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Transport and Dispersion of Pollutants in Surface Impoundments: A Finite Difference Model

G. T. Yeh

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TRANSPORT AND DISPERSION OF POLLUTANTS IN SURFACE IMPOUNDMENTS: A FINITE DIFFERENCE MODEL

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ACKNOWLEDGMENTS

The computer model described in this report was initially developed for hydrothermal analyses for the Northern State Power Company. It was expanded and modified to include both mass and thermal transports and the computer program was extended for generic application. Modification and expansion of the model were supported by the Office of Waste Management of the Department of Energy. Mr. R. S. McGinnis of Northern State Power Company and Y. Shen of Stone and Webster Engineering Corporation made major contributions to the example for Prairie Island Application.

ABSTRACT

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A surface impoundment model by finite-difference (SIMFD) has been developed. SIMFD computes the flow rate, velocity field, and the concentration distribution of pollutants in surface impoundments with any number of islands located within the region of interest. Theoretical derivations and numerical algorithm are described in detail. Instructions for the application of SIMFD and listings of the FORTRAN IV source program are provided. Two sample problems are given to illustrate the application and validity of the model.

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I. INTRODUCTION

Areas near surface water impoundments, either natural or man-made, have traditionally been the centers of industrial growth. A basic reason has been their capacity to receive, dilute and assimilate unwanted effluents. In recent years, however, the rapidly increasing quantities of such effluents and the growing concern over preservation of environmental quality have led to the need for rational planning of the utilization of impounding waters, instead of allowing uncontrolled expansion.

A major technical problem associated with such planning strategies is the prediction of how an effluent will migrate in a given body of water. The answer to this question is by no means simple. It involves knowledge of the flow field, on one hand, and the physicochemical characteristics of the pollutants on the other. The complex flow patterns in the surface water depend on meteorological conditions, bottom topography, boundary geometry, inflows, and outflows. To gain insight into the natural processes, three approaches may be followed: (1) direct measurements, (2) hydraulic modeling, and (3) mathematical modeling.

Measurements in water bodies are not only very expensive and site and time specific, but by themselves they cannot provide an adequate overall view of the processes of interest. However, they are necessary in conjunction with models of approaches (2) and (3), since they provide data required for input or for verification purposes. Hydraulic models can yield a very detailed picture of the phenomena, but considerable difficulties are encountered in the proper scaling of all relevant factors, inevitably resulting in some degree of simplification of the representation. They are, in general, site-specific and also are much more expensive than mathematical models. This last category consists essentially of the representation of the actual processes by mathematical equations, which are subsequently solved by analytical or numerical techniques. The more complex the mathematical representation, the more difficult, but supposedly the more accurate, the solution becomes. Mathematical models are relatively inexpensive and general enough so they they can be applied to different areas with only minor changes.

With the widespread use of high-speed computers, incresingly detailed mathematical formulation can be handled by various numerical methods. Several two-dimensional computational algorithms have been developed to describe the transient flow patterns in a water body (Lee 1972, Leendertse 1970, Simmons 1973, Liggett 1975, Abbott et al. 1975, Yeh 1976). However, numerous occasions exist that do not warrant the application of novel transient flow analysis. Furthermore, published transient models applied to a specific case often have the unfortunate characteristics of being inoperative when applied to a different problem. Thus, operational steady state flow models, which would yield adequate and reliable solutions of flow equations for a wide range of problems, are required for many situations. This report presents the development of one such model by alternating direction implicit (ADI) finite-difference method.

From a practical viewpoint, the main interest is not the flow field but rather the transport and dispersion of pollutants within a given flow field. Therefore, the information obtained from a hydrodynamic model is subsequently used as input to a pollutant transport model. The latter normally solves some form of the advective-dispersive equation, expressing the mass balance of the constituent of interest. Again, the ADI method is employed for solving the transport equation.

II. MODEL DEVELOPMENT

The space variations of the velocity from discharge, intakes, inflows, and outflows are simulated with a two-dimensional steady state hydrodynamic model. This is a modified version of the model developed previously (Yeh et al. 1973). The spatiotemporal variations of the pollutants (mass or thermal) are calculated with the aid of numerical solution of mass or thermal balance equation. The solution methods for both hydrodynamic and pollutant transport models are the alternating direction implicit (ADI) finite-difference scheme.

II.1 Hydrodynamic Model

The water in a surface impoundment is three-dimensional in nature. Because the flow is mainly horizontal and the impoundment is usually shallow, it is assumed that pressure is hydrostatic. Furthermore, only macro-velocity variations are considered. The effects of small-scale velocity fluctuations are combined with viscosity into shear stress terms. The equation of motion may be written as

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \frac{1}{\rho}\frac{\partial \tau_{xz}}{\partial z} + fv \qquad (1)$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial y} + \frac{1}{\rho}\frac{\partial \tau_{yz}}{\partial z} - fu \qquad (2)$$

$$\partial p/\partial z + \rho g = 0 \qquad (3)$$

where u, v, and w are the velocity components in he x, y, and z directions, respectively, ρ is the density of water, p is the pressure, g is the gravity acceleration, f is the coriolis coefficient, t is the time, and τ_{xz} and τ_{yz} are the combined apparent and viscous stress components in the x and y directions, respectively. It must be noted that terms, $\partial\tau_{xx}/\partial x$, $\partial\tau_{xy}/\partial y$ and $\partial\tau_{yx}/\partial x$, $\partial\tau_{yy}/\partial y$, in Eqs. (1) and (2), have been omitted because they are small compared to terms, $\partial\tau_{xz}/\partial z$ and $\partial\tau_{yz}/\partial z$, respectively.

The equation of continuity of fluid mass is

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \tag{4}$$

Because of the complicated boundary of a surface impoundment and the difficulty of dealing with three-dimensional computations of fluid flow, the problem is reduced to a two-dimensional one by vertical integration of the equations of motion and continuity. The nonlinear advective acceleration term is usually a small order of magnitude in comparison to the pressure or bottom frictional terms, and flow operation over the resident time is normally steady. Therefore in this report it will be assumed that the flow is steady and nonlinear advective terms are negligible. The validity of these assumptions is demonstrated in Appendix A. With these assumptions, the vertically integrated equations become:

$$f\bar{v} - g\frac{\partial\eta}{\partial x} + \frac{1}{\rho(h+\eta)}(\tau_x^w - \tau_x^b) = 0 \tag{5}$$

$$-f\bar{u} - g\frac{\partial\eta}{\partial y} + \frac{1}{(h+\eta)}(\tau_y^w - \tau_y^b) = 0 \tag{6}$$

$$\frac{\partial(h+\eta)u}{\partial x} + \frac{\partial(h+\eta)\bar{v}}{\partial y} = 0 \tag{7}$$

where η is the water surface elevation above the still water level, h is the water depth, and τ_x^w, τ_y^w and τ_x^b, τ_y^b are the shear-stresses due to the wind and at the bottom, respectively (Fig. 1). The vertically averaged velocity components, $\bar{u}$ and $\bar{v}$ are given by

$$\bar{u} = \frac{1}{h + \eta} \int_{-h}^{\eta} u(x,y,z)dz \quad (8a)$$

and

$$\bar{v} = \frac{1}{h +} \int_{-h}^{\eta} v(x,y,z)dz \quad (8b)$$

The surface wind shear stress components, τ_x^w and τ_y^w, dependent on the meteorological conditions, may be given by the following equations (Van Dorn 1953):

$$\tau_x^w = \rho_a k_a |W| W_x, \qquad \tau_y^w = \rho_a k_a |W| W_y \quad (9a)$$

where ρ_a is the air density, k_a is the wind stress coefficient, W_x and W_y are the wind velocity components in the x- and y-directions, repectively, and $|W| = \sqrt{W_x^2 + W_y^2}$ is the wind speed.

The bottom stress components, τ_x^b and τ_y^b, were assumed to be proportional to the squared velocity for turbulent flow (Leendertse 1970):

$$\tau_x^b = \rho C_f \sqrt{\bar{u}^2 + \bar{v}^2}\ \bar{u} \ : \ \tau_y^b = \rho C_f \sqrt{\bar{u}^2 + \bar{v}^2}\ \bar{v} \quad (9b)$$

in which C_f is the friction factor, depending on the bottom roughness and water depth (Wang and Connor 1975).

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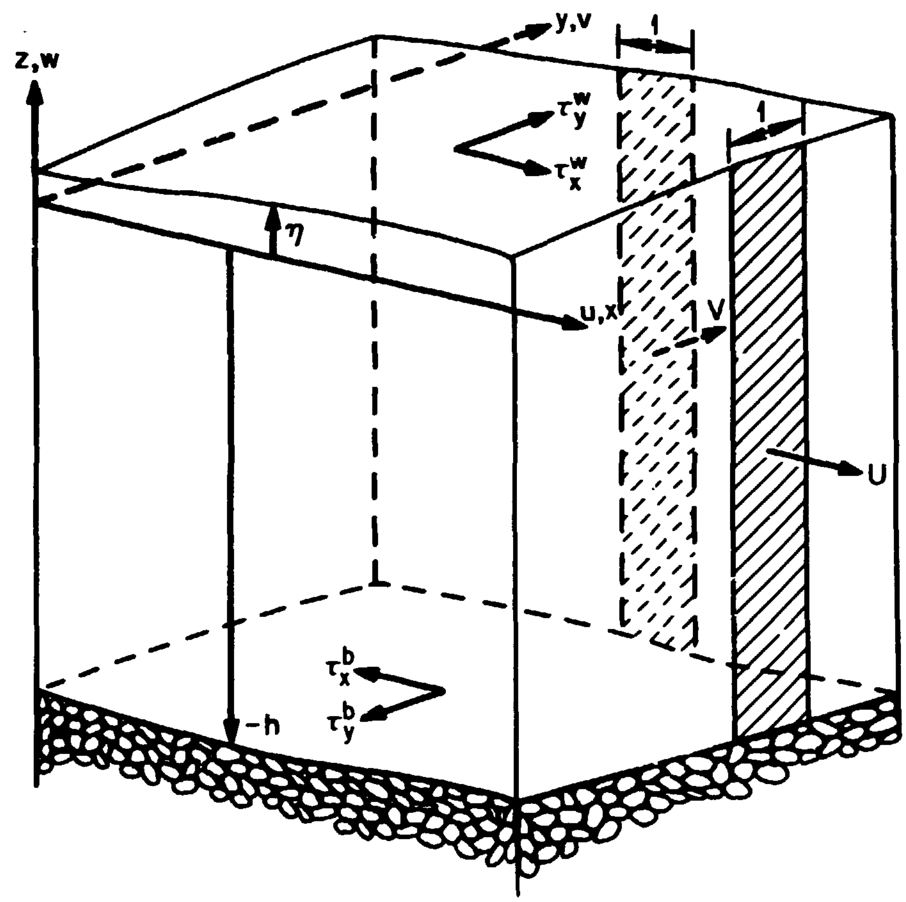

Fig. 1. Definition sketch of vertically integrated variables.

