+1./CP)*(Y-YS)
      TPREV=T
```

```
      T=2.*(XP-XS)/(V+VS-CS-CP)+TS
      QPREV=Q
      Q=QUPST(T)
      V=Q/AP
      IF(ABS(QPREV-Q).GT.0.001) GO TO 30
      IF(ABS(TPREV-T).GT.0.001) GO TO 30
      IF(ABS(YPREV-Y).GT.0.001) GO TO 30
      VP=V
      TP=T
      YP=Y
      QP=Q
      RETURN
C FORMATS
 9000 FORMAT(1X,9HY BEFORE=,F10.3)
 9010 FORMAT(1X,9HY  AFTER=,F10.3/)
      END
```

```
      FUNCTION HDN(T)
C DOWNSTREAM BOUNDARY DEPTH
C T IS TIME IN SEC
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     .  NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     .  MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     .  (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     .  TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     .  STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     .  UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     .  TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
C SCRATCH AREA TO BE OVERLAID IN THE VARIOUS SUBROUTINES
C TO KEEP MEMORY WITHIN SOME SORT OF REASONABLE BOUND
      COMMON /SCRATCH/
     .  DUMMY1(8570)
     .  ,H(48)
     .  ,DUMMY2(5668)
     .  ,KMAX
     .  ,SAVETUP(500),SAVEYUP(500),SAVEQUP(500)
C
C MAKE ENERGY BALANCE DEPTH CHANGE AT NO GATE CHANGE IN CROSS-SECTION
      IF(IPOOL.EQ.1) GO TO 10
      IF(STRTYPE(IPOOL-1).EQ.4) GO TO 40
      IF(STRTYPE(IPOOL-1).EQ.5) GO TO 40
 10   CONTINUE
      TIMEHR=T/3600.
      ITIME=TIMEHR
      ITIME=ITIME+1
      IF(ITIME.LT.1) ITIME=1
      IF(ITIME.GT.48) ITIME=48
      IF(ITIME.GT.1) GO TO 20
C T1,Y1 IS LAST COMPUTATION POINT ON D/S BOUNDARY
C  IN REGION 2
C MATCH WITH T1,Y1 IN 1ST HR
C THIS ASSUMES T1.LT. 1 HR
C CHECK WAVE TRAVEL TIME IF IN DOUBT
      IF(T1.GE.3600.) WRITE(6,9000) T1
      DELY=H(2)-Y1
      DELT=3600.-T1
      DT=T-T1
      DY=DELY*DT/DELT
      HDN=Y1+DY
      RETURN
C LINEARLY JOIN H(ITIME) AND H(ITIME+1)
 20   IF(ITIME.EQ.48) GO TO 30
      DELY=H(ITIME+1)-H(ITIME)
      DELT=3600.
      I=ITIME-1
```

```
      TBEG=I
      TBEG=TBEG*3600.
      DT=T-TBEG
      DY=DELY*DT/DELT
      HDN=H(ITIME)+DY
      RETURN
C HOLD DEPTH CONSTANT AFTER 47TH HOUR
 30   HDN=H(ITIME)
      RETURN
C MODIFIED NEWTONS METHOD FOR ENERGY BALANCE
C YUP+VUP**2/2*G=YDOWN+VDOWN**2/2*G
 40   CONTINUE
C SET DOWNSTREAM VALUES
C FIND DEPTH IN DOWNSTREAM SECTION
      DO 50 I=2,KMAX
      J=I
      IF(T.LE.SAVETUP(I)) GO TO 60
 50   CONTINUE
C T GREATER THAN TMAX - USE FINAL DEPTH
      YD=SAVEYUP(KMAX)
      GO TO 70
C INTERPOLATE FOR Y
 60   CONTINUE
      DELY=SAVEYUP(J)-SAVEYUP(J-1)
      DELT=SAVETUP(J)-SAVETUP(J-1)
      DT=T-SAVETUP(J-1)
      DY=DELY*DT/DELT
      YD=SAVEYUP(J-1)+DY
C GET AREA AND Q IN DOWNSTREAM SECTION
 70   CONTINUE
C QDN RETURNS Q UPSTREAM OF TURNOUT
      Q0=QDN(T)
C GET TURNOUT Q
      CALL TRNOUT(DELQ,T)
      QDS=Q0-DELQ
      QUS=Q0
C SET IPOOL FOR AREA ROUTINE
      IPOOL=IPOOL-1
      TYPPOOL=POOLTYP(IPOOL)
C IF SYPHON, CORRECT DEPTH FOR SYPHON LOSSES AND INVERT DROP
      IF(STRTYPE(IPOOL-1).NE.4) GO TO 75
C SYPHON EFFECTS ONLY - NO CHANGE IN CROSS-SECTION OF CHANNEL
C CHANGE IN CROSS-SECTION, IF ANY, IS TAKEN INTO ACCOUNT LATER
      Y=YD
      ABELOW=A(YD)
      YSYPHON=SYFONDY(IPOOL)
      SYPHON=SYFNLOS(IPOOL)
      C1=QDS**2/(2.*GGRAV*ABELOW**2)+YD-YSYPHON+SYPHON*QDS**2
      RAD=RADIUS(IPOOL)
 71   CONTINUE
      IF(TYPPOOL.EQ.2.AND.Y.GE.RAD) Y=RAD-0.1
      IF(TYPPOOL.EQ.3.AND.Y.GE.2.*RAD) Y=2.*RAD-0.1
      IF(Y.LT.0.0) Y=0.1
      F=Y+QDS**2/(2.*GGRAV*A(Y)**2)-C1
      FPRIME=1.-QDS**2/(GGRAV*A(Y)**3)*TW(Y)
      YPREV=Y
      Y=Y-F/FPRIME
```