These bottom stress components may also be assumed to be linearly proportional to the velocity component for laminar flow (Schlichting and Kestin 1968):

$$\tau_x^b = \rho k U_s \bar{u} \qquad \tau_y^b = \rho k U_s \bar{v} \tag{9c}$$

where k is the linearized frictional coefficient and U_s is a representative velocity scale. The linearization of the bottom stresses results in a mathematical simplification of the analysis. It may be justified for small values of velocity in a typical surface impoundment (Simons 1973). Therefore, it will be followed in this report.

By the substitution of Eq. (9c) into (5) and (6) and the assumptions that $\eta \ll h$, Eqs. (5), (6), and (7) become:

$$- g \frac{\partial \eta}{\partial x} + \frac{1}{\rho h} \tau_x^x - \frac{K}{h} \bar{u} + f\bar{v} = 0 \tag{10}$$

$$- g \frac{\partial \eta}{\partial y} + \frac{1}{\rho h} \tau_y^w - \frac{K}{h} \bar{v} - f\bar{u} = 0 \tag{11}$$

$$\frac{\partial \bar{u} h}{\partial x} + \frac{\partial \bar{v} h}{\partial y} = 0 \tag{12}$$

where $K = kU_s$ is defined as frictional parameter. One can define a stream function:

$$\bar{u} = - \frac{1}{h} \frac{\partial \Psi}{\partial y} \qquad \bar{v} = \frac{1}{h} \frac{\partial \Psi}{\partial x} \tag{13}$$

so that Eq. (12) is automatically satisfied. By eliminating η in Eqs. (10) and (11) and using Eq. (13), a single equation describing the stream function is obtained:

$$\frac{\partial^2\Psi}{\partial x^2} + \frac{\partial^2\Psi}{\partial y^2} - \frac{2}{h}\left[\frac{\partial h}{\partial x}\frac{\partial\Psi}{\partial x} + \frac{\partial h}{\partial y}\frac{\partial\Psi}{\partial y}\right] - \frac{f}{K}\left[\frac{\partial h}{\partial y}\frac{\partial\Psi}{\partial x} - \frac{\partial h}{\partial x}\frac{\partial\Psi}{\partial y}\right]$$

$$- \frac{h^2}{2\rho K}\left[\frac{\partial}{\partial x}\left(h\frac{\partial\rho}{\partial y}\right) - \frac{\partial}{\partial y}\left(h\frac{\partial\rho}{\partial x}\right)\right] = \frac{h^2}{\rho K}\left[\frac{\partial}{\partial x}\left(\frac{\tau_y^w}{h}\right) - \frac{\partial}{\partial y}\left(\frac{\tau_x^w}{h}\right)\right] \quad (14)$$

After Eq. (14) is solved, the flow rate components, U and V, can be computed as follows:

$$U = \bar{u}h = -\frac{\partial\Psi}{\partial y} \qquad V = \bar{v}h = \frac{\partial\Psi}{\partial x} \quad (15)$$

The flow rate components, together with the topography and the bathymetry of the water body, will serve as inputs to the pollutant transport model.

Boundary conditions to complete the solution of Eq. (14) are determined by the requirements that any water-land interface is a streamline whose values can be prescribed. The conditions at open-water boundaries such as discharge channel, intake canal, influx or efflux sections are determined by assuming the flow takes place normal to the sections. To write these conditions in mathematical terms, one has the following equations:

$$\Psi = \Psi_L(x,y) \qquad \text{on} \qquad L(x,y) = 0 \quad (16)$$

and

$$\nabla\Psi\cdot\vec{n} = 0 \qquad \text{or} \qquad S(x,y) = 0 \quad (17)$$

where $L(x,y) = 0$ is the curve of water-land interfaces, $S(x,y) = 0$ is the curve of open-water boundaries; $\vec{n}$ is a unit vector normal to the curve $S(x,y) = 0$. An option is also given that

$$\Psi = \Psi_S(x,y) \qquad \text{on } S(x,y) = 0 \tag{18}$$

In Eqs. (16) and (18), Ψ_L and Ψ_S are two known functions describing the boundary values of Ψ.

Equation (14) is an ellipitic partial differential equation. The central difference approximation would yield a well behaved system of algebraic equations. Several computational algorithms are available (Smith 1965). The alternating direction implicit (ADI) iteration scheme is adopted because of its economic in both computing time and computer storage for the problem at hand. The discrete values of the the variables are described on a grid cell. The stream functions and wind stress components are described at four corner points of a grid cell, (i.j), as shown in Fig. 2. They are designated as Ψ_{ij}, $\Psi_{i+1,j}$, $\Psi_{i,j+1}$, and $\Psi_{i+1,j+1}$, respectively. The x-component flow rate, U, is described on the left and right hand sides of the grid cell and is designated as $U_{i,j}$ and U_{i+j+1}, respectively. The y-component flow rate, V, is described on the lower and upper sides of the grid cell and is designated as $V_{i,j}$ and $V_{i,j+1}$, respectively. The water depth is described at the center of the grid cell and designated as $h_{i,j}$. This convention of describing the variables is particularly helpful in solving the pollutant transport model in the next section.

With the variables descretized in the aforementioned manner, the ADI iteration finite-difference approximations of Eq. (14), after neglecting the density gradient term, is defined by:

$$A(I)\Psi^{(p)}_{i-1,j} + B(I)\Psi^{(p)}_{i,j} + C(I)\Psi^{(p)}_{i+1,j} +$$
$$A(J)\Psi^{(q)}_{i,j-1} + B(J)\Psi^{(q)}_{i,j} + C(J)\Psi^{(q)}_{i,j+1} = D \tag{19}$$

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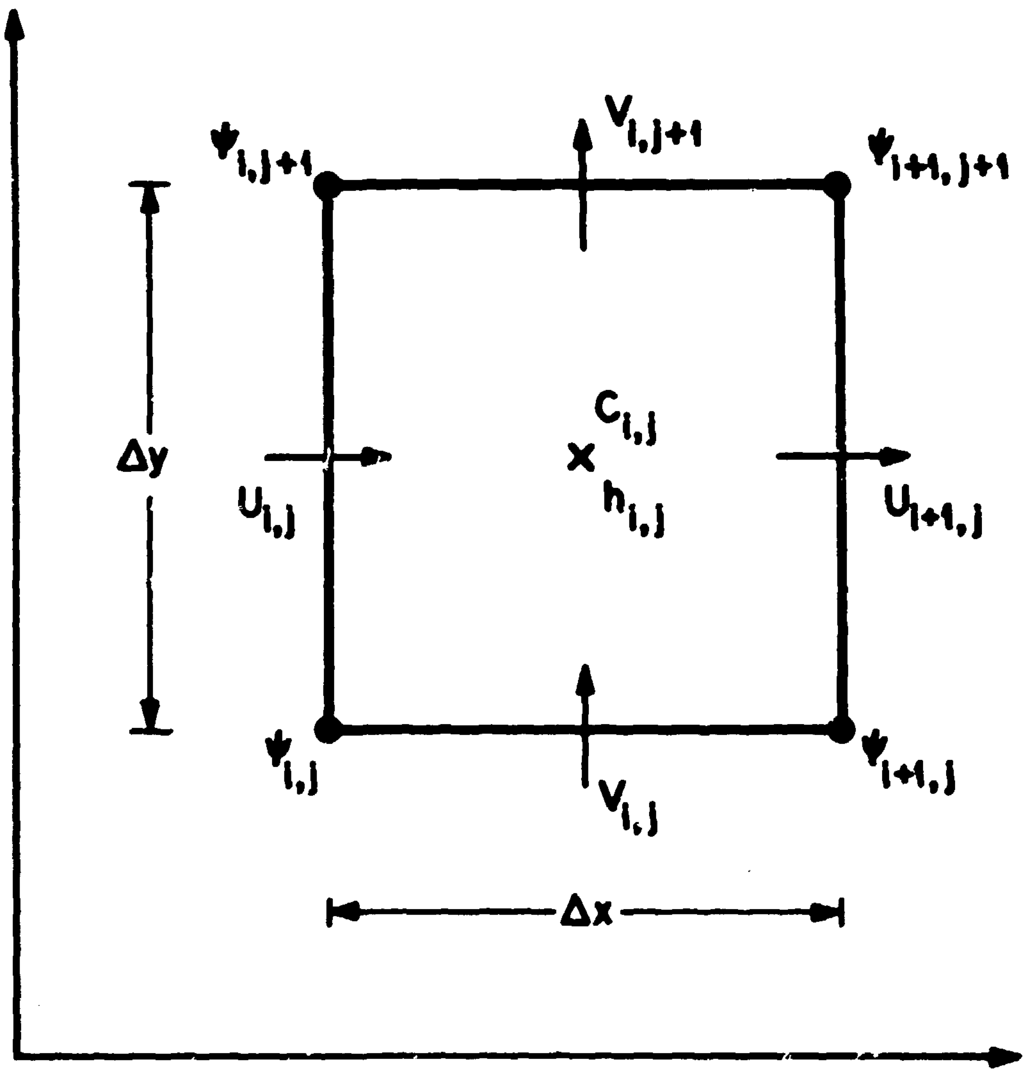

Fig. 2. Discretization of variables in a grid cell.

where

$$A(I) = [-0.5(h_{i+1,j} - h_{i-1,j})/h_{i,j} - 1]/\Delta x^2 - 0.25f\cdot(h_{i,j+1} - h_{i,j-1})/K\Delta x\Delta y \quad (20a)$$

$$B(I) = 2/\Delta x^2 + \omega/\Delta x^2 \quad (20b)$$

$$C(I) = [0.5(h_{i+1,j} - h_{i-1,j}) - 1]/\Delta x^2 + 0.25f\cdot(h_{i,j+1} - h_{i,j-1})/K\Delta x\Delta y \quad (20c)$$

$A(J)$, $B(J)$, and $C(J)$ are similarily defined but with suitable permutation on i and j and on x and y. In Eqs. (19) and (20a) through (20c), ω is an acceleration parameter and p and q are intergers representing the number of iterations (Smith 1965). For the x-direction implicit operation, $p = k + 1$ and $q = k$ (in which k is the last previous iteration), while for the y-direction implicit, $p = k$ and $q = k + 1$. Normally, the same value of ω is used in every iteration step. A faster rate of convergence can be obtained by varying ω for each iteration (Varga 1962, Wachspress 1962, Wachspress and Habetler 1960).

Having solved for the stream function, Ψ, the flow rates are obtained from the finite-difference approximation of Eq. (15). These flow rates at any grid cell are calculated as:

$$U_{i,j} = -(\Psi_{i,j+1} - \Psi_{i,j})/\Delta y \quad (21a)$$

and

$$V_{i,j} = (\Psi_{i+1,j} - \Psi_{i,j})/\Delta x \quad . \tag{21b}$$

It should be noted that the descretization of variables in Fig. 2 greatly facilitates the computation of flow rate components, which are after all the ultimate goal of the hydrodynamic model.

II.2 Pollutant (Mass or Thermal) Transport Model

The variations of pollutant concentration with space and time are simulated with a transient two-dimensional advective-dispersive partial differential equation. The model may be written according to the mass or thermal balance relationship:

$$\frac{\partial hC}{\partial t} + \frac{\partial UC}{\partial x} + \frac{\partial VC}{\partial y} = \frac{\partial}{x}(hK_x \frac{\partial C}{\partial x}) + \frac{\partial}{\partial y}(hK_y \frac{\partial C}{\partial y}) - K_m hC - \lambda hC - K_h^* C - \frac{M}{\rho} \, , \tag{22}$$

where C is the mass concentration or the excessive temperature; K_m is the mass degeneration rate due to chemical or biological action; λ is the decay constant; K_h^* the modified heat exchange coefficient, which is equal to the heat exchange coefficient, K_h, divided by the specific heat, c_p, and the water density, ρ (Edinger and Geyer 1965); M is the artificial source or sink, which may result from the discharge, intake, and river inflows and outflows. Pollutants recirculated between the intake and discharge are also included in the M term. In Eq. (22), the first term represents the rate of change of pollutant in a grid cell. The second and third terms represent the advective fluxes. The first two terms on the right hand side of the equation represent the dispersive fluxes by ambient turbulent and shear force. The third term is the mass degeneration by chemical or biological action. The fourth term is the mass reduction by decay. The fifth term represents the heat dissipation into the atmosphere. It should be noted that for the mass transport, K_h^* should be set equal to zero while for the thermal transport K_m and λ are set equal to zero.

Variables involved in Eq. (22) are U, V, K_x, K_y, K_m, K_h^* (or K_h), λ, h, and C. C is the unknown to be found. The water depth, h, the decay constant, λ, the degeneration rate, K_m, and the heat exchange coefficient, K_h, are the the input parameters. The flow rates, U and V, are determined from the hydrodynamic simulation model. The dispersion coefficients, K_x and K_y, have been proposed to relate to U and V as (Christodoulou et al. 1976):

$$hK_x = a_T W + (a_L - a_T)U^2/W + hD_m \tag{23a}$$

and

$$hK_y = a_T W + (a_L - a_T)V^2/W + hD_m \quad , \tag{23b}$$

where a_L and a_T are the longitudinal and transverse eddy disperivities, respectively; W is the magnitude of the resultant flow rates; and D_m is the molecular diffusion coefficient. D_m is, in general, very small compared to other terms; but is retained to achieve numerical stability when both flow rate components approach zero for some points in the field.

To complete the description of the concentration distribution, initial and boundary conditions are required in addition to Eq. (22). Two types of boundaries are considered: one is the water-land boundary and the other is the open-water boundary. For the water-land boundaries, no mass or heat flux across the boundaries is assumed. Since the normal velocity at the water-land boundaries is zero, this condition may be satisfied by assuming that the concentration gradient normal to the boundary is zero. At open-water boundaries, if the advection directs the flow into the region of interest, background concentration of incoming water are assigned as boundary values. If the advection directs flow out of the region, the boundary condition is defined which allows the concentration to seek its own level. Consequently, a zero gradient of concentration is specified at an outflow boundary.

For the finite-difference approximation, the concentraion field is discretized at the center of a grid cell as in Fig. 2. The ADI representation of Equation (27) is then written as follows:

$$[-\frac{U_{i,j}}{2\Delta x} - \frac{K_{xi,j}\bar{h}^{(x)}_{i,j}}{\Delta x^2}]\, C^{(p)}_{i-1,j} + [-\frac{U_{i+1,j}}{2\Delta x} - \frac{U_{i,j}}{2\Delta x} + \frac{K_{xi,j}\bar{h}^{(x)}_{i,j}}{\Delta x^2} + \frac{K_{xi+1,j}\bar{h}^{(x)}_{i+1,j}}{\Delta x^2}]\, C^{(p)}_{i,j} + [\frac{U_{i+1,j}}{2\Delta x} - \frac{K_{xi+1,j}\bar{h}^{(x)}_{i+1,j}}{\Delta x^2}]\, C^{(p)}_{i+1,j}$$

$$+ [-\frac{V_{i,j}}{2\Delta y} - \frac{K_{yi,j}\bar{h}^{(y)}_{i,j}}{\Delta y^2}]\, C^{(q)}_{i,j-1} + [\frac{V_{i,j+1}}{2\Delta y} - \frac{V_{i,j}}{2\Delta y} + \frac{K_{yi,j}\bar{h}^{(y)}_{i,j}}{\Delta y^2} + \frac{K_{yi,j+1}\bar{h}^{(y)}_{i,j+1}}{\Delta y^2}]\, C^{(q)}_{i,j} + [\frac{V_{i,j+1}}{2\Delta y} - \frac{K_{yi,j+1}\bar{h}^{(y)}_{i,j+1}}{\Delta y^2}]\, C^{(q)}_{i,j+1} + \tag{24}$$

$$[(\frac{1}{\Delta t} + \frac{K_m}{2} + \frac{\lambda}{2})h_{i,j} + \frac{K^{*}_{h}}{2}]C^{(k+1)}_{i,j} = [(\frac{1}{\Delta t} - \frac{K_m}{2} - \frac{\lambda}{2})h_{i,j} - \frac{K^{*}_{h}}{2}]C^{(k)}_{i,j} + \frac{M_{i,j}}{\rho\Delta x\Delta y}$$

where

$$C_{i,j}^{(k)} = C(i\Delta x,\ j\Delta y,\ k\Delta t) \quad (25a)$$

$$\bar{h}_{i,j}^{(x)} = (h_{i-1,j} + h_{i,j})/2 \quad (25b)$$

$$\bar{h}_{i,j}^{(y)} = (h_{i,j-1} + h_{i,j})/2 \quad (25c)$$

In the difference equation, Eq. (24), p and q will be replaced by k or k + 1 as demanded by the ADI algorithm, which is used to solve the resulting system of algebraic equations. As with the solution of the hydrodynamic equation, p will be equal to k + 1 and q equal to k for the x-direction implicit operation and p will be equal to k and q equal to k + 1 for the y-direction implicit operation.

III. COMPUTER IMPLEMENTATION

The computer program consists of 12 different subprograms, linked as shown in Fig. 3. As is implied by its name, the routine MAIN performs the control function and reads program parameters and grid systems.

Subroutine ECHO2 echoes the input data. Subroutine DEPTH reads the grid depth at the center of a grid cell and calculates the depth along the side and at the corners of the grid cell. Subrouting WINDS reads wind speed and computes the wind-stress components. Subroutine HYDRO sets up the tridiagonal matrix coefficient and the known load vector for the hydrodynamic model. The tridiagonal matrix equation is solved in the subroutine THOMAS. Finally, subroutine INFVEL and OBDVEL compute the velocity components at each infield point and boundary point, respectively.

Subroutine QEXY is called from the routine MAIN to calculate the flux across each of the four sides of a grid cell and to calculate the corresponding dispersion coefficients. Subroutine TMODEL calcultes the tridiagonal matrix coefficients and the load vector for the pollutant transport model. Subroutine THOMAS is again used to solve the resulting tridiagonal matrix equations. Subroutine OUTPRT is called by both HYDRO and TMODEL to print the velocity components and concentration distribution. Subroutine ALLOUT is called by the MAIN to print the classification of each grid point.

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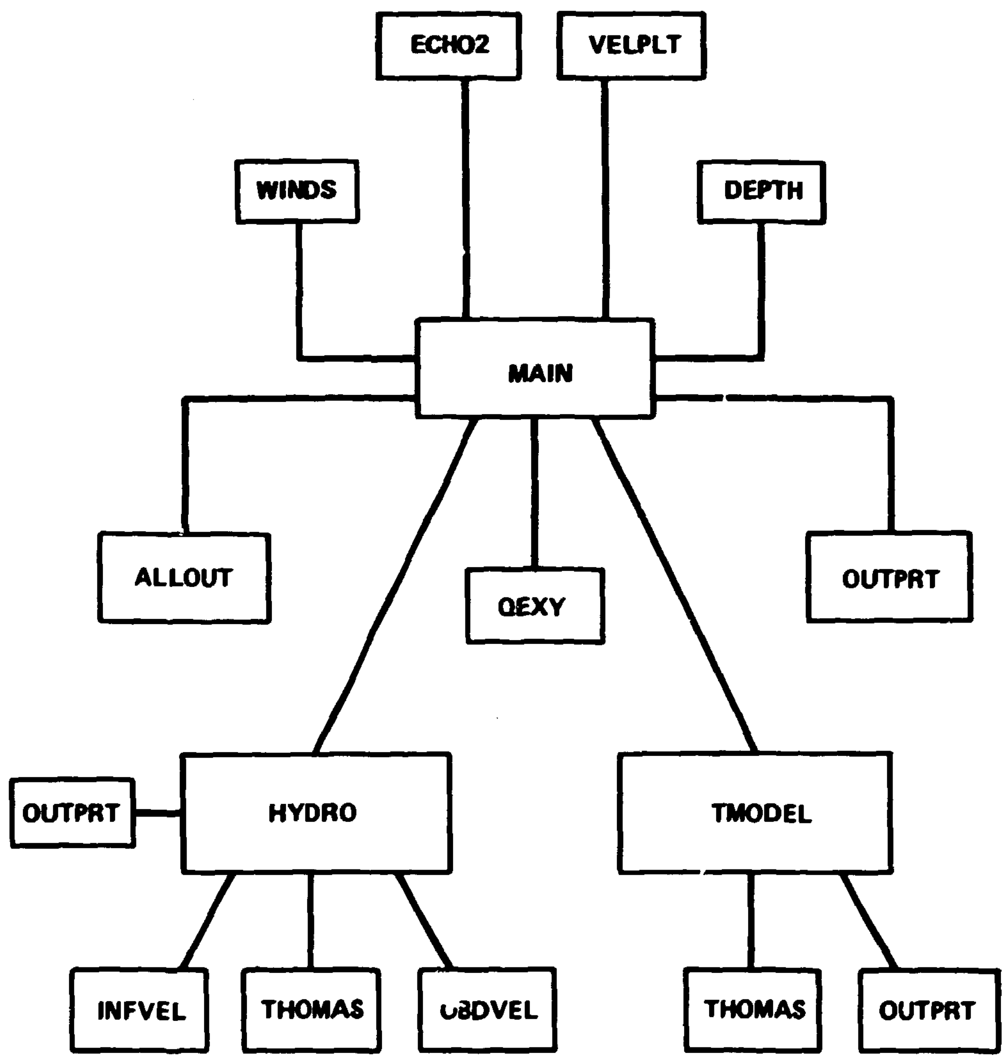