```
      IF(ABS(Y-YPREV).GT.0.001) GO TO 71
      YD=Y
C  CALCULATE EFFECT DUE TO CHANGE IN CROSS-SECTION
 75   CONTINUE
      AD=A(YD)
C RESET IPOOL FOR U/S POOL
      IPOOL=IPOOL+1
      TYPPOOL=POOLTYP(IPOOL)
      YU=YD
C ICOUNT STOPS PROGRAM IF NO CONVERGING
      ICOUNT=1
      RAD=RADIUS(IPOOL)
 80   CONTINUE
      YPREV=YU
      F=-YU+YD+(1./(2.*GGRAV)*(QDS**2/AD**2-QUS**2/A(YU)**2))
      FPRIME=-1.+QUS**2*TW(YU)/(GGRAV*A(YU)**3)
      YU=YU-F/FPRIME
      IF(YU.LT.0.1) YU=0.1
      IF(TYPPOOL.NE.2) GO TO 90
      IF(YU.GE.RAD) YU=RAD-0.1
 90   CONTINUE
      IF(TYPPOOL.NE.3) GO TO 100
      IF(YU.GE.2.*RAD) YU=2.*RAD-0.1
 100  CONTINUE
      ICOUNT=ICOUNT+1
      IF(ICOUNT.GT.20) WRITE(6,9010)
      IF(ICOUNT.GT.20) STOP
      IF(ABS(YU-YPREV).GT.0.001) GO TO 80
      HDN=YU
      RETURN
C FORMATS
 9000 FORMAT(1X,3HT1=,F10.3,7H IN HDN )
 9010 FORMAT(1X,11HSTOP IN HDN )
      END
```

```
      FUNCTION QDN(T)
C DOWNSTREAM FLOW AT EACH POOL
C SPECIFY Q AT POOL 1 IN QD
C Q CONTINUITY IS MAINTAINED FOR ALL OTHER POOLS
C T IS TIME IN SEC
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     .  NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     .  MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     .  (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     .  TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     .  STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     .  UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     .  TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
C SCRATCH AREA TO BE OVERLAID IN THE VARIOUS SUBROUTINES
C TO KEEP MEMORY WITHIN SOME SORT OF REASONABLE BOUND
      COMMON /SCRATCH/
     .  DUMMY1(8618),QD(48),DUMMY2(5620),KMAX,
     .  SAVETUP(500),SAVEYUP(500),SAVEQUP(500)
C
C
C USE SAVETUP, SAVEQUP FOR SECOND AND FOLLOWING POOLS
      IF(IPOOL.GE.2) GO TO 10
C Q STEPS AT EACH HOUR
      TIMEHR=T/3600.
      ITIME=TIMEHR
      ITIME=ITIME+1
      IF(ITIME.LT.1) ITIME=1
      IF(ITIME.GT.48) ITIME=48
      QDN=QD(ITIME)
C CHECK FOR TURNOUT
      CALL TRNOUT(DELQ,T)
      QDN=QDN+DELQ
      RETURN
C Q FOR SECOND AND FOLLOWING POOLS IN EACH REACH
C LINEAR INTERPOLATION OF UPSTREAM Q FROM PREVIOUS POOL
 10   CONTINUE
      LIM=KMAX-1
      DO 20 I=1,LIM
      K=I
      IF(T.GE.SAVETUP(I).AND.T.LT.SAVETUP(I+1)) GO TO 30
 20   CONTINUE
      IF(T.EQ.SAVETUP(KMAX)) GO TO 30
C LET T RUN BEYOND TMAX FOR MOST UPSTREAM POOL FOR LAST POINT
      IF((T.GT.SAVETUP(K)).AND.(IPOOL.EQ.NPOOLS)) GO TO 30
      WRITE(6,9000) T,IPOOL
      STOP
 30   CONTINUE
      DT=T-SAVETUP(K)
```

```
      DELT=SAVETUP(K+1)-SAVETUP(K)
      RATIO=DT/DELT
      QDN=SAVEQUP(K)+RATIO*(SAVEQUP(K+1)-SAVEQUP(K))
C CHECK FOR TURNOUT
      CALL TRNOUT(DELQ,T)
      QDN=QDN+DELQ
      RETURN
C FORMAT
 9000 FORMAT(1X,18HQ(T) NOT FOUND AT ,F10.3,
       13H SEC FOR POOL,I5/)
      END
```

```
      FUNCTION QUPST(T)
C UPSTREAM FLOW
C SPECIFY Q IN QU FOR MOST UPSTREAM POOL
C T IS TIME IN SEC
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     .  NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     .  MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     .  (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     .  TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     .  STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     .  UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     .  TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
C SCRATCH AREA TO BE OVERLAID IN THE VARIOUS SUBROUTINES
C TO KEEP MEMORY WITHIN SOME SORT OF REASONABLE BOUND
      COMMON /SCRATCH/
     . DUMMY1(8666),QU(48),DUMMY2(7073)
C
C Q STEPS AT EACH HOUR
      TIMEHR=T/3600.
      ITIME=TIMEHR
      ITIME=ITIME+1
      IF(ITIME.LT.1) ITIME=1
      IF(ITIME.GT.48) ITIME=48
      QUPST=QU(ITIME)
      RETURN
      END
```