Fig. 3. Flow chart of SIMFD.

Subroutine VELPLT is called from MAIN to plot the velocity vector with Calcum plotter. This subroutine uses the DISSPLA package available at ORNL. The user should be aware of this fact.

IV. RESULTS

In this chapter, two simulations are described. The first application for Prairie Island and the Mississippi River provides a comparison between the measured and predicted temperature distribution. The second one is for a proposed impoundment area in Spain, typifying a class of problems to which SIMFD may be applied.

IV.1 Prairie Island Application

The Priairie Island region is enclosed on the west by the river bank, on the east by Prairie Island. It extends to Sturgeon Lake on the north and to Barne's point on the south end as shown in Fig. 4. During the month of August 1975, a continuous flow rate of 30 m^3s^{-1} was discharged to the region through the discharge channel and 31 m^3s^{-1} was returned to the plant through intake canal. On August 1, 1975, a flow rate of 43.3 m^3s^{-1} was drawn from Sturgeon Lake past section EF into the region, 9.2 m^3s^{-1} and 33.3 m^3s^{-1} of flow were returned to the Mississippi River through sections AB and CD, respectively. Those inflows and outflows were obtained by a flow net analysis (Stefan and Anderson 1977).

The area of interest is discretized by a rectangular grid-cell system as shown in Fig. 4. Using the above inflow and outflow information, the hydrodynamic model generates the flow field as shown in Fig. 5. A constant temperature excess of 10.9°C was maintained at the discharge channel. The ambient temperature was about 27.2°C. The isotherms as simulated by the pollutant transport model, after reaching steady state, are shown in Fig. 6. Also shown in Fig. 6 are the

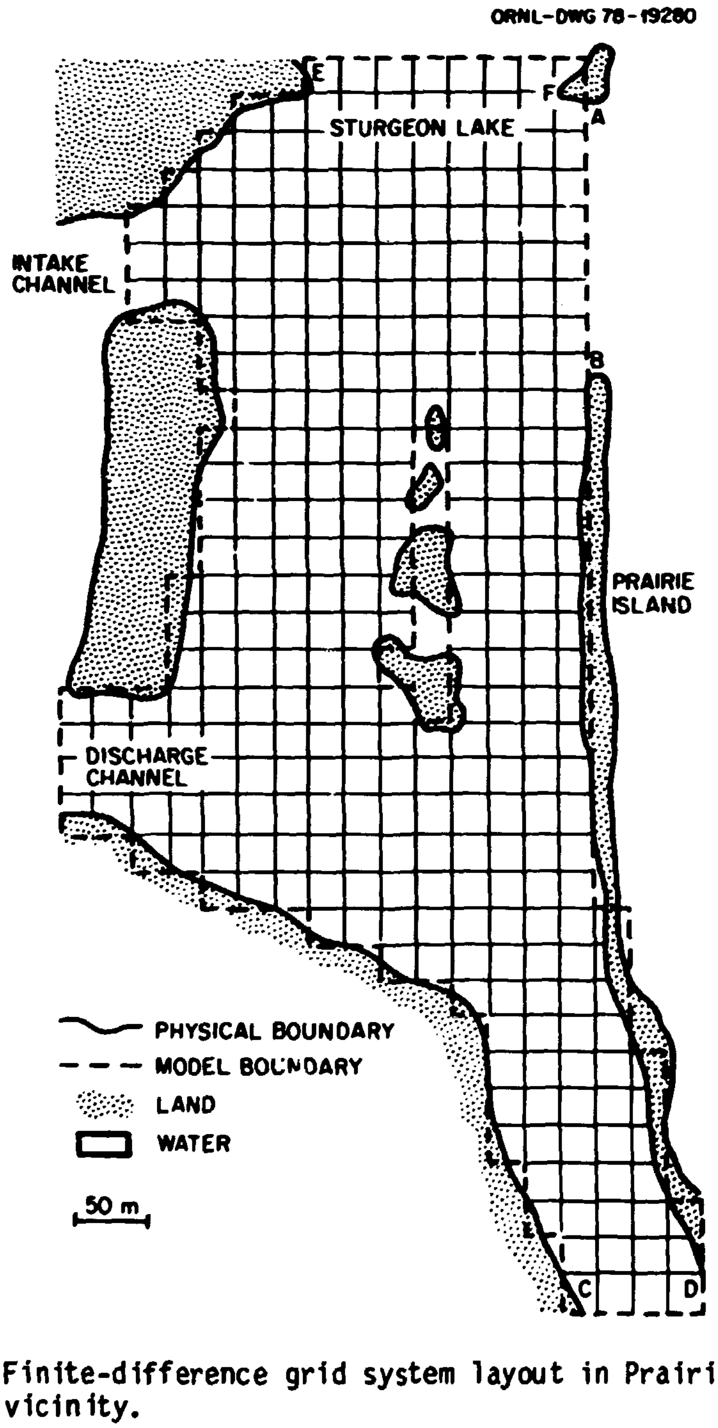

Fig. 4. Finite-difference grid system layout in Prairie Island vicinity.

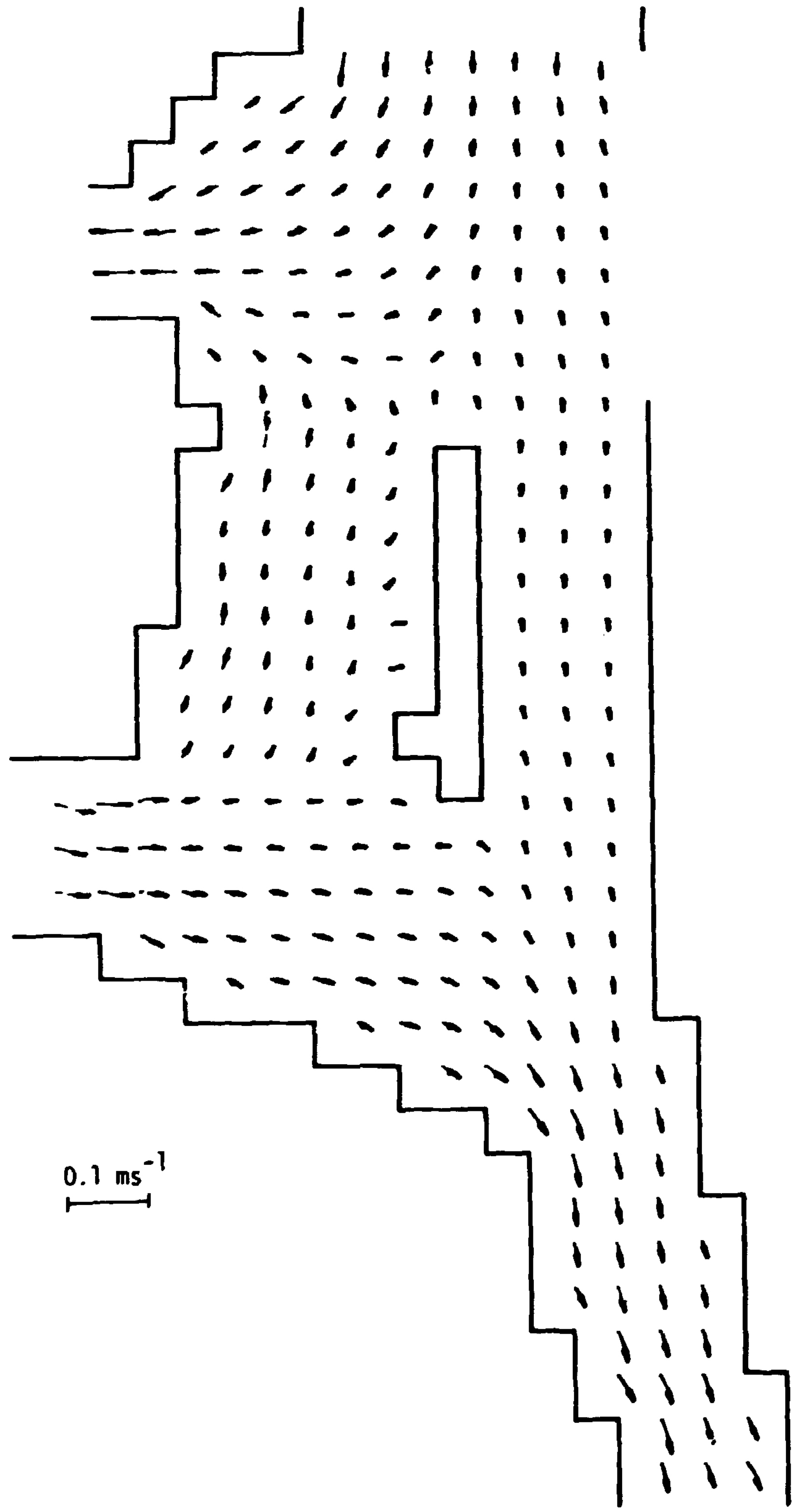

Fig. 5. Velocity field at Prairie Island vicinity on August 1, 1975.