```
      SUBROUTINE TRNOUT(DELQ,T)
C ROUTINE TO GET TURNOUT Q FOR USE IN FUNCTION QDN
C
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     .  NMANN,S0,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     .  MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     .  (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     .  TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     .  STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     .  UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     .  TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
C SCRATCH AREA TO BE OVERLAID IN THE VARIOUS SUBROUTINES
C TO KEEP MEMORY WITHIN SOME SORT OF REASONABLE BOUND
      COMMON /SCRATCH/
     .  DUMMY1(8714),QT(48,50),DUMMY2(4673)
C INITIALIZE TURNOUT Q
      DELQ=0.0
C
C NUMTRNS IS NUMBER OF TURNOUTS IN THIS REACH
      IF(NUMTRNS.EQ.0) RETURN
      TIMEHR=T/3600.
      ITIME=TIMEHR
      ITIME=ITIME+1
      IF(ITIME.LT.1) ITIME=1
      IF(ITIME.GT.48) ITIME=48
      DELQ=QT(ITIME,IPOOL)
      RETURN
      END
```

```
      SUBROUTINE GATEMO
C ROUTINE TO CALCULATE GATE OPENINGS
C AND PUMP SCHEDULES, IF ANY
C
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     . NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     . MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     . (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     . TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     . STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     . UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     . TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
C SCRATCH AREA TO BE OVERLAID IN THE VARIOUS SUBROUTINES
C TO KEEP MEMORY WITHIN SOME SORT OF REASONABLE BOUND
      COMMON /SCRATCH/
     . DUMMY1(12000)
     . ,TD(500),QD(500),YD(500)
     . ,TU(500),QU(500),YU(500)
     . ,DUMMY2(787)
C
C
      WRITE(6,9000)
C READ U/S T,Q,H OF FIRST STRUCTURE
C  IF THIS IS A GATE, THE DEPTH D/S OF THE GATE MUST
C  HAVE BEEN SPECIFIED IN DSRES
C  IF THIS IS A PUMP, SKIP CALCULATIONS AS Q WAS SCHEDULED
      READ(1,9010) LMAX
      READ(1,9020) (TU(I),I=1,LMAX)
      READ(1,9020) (QU(I),I=1,LMAX)
      READ(1,9020) (YU(I),I=1,LMAX)
C MOST D/S STRUCTURE IS IN ARRAYS(51)
      IF(STRTYPE(51).EQ.1) GO TO 10
C CALCULATE GATE OPENINGS FOR GATE OPENING INTO
C CONSTANT LEVEL RESERVOIR AT D/S END OF REACH
      YDN=DSRES
      IPOOL=0
      JPOOL=1
      KMAX=0
      ISTRTYP=2
      WRITE(6,9030) IPOOL,KMAX,ISTRTYP
      WRITE(6,9030) JPOOL,LMAX
C CALCULATE GATE OPENINGS AT TIMES T+TINC
      TMAX=TU(LMAX)
C LIMIT TO 24 HOURS
      IF(TMAX.GT.86400.) TMAX=86400.
      T=0.0
C CALCULATE AT 5 MINUTE INTERVALS
      TINC=300.
```

```
    4 CONTINUE
C INTERPOLATE UPSTREAM
      M=LMAX-1
      DO 7 I=1,M
      K=I
      IF(T.GE.TU(I).AND.T.LE.TU(I+1)) GO TO 8
    7 CONTINUE
    8 CONTINUE
      DT=T-TU(K)
      DELT=TU(K+1)-TU(K)
      RATIO=DT/DELT
      QUP=QU(K)+RATIO*(QU(K+1)-QU(K))
C Q THRU GATE IS Q U/S OF GATE LESS TURNOUT Q AT GATE
      IPOOL=1
      CALL TRNOUT(DELQ,T)
      IPOOL=0
      QDN=QUP-DELQ
      YUP=YU(K)+RATIO*(YU(K+1)-YU(K))
C U/S SIDE OF GATE
C SET CHANGE IN INVERT ELEVATION COMING INTO GATE
      EC=0.0
      EG=-USINVT(51)
      SYPHON=0.0
      YSYPHON=0.0
      IPOOL=IPOOL+1
      TYPPOOL=POOLTYP(IPOOL)
      IUPRDWN=1
      CALL GATEY(QUP,YUP,EC,EG,SYPHON,YSYPHON,YGATE,QDN,IUPRDWN)
      YUP=YGATE
      IPOOL=IPOOL-1
C CHECK THAT U/S DEPTH IS GREATER THAN D/S DEPTH
      IF(YUP.LT.YDN) GO TO 500
C
C CALCULATE GATE OPENING
      G=YUP
      IF(ABS(YUP-YDN).LT.0.01) GO TO 11
    9 GPREV=G
      GOY=G/YUP
      IF(GOY.LT.0.0) GOY=0.0
      IF(GOY.GT.1.0) GOY=1.0
C SET IPOOL FOR COEFFICIENT ROUTINE
      IPOOL=51
      COEFF=CD(GOY)
C RESET IPOOL
      IPOOL=0
      ADN=BOTGATE(51)*YDN
C SET IPOOL FOR AREA ROUTINE
      IPOOL=IPOOL+1
      TYPPOOL=POOLTYP(IPOOL)
      AUP=YUP*BOTGATE(51)
C RESET IPOOL FOR D/S POOL
      IPOOL=IPOOL-1
      G=QDN/(BOTGATE(51)*COEFF*SQRT(2.*GGRAV*(YUP-YDN)
     + +QDN**2/AUP**2))
      IF(G.GT.YUP) G=YUP
      G=0.5*(G+GPREV)
      IF(ABS(G-GPREV).GT.0.001) GO TO 9
```