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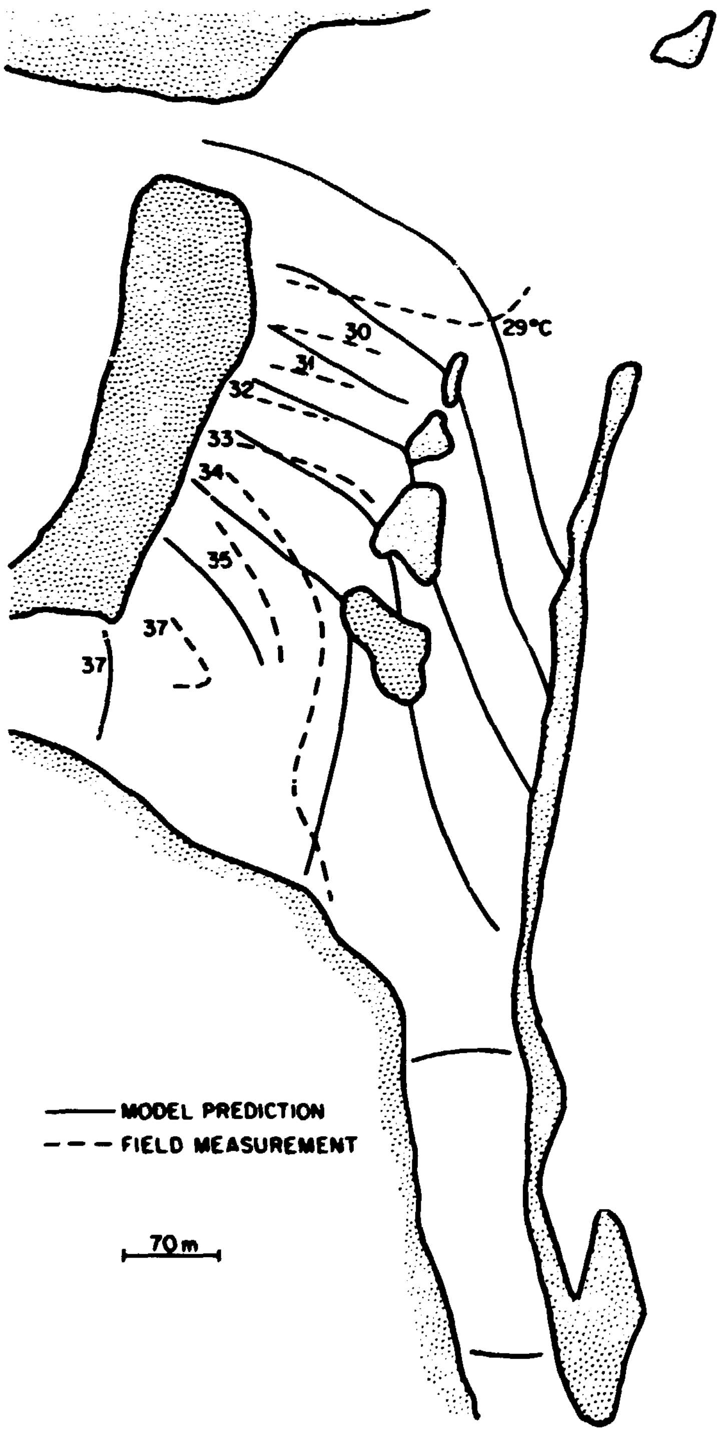

Fig. 6. Comparison between predicted and measured isotherms at Prairie Island on August 1975.

results of thermal survey data. Favorable agreement between the simulation and field measurement was obtained.

IV.2 Artificial Impoundment Application

An artificial impoundment in Spain was proposed to dissipate heat for emergency shutdown of a nuclear power plant. The configuration of the pond is shown in Fig. 7. The depth of the pond is about 3 meters. A dike is provided to separate the intake and discharge. This would prevent short circuiting of the flow. The simulated area is covered by a rectangular grid-cell system as shown in Fig. 7. The grid size is 30 meters. A continuous flow rate of 1.2 m^3s^{-1} is circulated through the pond. A temperature rise of 22.2°C is maintained at the discharge point. Figure 8 shows the flow pattern of this circulation. Figure 9 shows the temperature rise isotherms. The temperature rise at the intake is computed to be about 3.7°C. The remaining heat has been dissipated to the atmosphere. A typical value of 0.001 cal/cm^2-sec-°C in the summer is assumed for the heat exchange coefficient in this particular simulation (Sundaram et al. 1969). It is noted that if the whole pond area were credited for heat dissipation, the excessive temperature at intake point would have been about 1.1°C using a plug flow analysis (Edinger and Geyer 1965). Since complete prevention of short circuiting is not obtained, the excessive intake temperature is higher than that obtained from the ideal plug flow analysis.

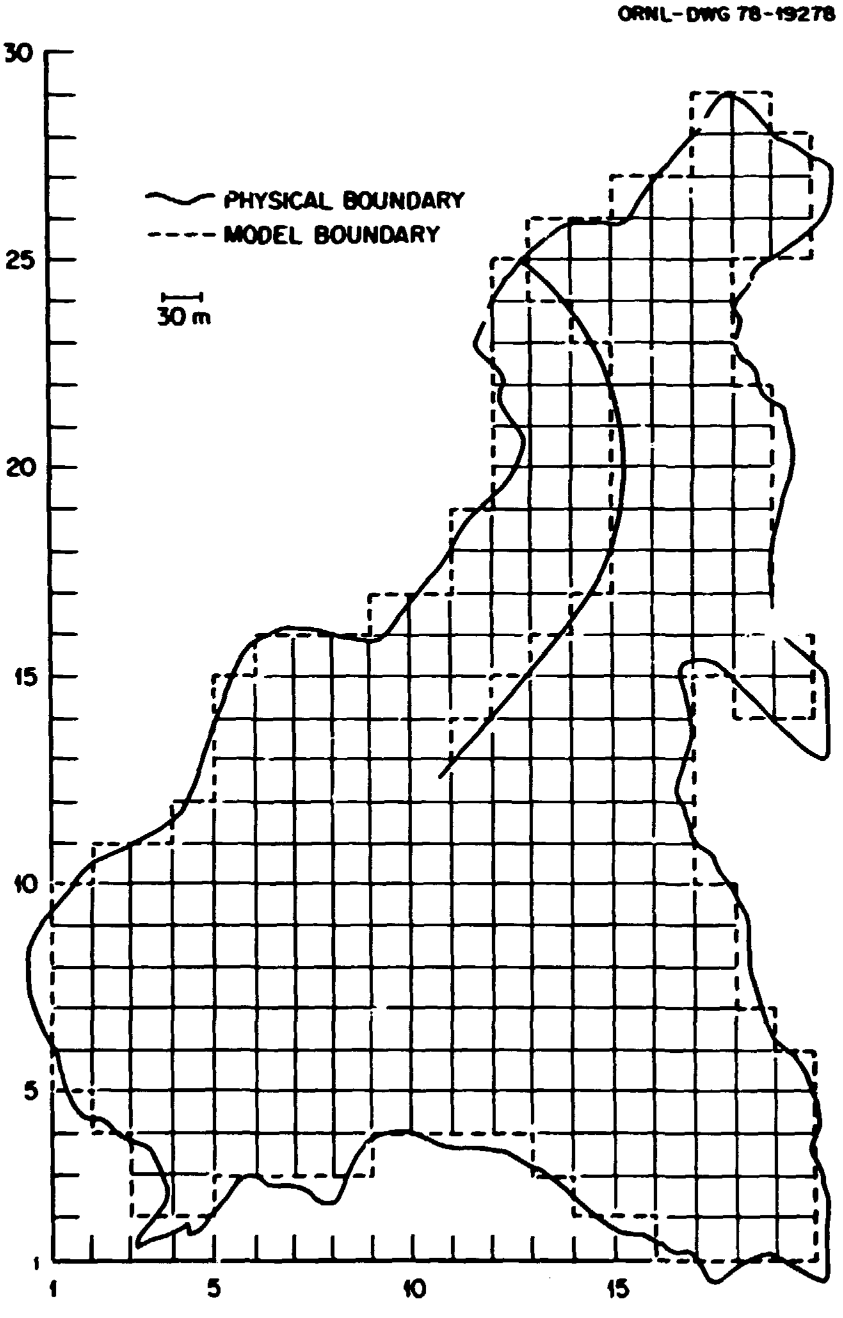

Fig. 7. Finite-difference grid system layout of an artificial impoundment in Spain.