```
   11 CONTINUE
      WRITE(2,9040) T,G,YUP,YDN
      T=T+TINC
      IF(T.LE.TMAX) GO TO 4
C READ IN DOWNSTREAM AND UPSTREAM T,Q,H OF GATE
C INDEX IPOOL IS ON DOWNSTREAM SIDE OF GATE
C
C GATE TYPE IS DATA ON DOWNSTREAM SIDE OF GATE
C
C ISTRTYP=0  POOL NOT USED
C        =1  PUMPS
C        =2  NORMAL GATE
C        =3  SYPHON DOWNSTREAM OF GATE
C        =4  SYPHON WITH NO GATE
C        =5  NO GATE
C
   10 CONTINUE
      READ(1,9030) IPOOL,KMAX,ISTRTYP
      IF(EOF(1)) 400,20
   20 CONTINUE
      WRITE(6,9030) IPOOL,KMAX,ISTRTYP
      READ(1,9020) (TD(I),I=1,KMAX)
      READ(1,9020) (QD(I),I=1,KMAX)
      READ(1,9020) (YD(I),I=1,KMAX)
      READ(1,9030) JPOOL,LMAX
      IF(EOF(1)) 35,30
   30 WRITE(6,9030) JPOOL,LMAX
      READ(1,9020) (TU(I),I=1,LMAX)
      READ(1,9020) (QU(I),I=1,LMAX)
      READ(1,9020) (YU(I),I=1,LMAX)
      GO TO 36
C FINISHED IF LAST STRUCTURE IS NOT STROKED
   35 IF(STUDY.EQ.1) GO TO 400
   36 CONTINUE
C SKIP NO GATE BOUNDARIES
      IF(ISTRTYP.EQ.4.OR.ISTRTYP.EQ.5) GO TO 10
C CALCULATE GATE OPENINGS OR PUMP DISCHARGES AT TIMES T+TINC
      TMAX=TU(LMAX)
C LIMIT TO 24 HOURS
      IF(TMAX.GT.86400.) TMAX=86400.
      T=0.0
C CALCULATE AT 5 MINUTE INTERVALS
      TINC=300.
   40 CONTINUE
C INTERPOLATE DOWNSTREAM
      M=KMAX-1
      DO 50 I=1,M
      K=I
      IF(T.GE.TD(I).AND.T.LT.TD(I+1)) GO TO 60
   50 CONTINUE
   60 CONTINUE
      DT=T-TD(K)
      DELT=TD(K+1)-TD(K)
      RATIO=DT/DELT
      QDN=QD(K)+RATIO*(QD(K+1)-QD(K))
      YDN=YD(K)+RATIO*(YD(K+1)-YD(K))
C INTERPOLATE UPSTREAM
```

```
C SET U/S DEPTH JUST IN CASE THIS IS A GATE AT MOST U/S END OF REACH
      YUP=USRES
      IF(IPOOL.EQ.NPOOLS) GO TO 85
      M=LMAX-1
      DO 70 I=1,M
      K=I
      IF(T.GE.TU(I).AND.T.LE.TU(I+1)) GO TO 80
 70   CONTINUE
 80   CONTINUE
      DT=T-TU(K)
      DELT=TU(K+1)-TU(K)
      RATIO=DT/DELT
      QUP=QU(K)+RATIO*(QU(K+1)-QU(K))
      YUP=YU(K)+RATIO*(YU(K+1)-YU(K))
 85   CONTINUE
C IS THIS A PUMP
      IF(ISTRTYP.EQ.1) GO TO 600
      IF(ISTRTYP.NE.2) GO TO 200
C CALCULATE Y IN NORMAL GATE STRUCTURE
C SET CHANNEL X-SECTION TYPE FOR AREA ROUTINE
      TYPPOOL=POOLTYP(IPOOL)
C IPOOL HAS BEEN READ IN ABOVE
C ZERO OUT SYPHON PARAMETERS
      SYPHON=0.0
      YSYPHON=0.0
C D/S SIDE OF GATE
C INVERT DROP TO TRAPEZOIDAL CHANNEL
C EC IS CHANNEL INVERT ELEVATION
C EG IS GATE INVERT ELEVATION
C
      EC=0.0
      EG=DSINVT(IPOOL)
C IUPRDWN =0 FOR D/S SIDE OF GATE, =1 FOR U/S SIDE
      IUPRDWN=0
      CALL GATEY(QDN,YDN,EC,EG,SYPHON,YSYPHON,YGATE,QDN,IUPRDWN)
      YDN=YGATE
C U/S SIDE OF GATE
      IF(IPOOL.EQ.NPOOLS) GO TO 310
C SET CHANGE IN INVERT ELEVATION COMING INTO GATE
      EC=0.0
      EG=-USINVT(IPOOL)
      IPOOL=IPOOL+1
      TYPPOOL=POOLTYP(IPOOL)
      IUPRDWN=1
      CALL GATEY(QUP,YUP,EC,EG,SYPHON,YSYPHON,YGATE,QDN,IUPRDWN)
      YUP=YGATE
      IPOOL=IPOOL-1
      TYPPOOL=POOLTYP(IPOOL)
      GO TO 310
 200  IF(ISTRTYP.NE.3) GO TO 10
C SYPHON
C
C SET CHANNEL X-SECTION TYPE FOR AREA ROUTINE
      TYPPOOL=POOLTYP(IPOOL)
C D/S SIDE OF GATE
C SET SYPHON HEAD LOSS AND SYPHON DROP
      SYPHON=SYFNLOS(IPOOL)
```

```
      YSYPHON=SYFONDY(IPOOL)
C SET GATE AND CHANNEL ELEVATIONS
C INVERT DROP FROM GATE THRU SYPHON LUMPED IN SYFONDY
      EG=0.0
      EC=0.0
      IUPRDWN=0
      CALL GATEY(QDN,YDN,EC,EG,SYPHON,YSYPHON,YGATE,QDN,IUPRDWN)
      YDN=YGATE
C U/S SIDE OF GATE
      IF(IPOOL.EQ.NPOOLS) GO TO 310
C SET CHANGE IN INVERT ELEVATION GOING INTO GATE
      SYPHON=0.0
      YSYPHON=0.0
      EC=0.0
      EG=-USINVT(IPOOL)
      IPOOL=IPOOL+1
      TYPPOOL=POOLTYP(IPOOL)
      IUPRDWN=1
      CALL GATEY(QUP,YUP,EC,EG,SYPHON,YSYPHON,YGATE,QDN,IUPRDWN)
      YUP=YGATE
      IPOOL=IPOOL-1
      TYPPOOL=POOLTYP(IPOOL)
  310 CONTINUE
C CHECK THAT U/S DEPTH IS GREATER THAN D/S DEPTH
      IF(YUP.LT.YDN) GO TO 500
C
C CALCULATE GATE OPENING
C DEPTHS AND QS ARE INSIDE GATE SECTION
      G=YUP
      IF(ABS(YUP-YDN).LT.0.01) GO TO 330
  320 GPREV=G
      GOY=G/YUP
      IF(GOY.LT.0.0) GOY=0.0
      IF(GOY.GT.1.0) GOY=1.0
      COEFF=CD(GOY)
      TYPPOOL=POOLTYP(IPOOL)
      ADN=YDN*BOTGATE(IPOOL)
C GET AREA IN UPSTREAM SIDE OF GATE SECTION
      AUP=YUP*BOTGATE(IPOOL)
      G=QDN/(BOTGATE(IPOOL)*COEFF*SQRT(2.*GGRAV*(YUP-YDN)
     1 +QDN**2/AUP**2))
      IF(G.GT.YUP) G=YUP
      G=0.5*(G+GPREV)
      IF(ABS(G-GPREV).GT.0.001) GO TO 320
  330 CONTINUE
      WRITE(2,9040) T,G,YUP,YDN
      T=T+TINC
      IF(T.LE.TMAX) GO TO 40
      GO TO 10
  400 REWIND 1
      REWIND 2
      RETURN
C REVERSE FLOW THRU GATE - STOP
  500 CONTINUE
      WRITE(6,9050) IPOOL,JPOOL,ISTRTYP,T,YUP,YDN
      STOP
C PUMP STROKING
```

```
 600  CONTINUE
      WRITE(2,9040) T,QDN,YUP,YDN
      T=T+TINC
      IF(T.LE.TMAX) GO TO 40
      GO TO 10
C FORMATS
 9000 FORMAT(1X,9HIN GATEMO/1X,
     . 30H      POOL      KMAX  STR TYPE/)
 9010 FORMAT(1X,10X,I10)
 9020 FORMAT(1X,10F10.3)
 9030 FORMAT(1X,4I10)
 9040 FORMAT(1X,4F10.3)
 9050 FORMAT(1X,43HU/S DEPTH LESS THAN D/S DEPTH BETWEEN POOLS,
     . I5,4H AND,I5/1X,9HGATE TYPE,I5/1X,5HAT T=,F10.3
     . /1X,10HU/S DEPTH=,F10.3/1X,10HD/S DEPTH=,F10.3)
      END
```

```
      SUBROUTINE GATEY(QCHANNL,YCHANNL,ECHANNL,EGATE,SYPHON,YSYPHON,
        YGATE,QGATE,IUPRDWN)
C ROUTINE TO CALCULATE DEPTH IN GATE STRUCTURE FROM CHANNEL DEPTH
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     .  NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     .  MANN(50).BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     .  (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     .  TMAX.XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     .  STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     .  UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     .  TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
C IUPRDWN=0 FOR D/S SIDE OF GATE, =1 FOR U/S SIDE
      IF(IUPRDWN.EQ.1) GO TO 20
C
C D/S SIDE OF GATE
C
      Y=YCHANNL
      ACHANNL=A(Y)
      C1=QCHANNL**2/(2.*GGRAV*ACHANNL**2)+YCHANNL+ECHANNL-EGATE
     .  -YSYPHON+SYPHON*QCHANNL**2
C GATE BOTTOM WIDTH
      B=BOTGATE(IPOOL)
      C2=QCHANNL**2/(2.*GGRAV*B**2)
 10   CONTINUE
C USE RECTANGULAR SECTION AT GATE
      IF(Y.LE.0.) Y=0.1
      F=Y+C2/Y**2-C1
      FPRIME=1.-2.*C2/Y**3
      YPREV=Y
      Y=Y-F/FPRIME
      IF(ABS(Y-YPREV).GT.0.001) GO TO 10
      YGATE=Y
      RETURN
C
C U/S SIDE OF GATE
C
C IPOOL AND TYPPOOL WERE SET IN GATEMO FOR THE U/S POOL
 20   CONTINUE
      Y=YCHANNL
      ACHANNL=A(Y)
C RESET TO D/S POOL FOR GATE PROPERTIES
      IPOOL=IPOOL-1
      IF(IPOOL.EQ.0) IPOOL=51
      TYPPOOL=POOLTYP(IPOOL)
      C1=QCHANNL**2/(2.*GGRAV*ACHANNL**2)+YCHANNL+ECHANNL-EGATE
C GATE BOTTOM WIDTH
      B=BOTGATE(IPOOL)
      C2=QGATE**2/(2.*GGRAV*B**2)
```

```
            C RESET TO U/S POOL BEFORE RETURN TO GATEMO
                    IF(IPOOL.EQ.51) IPOOL=0
60                  IPOOL=IPOOL+1
                    TYPPOOL=POOLTYP(IPOOL)
             30     CONTINUE
            C USE RECTANGULAR SECTION AT GATE
                    IF(Y.LE.0.) Y=0.1
65                  F=Y+C2/Y**2-C1
                    FPRIME=1.-2.*C2/Y**3
                    YPREV=Y
                    Y=Y-F/FPRIME
                    IF(ABS(Y-YPREV).GT.0.001) GO TO 30
70                  YGATE=Y
                    RETURN
                    END
```