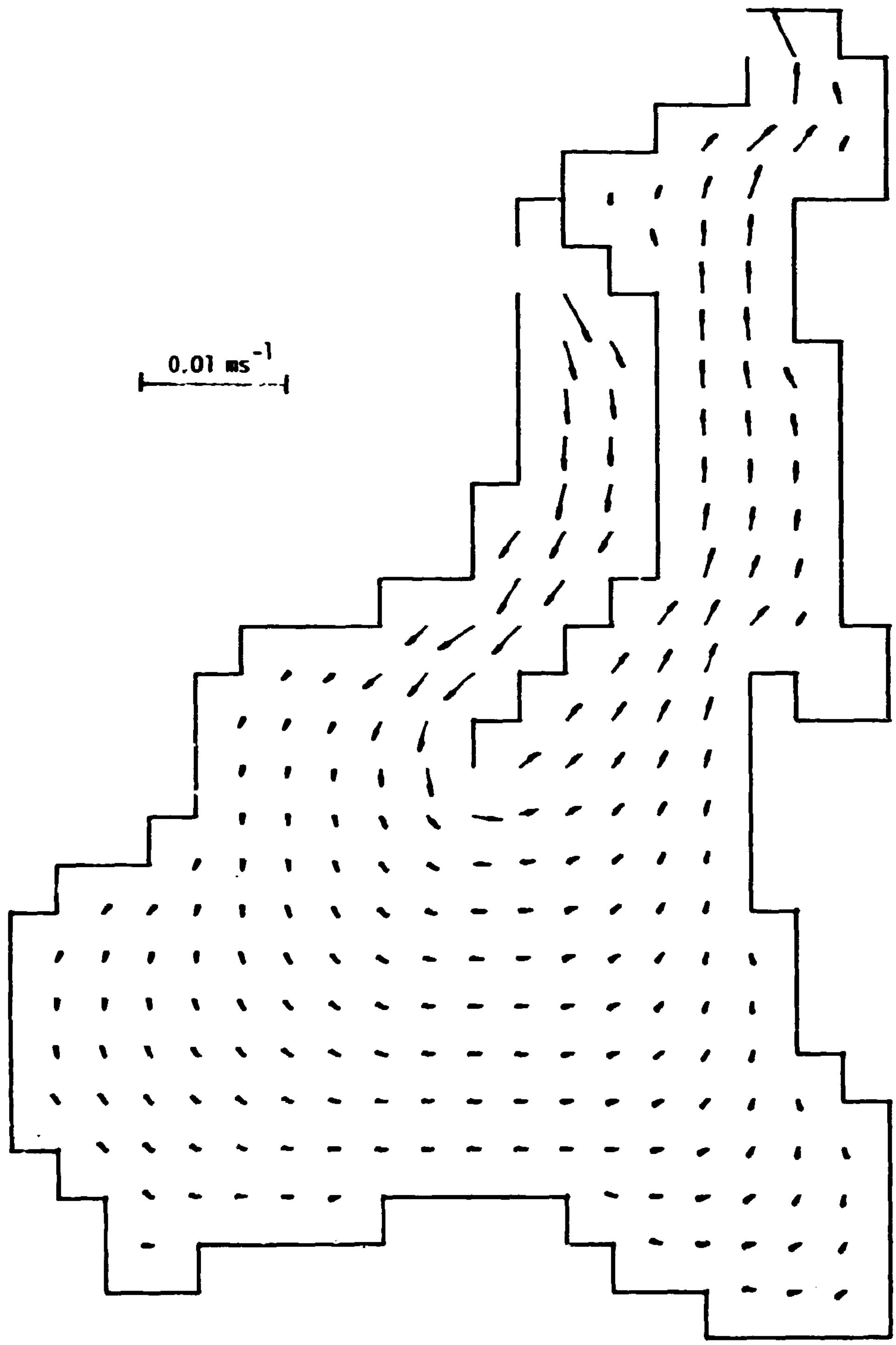

Fig. 8. Velocity field in an artificial impoundment in Spain.

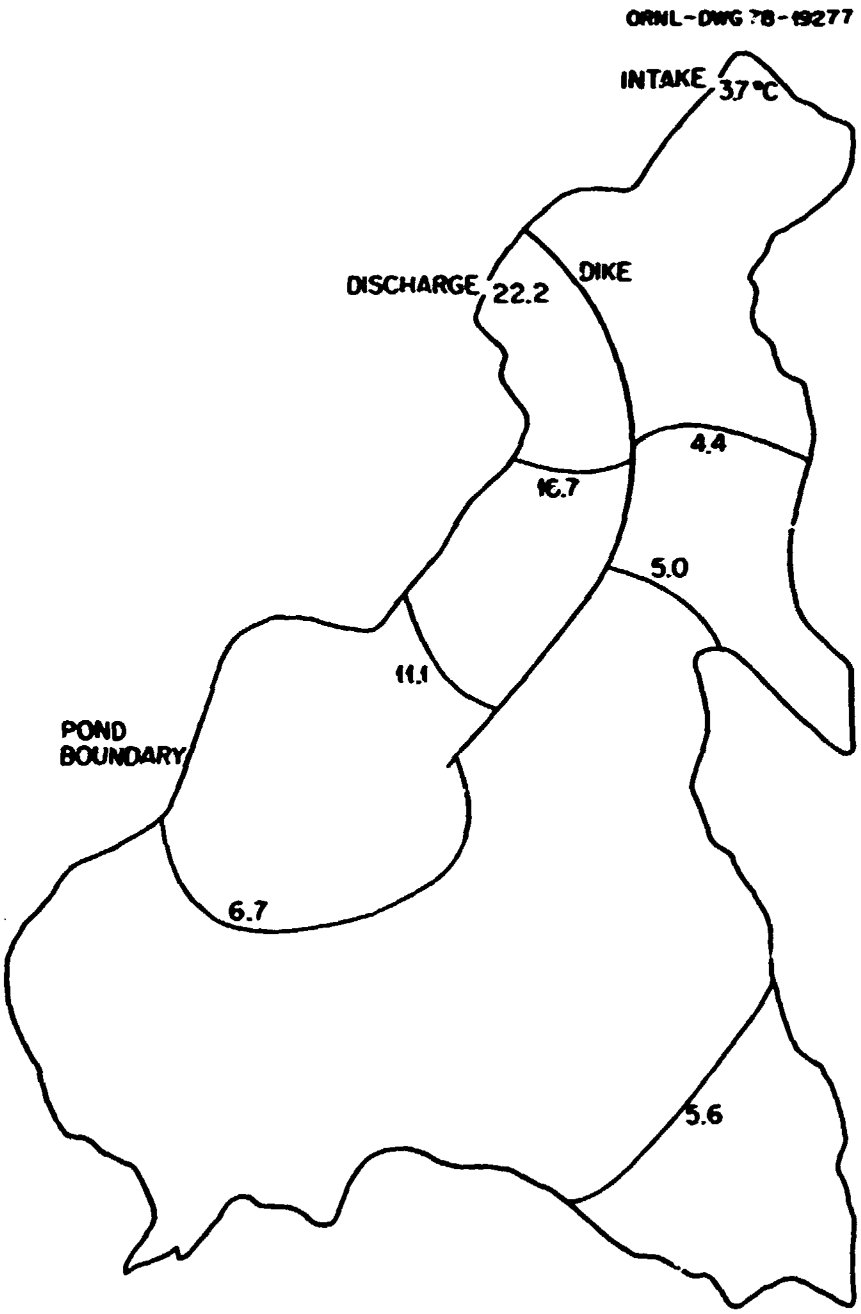

Fig. 9. Iso-temperature rise in an artificial impoundment in Spain.

V. NOTATION

A(I)	Equation coefficient associated with $\Psi_{i-1,j}$ in the x-implicit operation.
A(J)	Equation coefficient associated with $\Psi_{i,j+1}$ in the y-implicit operation.
a_L	Longitudinal eddy dispersivity
a_T	Transverse eddy dispersivity
B(I)	Equation coefficient associated with $\Psi_{i,j}$ in the x-implicit operation.
B(J)	Equation coefficient associated with $\Psi_{i,j}$ in the y-implicit operation.
C	Concentration distribution or excess temperature.
C(I)	Equation coefficient associated with $\Psi_{i+1,j}$ in the x-implicit operation.
C(J)	Equation coefficient associated with $\Psi_{i,j+1}$ in the y-implicit operation.
$C_{i,j}^{(k)}$	Discrete value of C at point (i,j) at time k
c_p	Specific heat of water

D	Load term in the algebraic equations
D_m	Molecular-diffusion coefficient.
f	Coriolis coefficient
g	Gravitational acceleration
h	Water depth
$h_{i,j}$	Discrete value of h at point (i,j)
k	Frictional coefficeint
K	Frictional parameter = kU_s
K_h	Heat exchange coefficient
K_h^*	Modified heat exchange coefficient = $K_h/(c_p\rho)$.
K_m	Mass degeneration rate
K_x	Dispersion coefficient in the x-direction
K_y	Dispersion coefficient in the y-direction
M	Artificial source/sink of pollutant or thermal energy
p	Iteration index
q	Iteration index

t	Time
u,v,w	Velocity components in the x-, y-, and z-directions, respectively.
$\bar{u},\bar{v}$	Vertically averaged velocity components in the x- and y-direction, respectively.
U,V	Flow rate components in the x- and y-directions, respectively.
U_s	Representative velocity scale.
$U_{i,j}$	Discrete value of U at point (i,j)
W	Resultant flow rate in the horizontal plane
x,y	Horizontal coordinates.
z	Vertical coordinate.
ρ	Density of water
Ψ	Stream function
Ψ_L	Value of Ψ on the water-land interface, $L(x,y) = 0$
Ψ_S	Value of Ψ on the open-water boundary, $S(x,y) = 0$
$\Psi_{i,j}$	Discrete value of Ψ at point (i,j)
λ	Radioactive decay constant
τ_x^w,τ_y^w	Wind stress components in the x- and y-directions, respectively.

ω Iteration parameter.

τ_x^b, τ_y^b Bottom shear stress components in the x- and y-directions, respectively.

τ_x, τ_y Internal shear stress components in the x- and y-directions, respectively.

η *Water surface elevation above still water level*

$\Delta x, \Delta y$ Finite difference grid spacing in the x- and y-directions, respectively.

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VII. APPENDICES

APPENDIX A. APPLICABILITY OF HYDRODYNAMIC SUBMODEL

The applicability of the SIMFD lies on the assumption of the steady motion and the small convective-inertia force. The validity of these two assumptions is demonstrated below.

It is noted that the number of unknowns in Eqs. (1) through (4) in Section II.1 exceeds the number of unknowns for the problem. this can be hurdled by relating the stress components, τ_{xz} and τ_{yz} to the velocity components, u and v, through the concept of eddy viscosity. For the present problem, this can be written as:

$$\tau_{xz} = \rho\nu_e \frac{\partial u}{\partial z} \tag{A1}$$

and

$$\tau_{yz} = \rho\nu_e \frac{\partial v}{\partial z} \tag{A2}$$

where ν_e is the total vertical eddy viscosity.

It has been pointed out (Lamb 1932) that the effects of wind on an water body, to which Eqs. (1) through (4) of Section II.1 applies, would approach steady state for a time scale, t_e

$$t_e = 4\pi h^2/(\pi^2 \nu_e) \tag{A3}$$

In the meantime, it has been shown (Lamb 1932) that the effect of earth rotation on the water body would approach steady for a time scale, t_f.

$$t_f = \frac{h}{\sqrt{\nu_e f}} \qquad \text{(A4)}$$

A third time scale one has to consider for the steady motion is the resident time of the water particle in the water body. This resident time, t_q, can be approximated by:

$$t_q = \frac{v}{Q} = \frac{hL^2}{Q} \qquad \text{(A5)}$$

where v is the volume of water body, Q is the total flow-through rate, and L is the represetnative horizontal length scale.