```
      FUNCTION CD(GOY)
C ROUTINE TO CALCULATE GATE COEFFICIENT AS FUNCTION
C OF GATE OPENING/YUPSTREAM
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     . NMANN,S0,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     . MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     . (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     . TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     . STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     . UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     . TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
C FIT PARABOLA TO 3 POINTS NEAR GOY
      K=GOY*10.+1.
      IF(K.LT.1) K=1
      IF(K.GT.9) K=9
      OFFSET=K
      X=GOY*10.-OFFSET
      I=IPOOL
      A1=0.5*(GATECO(K,I)-2.*GATECO(K+1,I)+GATECO(K+2,I))
      B1=0.5*(GATECO(K+2,I)-GATECO(K,I))
      C1=GATECO(K+1,I)
      CD=A1*X**2+B1*X+C1
      RETURN
      END
```

```
      SUBROUTINE FOLOWER
C ROUTINE TO FOLLOW GATE STROKING GATE MOTIONS TO DETERMINE
C START TIMES AND FINAL POSITIONS OF GATES
C OR TO TURN PUMPS ON AND OFF
C
C SPEED IS GATE SPEED IN FT/MIN
C DEDBAND IS DIFFERENCE ALLOWED IN GATE OPENING BETWEEN
C ACTUAL POSITION AND STROKING SOLUTION BEFORE MOVING GATE
C
C PUMPDQ IS INCREMENTAL DISCHARGE FOR PUMPS
      COMMON /ALL/
C PHYSICAL PARAMETERS
     . NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     . MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     . (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     . TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     . STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     . UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     . TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
C SCRATCH AREA TO BE OVERLAID IN THE VARIOUS SUBROUTINES
C TO KEEP MEMORY WITHIN SOME SORT OF REASONABLE BOUND
      COMMON /SCRATCH/
     . DUMMY1(12000)
     . ,T(500),G(500),TMIN(500),GPOSN(500)
     . ,DUMMY2(1787)
C
C EQUIVALENCE Q AND G SO PUMP STROKING VARIABLE NAMES MAKE
C  SOME SENSE
C  IF THIS IS A PUMP, GATEMO WROTE Q; IF IT IS A GATE, GATEMO
C  WROTE GATE OPENING, G
C
      DIMENSION Q(500),QLAST(500)
      EQUIVALENCE (Q(1),G(1)),(QLAST(1),GPOSN(1)),(PUMPQ,GATEOPN)
C
C
C
      REWIND 2
      REWIND 5
      IPOOL=51
C READ IN T AND GATE OPENING
      NGATE=1
 10   I=1
      IEOF=0
      READ(2,9010) T(I),G(I)
      IF(EOF(2)) 70,20
 20   I=I+1
      READ(2,9010) T(I),G(I)
      IF(EOF(2)) 70,30
 30   IF(T(I).NE.0.0) GO TO 20
      BACKSPACE 2
```

```
 40    MAX=I-1
C CALCULATE START TIMES
C INITIAL OPENING
C TIME IN MINUTES NOW
       TMIN(1)=0.0
       GPOSN(1)=G(1)
       GATEOPN=GPOSN(1)
       I=2
C FIND POOL D/S OF THIS GATE
 42    IF(STRTYPE(IPOOL).EQ.2) GO TO 45
       IF(STRTYPE(IPOOL).EQ.3) GO TO 45
C SKIP STROKING MOST D/S PUMP
       IF(IPOOL.EQ.51) GO TO 44
       IF(STRTYPE(IPOOL).EQ.1) GO TO 80
 44    CONTINUE
       IF(IPOOL.EQ.51) IPOOL=0
       IPOOL=IPOOL+1
       GO TO 42
 45    CONTINUE
       DO 50 J=2,MAX
       IF(ABS(GATEOPN-G(J)).LT.DEDBAND(IPOOL)) GO TO 50
C MOVE GATE
       DELY=ABS(GATEOPN-G(J))
       DELT=DELY/SPEED(IPOOL)
       TMIN(I)=T(J)/60.-DELT
       GPOSN(I)=G(J)
       GATEOPN=G(J)
       I=I+1
 50    CONTINUE
       NOMOVE=I-1
       WRITE(6,9020) NGATE,NOMOVE
C SAVE FOR ROUTINE WRITEIT TO OUTPUT IN REVERSE ORDER
       WRITE(5,9020) NGATE,NOMOVE
       NGATES=NGATE
       DO 60 I=1,NOMOVE
       WRITE(5,9010) TMIN(I),GPOSN(I),SPEED(IPOOL)
 60    CONTINUE
       WRITE(6,9000) DEDBAND(IPOOL)
       NGATE=NGATE+1
       IF(IPOOL.EQ.51) IPOOL=0
       IPOOL=IPOOL+1
       IF(IEOF.EQ.0) GO TO 10
       REWIND 5
       RETURN
 70    IEOF=1
       GO TO 40
C PUMP STROKING
 80    CONTINUE
C SET INITIAL DISCHARGE TO N*PUMPDQ
       N=0
 85    CONTINUE
       FN=N
       QTEST=PUMPQ-FN*PUMPDQ(IPOOL)
       IF(QTEST.LT.0.0) GO TO 90
       N=N+1
       GO TO 85
 90    N=N-1
```

```
      FN=N
      PUMPQ=FN*PUMPDQ(IPOOL)
      QLAST(1)=PUMPQ
      DO 110 J=2,MAX
      IF(ABS(PUMPQ-Q(J)).LT.PUMPDQ(IPOOL)) GO TO 110
C TURN PUMP ON OR OFF
      IF(PUMPQ.LT.Q(J)) GO TO 100
C TURN PUMP OFF
      TMIN(I)=T(J)/60.
   95 CONTINUE
      QLAST(I)=PUMPQ-PUMPDQ(IPOOL)
      PUMPQ=QLAST(I)
      IF(ABS(PUMPQ-Q(J)).GE.PUMPDQ(IPOOL)) GO TO 95
      I=I+1
      GO TO 110
C TURN PUMP ON
  100 CONTINUE
      TMIN(I)=T(J)/60.
  105 CONTINUE
      QLAST(I)=PUMPQ+PUMPDQ(IPOOL)
      PUMPQ=QLAST(I)
      IF(ABS(PUMPQ-Q(J)).GE.PUMPDQ(IPOOL)) GO TO 105
      I=I+1
  110 CONTINUE
      NOMOVE=I-1
      WRITE(6,9030) NGATE,NOMOVE
      WRITE(5,9030) NGATE,NOMOVE
      NGATES=NGATE
      DO 120 I=1,NOMOVE
      WRITE(5,9040) TMIN(I),QLAST(I)
  120 CONTINUE
      WRITE(6,9050) PUMPDQ(IPOOL)
      NGATE=NGATE+1
      IPOOL=IPOOL+1
      IF(IEOF.EQ.0) GO TO 10
      REWIND 5
      RETURN
C FORMATS
 9000 FORMAT(1X,24HGATE MOVEMENT DEADBAND =,F10.3,3H FT)
 9010 FORMAT(1X,3F10.3)
 9020 FORMAT(1X,4HGATE,I5,I10,2X,9HMOVEMENTS)
 9030 FORMAT(1X,4HPUMP,I5,I10,2X,9HCHANGES   )
 9040 FORMAT(1X,2F10.3,10X)
 9050 FORMAT(1X,14HPUMP DELTA Q =,F10.3)
      END
```

```
      SUBROUTINE WRITEIT
C ROUTINE TO MERGE TURNOUT SCHEDULES, GATE SCHEDULES
C AND PUMP SCHEDULES INTO INPUT FILE FOR UNSTEADY MODEL
C FILE ON TAPE 8 IS POSITIONED AT END OF INITIAL CONDITIONS
C OUTPUT IS FROM UPSTREAM TO DOWNSTREAM
C
      COMMON /ALL/
C PHYSICAL PARAMETERS
     . NMANN,SO,GGRAV,PI,BOTTOM(50),SIDSLOP(50),RADIUS(50),BOTGATE(51),
     . MANN(50),BOTGRAD(50),SYFONDY(50),SYFNLOS(50),SPEED(51),PUMPDQ
     . (51),DEDBAND(51),NGATES,GATECO(11,51),DSINVT(50),USINVT(51),
C WORKING VARIABLES
     . TMAX,XEND,TINC,NXINC,NPOOLS,IPOOL,TYPPOOL,STABEG(50),
     . STAEND(50),T1,Y1,STUDY,
C CANAL DESCRIPTION
     . UPSTA(50),DWNSTA(50),NOPOOLS,POOLTYP(50),STRTYPE(51),
     . TMAXI,NUMTRNS,USRES,DSRES
C
      REAL NMANN,MANN
      INTEGER TYPPOOL,POOLTYP,STRTYPE,STUDY
C
C
C SCRATCH AREA TO BE OVERLAID IN THE VARIOUS SUBROUTINES
C TO KEEP MEMORY WITHIN SOME SORT OF REASONABLE BOUND
      COMMON /SCRATCH/
     . DUMMY1(8618),QD(48),QU(48),QT(48,50),DUMMY2(886),
     . TMOVE(500),GO(500),SPED(500),DUMMY3(2287)
C
      DIMENSION Q(500)
C EQUIVALENCE GATE OPENING, GO, FOR GATES WITH Q FOR
C  PUMPS SO VARIABLE NAMES WILL MAKE SOME SENSE.
C  GO AND Q ARE IN THE SAME FIELD ON TAPE 5.
C
      EQUIVALENCE (GO(1),Q(1))
C
C START AT UPSTREAM END
      NGATE=NGATES
      JPOOL=1
      K=NOPOOLS
C WAS U/S STRUCTURE A GATE OR A PUMP
      IF(STRTYPE(K).EQ.1) GO TO 50
C GATE
C FIND GATE SCHEDULE ON TAPE 5
      REWIND 5
 10   READ(5,9110) IGATE,IMOVE
      DO 20 I=1,IMOVE
      READ(5,9120) TMOVE(I),GO(I),SPED(I)
 20   CONTINUE
      IF(IGATE.NE.NGATE) GO TO 10
C SET FOR NEXT D/S STRUCTURE
      NGATE=NGATE-1
      WRITE(9,9130) JPOOL,STRTYPE(K),IMOVE
      DO 30 I=1,IMOVE
      WRITE(9,9140) TMOVE(I),GO(I),SPED(I)
 30   CONTINUE
      GO TO 120
C PUMP
```