If the assumption of steady motion is to be valid, the time scales, t_F's for the applied external forcing must be greater than those given in Eqs. (A3) through (A4), respectively. It can be seen that all conditions presented above can be met by most of the surface impoundments. Take for example, a typical value of ν_e = 100 cm^2/sec (0.1 ft^2/sec), h = 500 cm (15 ft), and f = 10^{-4} s^{-1} would yield t_e = 17 minutes and t_f = 1.4 minutes. Thus, if wind is steady over 17 mintues, the effect of wind and earth rotation would yield steady motion. The time for constant flow operation is normally larger than that given by Eq. (A5). Thus, steady motion assumption is a reasonable one.

The ratio of the convective inertia force to the turbulent shear force in Eqs. (1) and (2) of Section II.1 can be characterized by a modified Reynolds number, R_N^*

$$R_N^* = \frac{U_s h}{\nu_e} \frac{h}{L} \tag{A6}$$

where U_s is a representative velocity scale. This characterization is made based on the analysis of the relative magnitude of order of the convective-inertia and turbulent shear stress. If this R_N^* is much less than unit, then the assumption of small convective-inertia force is valid. Indeed, R_N^* is much less than unit for most of the surface impoundments. Expressed in the C. G. S. unit, U_s is in the order of 10^0, h is in the order of 10^2, and ν_e is in the order of 10^2. Thus, R_N^* is in the order of h/L which is much smaller than unit for practically all surface impoundments. Hence, it is valid to assume that convective-inertia force is small compared to the bottom frictional force, which results from the turbulent shear stress:

$$\tau_x^b = \rho \nu_e \left. \frac{\partial \tau_{xz}}{\partial z} \right|_{z = -h} \tag{A7}$$

and

$$\tau_y^b = \rho \nu_e \left. \frac{\partial \tau_{yz}}{\partial z} \right|_{z = -h} \tag{A8}$$

APPENDIX B. DATA INPUT GUIDE

CARD GROUP I	FORMAT(15A4,I5)
TITLE	Column 1 to 60 contain any description
IMODL	An integer indicating if both hydrodynamic and thermal models are to be run: = 1 if only hydrodynamic model = 2 if both models

CARD GROUP II	FORMAT(8F8.3,2F8.6)
CV	Representative velocity scale, [L/T]
CL	Length scale, [L]
Q	Total flow rate into or out of the region, [L^3/T]
WINS	Wind speed, [L/T]
WINANG	The angle between x-axis and the wind direction, Degree
AVH	Average water depth, [L]
RHOW	Water density, [M/L^3]
RHOA	Air density, [M/L^3]
CKWIN	Wind stress coefficient
CKWAT	Linearized bottom stress coefficient

CARD GROUP III	NAMELIST/CONTRL/
NX	Maximum column number in the x-direction
NY	Maximum row number in the y-direction
JOPT	An optional control: = 0 if the source/sink version is used = 1 if the inflow concentration is used
IREC	An integer to control the implementation of recirculation: = 0 if no recirculation of pollutant is implied, = 1 if the recirculation of pollutant is implied
NUMMAX	Total number of continuous interior segments that are parallel to the x-axis for the hydrodynamic model
MUMMAX	Total number of continuous interior segments that are parallel to the y-axis for the hydrodynamic model

MAXIT	Maximum number of iterations allowed in solving for stream function
NPRIN	Number of iterations that intermittent values of stream function are to be printed
EPS	Maximum error allowed in solving for stream function
INTER	An indicator for the intermittent printout of the stream function, = 0 no intermittent values are desired, = 1 intermittent values are desired
NUMAXT MUMAXT NPRINT EPST INTERT MAXITT	Same as NUMMAX, MUMMAX, NPRIN, EPS, INTER, and MAXIT, but for the pollutant transport model

CARD GROUP IV NAMELIST/BOUND/

MBD(k)	Column number of the k-th successive conditinuous interior grid line segment that is parallel to y-axis for the hydrodynamic model
MBDB(k)	Row number of the first grid point in column MBD(k)
MBDE(k)	Row number of the last grid point in column MBD(k)
NBD(k) NBDB(k) NBDE(k)	Same as in MBD(k), MBDB(k), and MBDE(k) except they refer to rows instead of column

CARD GROUP V NAMELIST/OBND/

NOBD	Number of open boundaries
NPTOBD(k)	Total number of points on the k-th open boundary

IBXOBD(k)	The beginning x-coordinate of the k-th open boundary
JBYOBD(k)	The beginning y-coordinate of the k-th open boundary
IEXOBD(k)	The ending x-coordinate of the k-th open boundary
JEYOBD(k)	The ending y-coordinate of the k-th open boundary
INDOBD(k)	Index of the k-th open boundary, = 0 for the infow section = 1 for the outflow section

IBXOBD, JBYOBD, IEXOBD, and JEYOBD are in terms of grid units.

CARD GROUP VI NAMELIST/CBND/

NCBD	Number of water-land interfacial boundaries
BXCBD(k)	The beginning x-coordinate of the k-th water-land boundary
BYCBD(k)	The beginning y-coordinate of the k-th water-land boundary
EXCBD(k)	The end x-coordinate of the k-th water-land boundary
EYCBD(k)	The end y-coordinate of the k-th water-land boundary

BXCBD, BYCBD, EXCBD, EYCBD are in terms of grid units.

CARD GROUNP VII NAMELIST/HBNV/

NBV	Total number of boundary points having known stream function
IBV(k)	Column number of the k-th boundary point with known stream function
JBV(k)	Row number of k-th boundary point with known stream function
BV(k)	The value of stream function of the k-th boundary points, this is in terms of Q

CARD GROUP VIII NAMELIST/PATCH/

IN(i,j)	Index of every grid point to indicate if the grid point is an interior point, a boundary point, or an exterior point, or an island point, or a corner point,

= 1 for exterior point
= 2 for Dirichlet boundary point
= 4 for interior point
= 6 for corner point
= 8 for Neumann boundary point
= 10, 18, 26, ... for island points
= 14, 22, 30, ... for island corner point

It is noted that the index value of 1, 2, and 4 are generated by the program. Thus only the index for corner point, Neumann boundary point, island point, and island corner point have to be read in.

CARD GROUP IX — NAMELSIT/HIGH/

HIN(i,j) — The depth of the i-th point, the depths read in here are only the interior points

CARD GROUP X — FORMAT(2I5)

NPOW — Number of the discharge and intake points

NRIV — Number of inflow and outflow points

CARD GROUP XI — FORMAT(8F10.0)

DIFX — Longitudinal dispersivity, [L]

DIFY — Transverse dispersivity, [L]

TINC — Time step size, [T]

TURHOW — Two times of the water density, $[M/L^3]$

RKH — Heat Exchange coefficient, $[E/L^2/T/Deg]$

RKM — Mass degeneration rate, $[T^{-1}]$

RAMADA — Radioactive decay constant, $[T^{-1}]$

CARD GROUP XII — NAMELIST/BOUNDT/

NUMAXT — Total number of continuous grid cell segments that are parallel to the x-axis for the pollutant transport model

MUMAXT	Total number of continuous grid cell segments that are parallel to the y-axis for the pollutant transport model
MBDT(k)	Column number of the k-th continuous grid cell segment that are parallel to the y-axis
MBDBT(k)	Row number of the first grid cell in column MBDT(k)
MBDET(k)	Row number of the last grid cell in column MBDT(k)
MBDIND(k)	Index for the MBDT(k) column: = 99 if the whole segment is the Dirichlent boundary points = 11 if both ends are the no-flux boundary points = 10 if the lower end is the no-flux boundary point and the upper end is the Dirichlet boundar point = 1 if the lower end is the Dirichlet boundary point and the upper end is the no-flux boundary point = 0 if both ends are the Dirichlet boundary points
NBDT(k)	
NBDBT(k)	Same as MBDT(k), MBDBT(k), MBDET(k), and MNDIND(k) except they refer to rows instead of columns
NBDET(k)	
NBDIND(k)	

<u>CARD GROUP XIII</u> NAMELIST/TBNV/

NBVT	Total number of points having given concentration
IBVT(k)	Column number of the k-th known concentration point
JBVT(k)	Row number of the k-th known concentration point
BVT(k)	Concentration of the k-th known concentration point, $[M/L^3]$
QBVT(k)	Flow rate at the k-th known concentration point, $[L^3/T]$

<u>CARD GROUP XIV</u> FORMAT(A8,2X, 2I5,2F20.0)

PNAME(k)	Name of the k-th discharge or intake point
IPOW(k)	Column number of the k-th discharge or intake point
JPOW(k)	Row number of the k-th discharge or intake point

QPOW(k)	Flow rate of the k-th discharge or intake point, $[L^3/T]$
TPOW(k)	Concentration of the k-th discharge or intake point, $[M/L^3]$

<u>CARD GROUP XV</u> FORMAT(A8,2X,2I5,2F20.4)

RNAME(k)	
IRIV(k)	
JRIV(k)	Same as CARD GROUP XIV but for inflows or outflows
QRIV(k)	
TRIV(k)	