```
 50    CONTINUE
C WAS PUMP SCHEDULED OR STROKED
       IF(STUDY.EQ.2) GO TO 80
C SCHEDULED
C EXTRACT Q CHANGES FROM QU
       IMOVE=1
       TMOVE(1)=0.0
       Q(1)=QU(1)
       DO 60 J=2,48
       IF(QU(J).EQ.QU(J-1)) GO TO 60
       IMOVE=IMOVE+1
       TMOVE(IMOVE)=(J-1)*60
       Q(IMOVE)=QU(J)
 60    CONTINUE
       WRITE(9,9130) JPOOL,STRTYPE(K),IMOVE
       DO 70 I=1,IMOVE
       WRITE(9,9150) TMOVE(I),Q(I)
 70    CONTINUE
       GO TO 120
C STROKED
 80    CONTINUE
C FIND PUMP SCHEDULE ON TAPE 5
       REWIND 5
 90    READ(5,9110) IGATE,IMOVE
       DO 100 I=1,IMOVE
       READ(5,9120) TMOVE(I),Q(I)
 100   CONTINUE
       IF(IGATE.NE.NGATE) GO TO 90
C SET FOR NEXT D/S STRUCTURE
       NGATE=NGATE-1
       WRITE(9,9130) JPOOL,STRTYPE(K),IMOVE
       DO 110 I=1,IMOVE
       WRITE(9,9150) TMOVE(I),Q(I)
 110   CONTINUE
C IS THERE A TURNOUT AT D/S END OF POOL
 120   CONTINUE
       DO 130 I=1,48
       IF(QT(I,K).NE.0.0) GO TO 140
 130   CONTINUE
       GO TO 200
C EXTRACT TURNOUT Q CHANGES FROM QT
 140   CONTINUE
       IMOVE=1
       TMOVE(1)=0.0
       Q(1)=QT(1,K)
       DO 150 J=2,48
       IF(QT(J,K).EQ.QT(J-1,K)) GO TO 150
       IMOVE=IMOVE+1
       TMOVE(IMOVE)=(J-1)*60
       Q(IMOVE)=QT(J,K)
 150   CONTINUE
       ITRNTYP=99
       WRITE(9,9130) JPOOL,ITRNTYP,IMOVE
       DO 160 I=1,IMOVE
       WRITE(9,9150) TMOVE(I),Q(I)
 160   CONTINUE
C
```

```
C INTERIOR BOUNDARIES
C
  200 CONTINUE
      REWIND 5
      K=K-1
      JPOOL=JPOOL+1
      IF(K.EQ.0) GO TO 900
C IS THERE A STRUCTURE AT U/S END OF THIS POOL
      IF(STRTYPE(K).EQ.4) GO TO 300
      IF(STRTYPE(K).EQ.5) GO TO 300
      IF(STRTYPE(K).NE.1) GO TO 240
C PUMPS
C FIND PUMP SCHEDULE ON TAPE 5
  210 READ(5,9110) IGATE,IMOVE
      DO 220 I=1,IMOVE
      READ(5,9120) TMOVE(I),Q(I)
  220 CONTINUE
      IF(IGATE.NE.NGATE) GO TO 210
C SET FOR NEXT D/S STRUCTURE
      NGATE=NGATE-1
      WRITE(9,9130) JPOOL,STRTYPE(K),IMOVE
      DO 230 I=1,IMOVE
      WRITE(9,9150) TMOVE(I),Q(I)
  230 CONTINUE
      GO TO 300
C GATE
  240 CONTINUE
C FIND GATE SCHEDULE ON TAPE 5
  250 READ(5,9110) IGATE,IMOVE
      DO 260 I=1,IMOVE
      READ(5,9120) TMOVE(I),GO(I),SPED(I)
  260 CONTINUE
      IF(IGATE.NE.NGATE) GO TO 250
C SET FOR NEXT D/S STRUCTURE
      NGATE=NGATE-1
      WRITE(9,9130) JPOOL,STRTYPE(K),IMOVE
      DO 270 I=1,IMOVE
      WRITE(9,9140) TMOVE(I),GO(I),SPED(I)
  270 CONTINUE
C IS THERE A TURNOUT AT D/S END OF THIS POOL
  300 CONTINUE
      DO 310 I=1,48
      IF(QT(I,K).NE.0.0) GO TO 320
  310 CONTINUE
      GO TO 200
C EXTRACT CHANGES IN TURNOUT Q FROM QT
  320 CONTINUE
      IMOVE=1
      TMOVE(1)=0.0
      Q(1)=QT(1,K)
      DO 330 J=2,48
      IF(QT(J,K).EQ.QT(J-1,K)) GO TO 330
      IMOVE=IMOVE+1
      TMOVE(IMOVE)=(J-1)*60
      Q(IMOVE)=QT(J,K)-QT(J-1,K)
  330 CONTINUE
      ITRNTYP=99
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      WRITE(9,9130) JPOOL,ITRNTYP,IMOVE
      DO 340 I=1,IMOVE
      WRITE(9,9150) TMOVE(I),Q(I)
  340 CONTINUE
      GO TO 200
C
C MOST D/S STRUCTURE
C
  900 CONTINUE
C Q WAS SCHEDULED IN QD
C IS THIS A PUMP
      IF(STRTYPE(51).NE.1) GO TO 950
C PUMP
C EXTRACT CHANGES IN Q FROM QD
      IMOVE=1
      TMOVE(1)=0.0
      Q(1)=QD(1)
      DO 910 J=2,48
      IF(QD(J).EQ.QD(J-1)) GO TO 910
      IMOVE=IMOVE+1
      TMOVE(IMOVE)=(J-1)*60
      Q(IMOVE)=QD(J)
  910 CONTINUE
      WRITE(9,9130) JPOOL,STRTYPE(51),IMOVE
      DO 920 I=1,IMOVE
      WRITE(9,9150) TMOVE(I),Q(I)
  920 CONTINUE
      GO TO 1000
C GATE
  950 CONTINUE
      READ(5,9110) IGATE,IMOVE
      WRITE(9,9130) JPOOL,STRTYPE(51),IMOVE
      DO 960 I=1,IMOVE
      READ(5,9120) TMOVE(I),GO(I),SPED(I)
      WRITE(9,9140) TMOVE(I),GO(I),SPED(I)
  960 CONTINUE
 1000 CONTINUE
      REWIND 5
      REWIND 9
      RETURN
 9110 FORMAT(5X,I5,I10)
 9120 FORMAT(1X,3F10.3)
 9130 FORMAT(3I10)
 9140 FORMAT(3F10.3)
 9150 FORMAT(2F10.3,10X)
      END
```