APPENDIX C. INPUT AND OUTPUT OF PRAIRIE ISLAND APPLICATION

INPUT

```
 PRAIRIE ISLAND CALIBRATION 8/1/1972                                2
1.0      80.     2595.8  18.92    290.     8.0      1.93    0.00237 .000001 0.005
&CONTRL NX=19,NY=35,NUMMAX=42,NUMMAY=23,MAXIT=100,NPRIN=10,INTER=0,EPS=0.001,
NUMAXT=42,NUMAYT=23,MAXITT=200,NPRINT=10,INTERT=0,EPST=0.01, JOPT=1,IREC=0,
&END
&BOUND  MBD=2,3,4,4,5,5,6,6,7,8,9,10,10,11,11,12,12,13,14,15,16,17,18, 76*0,
 MBDB=15,15,14,29,14,29,13,27,13,13,12,12,20,11,26,11,26, 10,6,4,2,2,2, 76*0,
 MBDE=17,17,17,30,20,31,24,32,33,33,34,17,34,16,34,16,34,34,34,34,11,7,3,76*0,
 NBD=2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,17,18,18,19,19,20,20,21,21,22,22,
     23,23,24,24,25,25 -26,27,28,29,30,31,32,33,34,    57*0,
 NBDB=16,16,15,15,14,14,14,14,13,11,9,6,4,2,2,2,13,5,13,5,13,5,13,
     6,13,6,13,6,13,6,13,7,13,7,6,6,4,4,5,6,7,9,    57*0,
 NBDE=18,18,17,17,17,17,16,16,16,16,15,15,15,15,15,10,15,9,15,9,15,10,15,
     10,15,10,15,10,15,10,15,10,      10*15,  57*0,   &END
&OBND NOBD=5, NPTOBD=5, 4,9, 9,5,  94*0,, IBXOBD=1,3,8,16,15,  94*0,
    IEXOBD=1,3,16,16,19, 94*0,  JBYOBD=14,28,35,26,1, 94*0,
    JEYOBD=18,31,35,34,1,  94*0,   INDOBD=0,1,0,1,1,  94*0,  &END
&CBND NCBD=49, BXCBD=1,4,4,5,5,6,5,5,3,3,4,4,5,5,6,6,8,16,16,16,17,17,18,
   18,19,15,14,14,13,13,12,12,10,10,10,8,5,5,3,3,1,11,10,10,11,11,12,12,11,
50*0,
   BYCBD=18,18,21,21,25,25,26,26,28,31,31,32,32,33,33,34,34,34,12,12,
    8,8,4,4,1,1,3,3,5,5,9,9,10,10,11,11,12,12,13,13,14,18,18,19,19,25,25,17,17,
50*0,
   EXCBD=4,4,5,5,6,6,6,5,5,4,4,5,5,6,6,8,8,16,16,17,17,18,18,19,
    19,15,15,14,14,13,13,12,12,10, 8,8,8,5,5,3,3,10,10,11,11,12,12,11,11,50*0,
   EYCBD=18,21,21,25,25,26,26,28,28,31,32,32,33,33,34,34,35,35,26,
   12,12,8,8,4,4,3,3,5,5,9,9,10,10,11,11,12,12,13,13,14,14,18,19,19,25,25,17,
17,18,50*0,     &END
&HBNV BV=10*1.0,0.926,0.852,0.778,0.704,0.630,0.556,0.482,0.408,0.422,0.436,
0.450,0.464,0.477,0.491,0.505,0.519,29*0.533,0.646,0.760,0.873,28*0.986,0.884,
0.782,0.680,19*0.578,0.719,0.859, 189*0.0,
IBV=3,2*4,2*5,2*6,7,2*8,9,10,11,12,13,14,15,24*16,5*17,5*18,4*19,18,17,16,3*15,
3*14,5*13,2*12,11,2*10,9,2*8,7,6,2*5,4,2*3,2,5*1,2,3,4*4,5*5,2*6,3*5,4,3*3,
189*0,
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18,17,16,15,14,13,2*12,11,10,9,2*8,7,6,5,2*4,3,2,5*1,2,2*3,4,2*5,6,7,8,2*9,
3*10,3*11,4*12,3*13,3*14,15,16,17,4*18,19,20,2*21,22,23,24,2*25,2*26,27,3*28,
29,30,189*0,     NBV=110,   &END
&PATCH IN(1,18)=6,IN(4,21)=6,IN(5,25)=6,IN(5,26)=6,IN(3,28)=6,IN(3,31)=6,
       IN(15,1)=6,IN(14,3)=6,IN(13,5)=6,IN(12,9)=6,IN(10,10)=6,IN(8,11)=6,
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       IN(10,19)=10,IN(11,19)=10,IN(11,20)=10,IN(11,21)=10,IN(11,22)=10,
       IN(11,23)=10,IN(11,24)=10,IN(11,25)=10,IN(12,25)=10,IN(12,24)=10,
       IN(12,23)=10,IN(12,22)=10,IN(12,21)=10,IN(12,20)=10,IN(12,19)=10,
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  2.0,    16.5,14.5,12.5,2.0,    16.5,14.5,12.5,2.0,    15.5,14.5,10.0,    15.5,13.0,
  2.0,    13.5,11.5,12.0,2.0,    7.5,13.0,14.5,11.5,10.0,2.0,    10.5,11.5,12.5,13.5,
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  10.5,11.5,11.5,11.5,11.5,11.0,10.5,10.0,11.5,13.5,12.5,10.0,    10.5,10.5,11.5,
  11.5,11.5,11.5,10.5,9.0,9.5,7.5,7.5,14.5,13.5,10.0,      10.5,10.5,11.5,11.5,
  10.5,8.0,5.5,4.5,2.0,2.0,5.0,16.0,12.5,8.0,      2.0,2.0,6.0,6.5,2.5,2.5,2.5,
  2.5,2.0, 17.5,17.5,2.0,      7.5,3.5,2.5,2.5,2.0, 18.0,18.5,2.0,      3.5,3.5,
  2.5,2.5,2.0, 17.5,18.5,2.0,    4.0,5.5,2.5,2.5,2.5,2.0, 16.5,18.5,2.0,
  6.5,2.0,2.0, 2.5,2.0, 17.0,18.5,2.0,      7.5,2.0,2.5,2.5,2.0,17.5,19.0,2.0,
  7.0,2.5,2.5,2.5,2.5,             18.5,18.0,8.0,      3.0,3.0,2.0,2.0,2.5,
  19.5,17.5,10.0,       3.5,2.0, 3.5,2.5,            18.0,16.5,10.0,     8.5,9.5,9.5,
  8.0,1.5,9.5,18.0,16.0,16.0,         9.0,10.0,10.5,11.0,10.5,4.5,10.5,17.5,16.0,
  12.0,       10.5,11.5,10.0,9.5,10.5,11.5,10.5,16.0,15.0,12.0,      10.5,12.5,12.5,
  11.5,10.0,11.5,10.5,11.0,11.5,15.0,14.5,12.0,       8.5,12.5,11.5,11.5,11.5,11.5,
  9.5,10.5,11.5,14.5,14.5,12.0,       8.5,10.5,9.5,11.0,9.5,8.5,10.5,11.5,14.5,
  14.5,10.0,    8.5,10.5,10.5,10.5,10.5,10.5,11.5,14.5,11.5,11.0,
```

APPENDIX C. INPUT (continued)

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2.0,5.0,7.5,10.5,11.0,11.5,14.5,5.5,12.0,       7.5,10.5,11.0,11.5,14.5,5.5,
2.0,      7.5,10.5,11.0,11.5,14.5,5.5,2.0,      &END
   7   20
75.0      75.0      30.0      124.8      0.002      0.0      0.0
&BOUNDT NBDT=1,2,3,3,4,4,5,5,6,7,8,9,10,10,11,11,12,13,14,15,16,17,18, 76*0,
NBDBT=14,14,13,28,13,28,12,26,12,12,11,11,10,19,10,25,9,5,3,4*1,  76*0,
NBDET=17,17,17,30,20,31,24,32,33,33,34,34,17,34,16,34,34,34,34,34,11,7,3,76*0,
NBDIND=99,22*11,76*0, MBDIND=13*11,4*1,25*11,57*0,
MBDT=1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,17,18,18,19,19,20,20,21,21,22,
22,23,23,24,24,25,26,27,28,29,30,31,32,33,34,  57*0,
MBDBT=15,15,14,14,13,13,13,13,12,10,8,5,3,4*1,12,4,12,4,12,4,12,5,12,5,12,5,13,
5,12,6,5,5,3,3,3,4,5,6,8,  57*0,  MBDET=3*18,4*17,4*16,5*15,10,15,9,15,10,15,
10,15,10,15,10,15,10,15,10,15,13*15,57*0,        &END
&TBNV QBVT=4*297.5,3*406.67,92*0.,  SVT=4*19.6,3*0.,92*0.,  IBVT=4*1,3*3,92*0,
JBVT=14,15,16,17,28,29,30,92*0,  INDBT=4*1,3*0,92*0,  NBVT=7,  &END
DISCHARGE     1   14  265.00          19.6
DISCHARGE     1   15  265.00          19.6
DISCHARGE     1   16  265.00          19.6
DISCHARGE     1   17  265.00          19.6
INTAKE        3   28  -365.00         0.
INTAKE        3   29  -365.00         0.
INTAKE        3   30  -365.00         0.
CH42 OUT     15    1  -293.8          0.
CH42 OUT     16    1  -293.8          0.
CH42 OUT     17    1  -293.8          0.
CH42 OUT     18    1  -293.8          0.
CH26 OUT     15   26  -40.590         0.
CH26 OUT     15   27  -40.690         0.
CH26 OUT     15   28  -40.690         0.
CH26 OUT     15   29  -40.690         0.
CH26 OUT     15   30  -40.690         0.
CH26 OUT     15   31  -40.690         0.
CH26 OUT     15   32  -40.690         0.
CH26 OUT     15   33  -40.670         0.
CH36 IN       8   34  191.98          0.
CH36 IN       9   34  191.98          0.
CH36 IN      10   34  191.98          0.
CH36 IN      11   34  191.98          0.
CH36 IN      12   34  191.98          0.
CH36 IN      13   34  191.98          0.
CH36 IN      14   34  191.98          0.
CH36 IN      15   34  191.94          0.
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APPENDIX C. OUTPUT

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PRAIRIE ISLAND CALIBRATION 8/1/1972

INPUT DATA FOR HYDRO MODEL

VELOCITY SCALE   =  1.00 FT/SEC      LENGTH SCALE    =  80.0 FT
TOTAL DISCHARGE  = 2595.8 CFS        WIND SPEED      = 18.92 FT/SEC
WIND DIRECTION   = 290.0 DEGREE      AVERAGE DEPTH   =  8.00 FT
WATER DENSITY    = 1.930 SLUG/FT3    AIR DENSITY     = 0.0024 SLUG/FT3
WIND STRESS COEF =0.0000010          BOTOM STRESS COEF = 0.005000
```

THE INDEX OF EACH POINT

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
35	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	1	1	1	1
34	1	1	1	1	1	1	2	2	4	4	4	4	4	4	4	2	1	[illegible]	1
33	1	1	1	1	1	2	4	4	4	4	4	4	4	4	4	2	1	[illegible]	1
32	1	1	1	1	2	4	4	4	4	4	4	4	4	4	4	2	1	1	1
31	1	1	6	2	4	4	4	4	4	4	4	4	4	4	4	2	1	1	1
30	1	1	2	4	4	4	4	4	4	4	4	4	4	4	4	2	1	1	1
29	1	1	2	4	4	4	4	4	4	4	4	4	4	4	4	2	1	1	1
28	1	1	6	2	2	4	4	4	4	4	4	4	4	4	4	2	1	1	1
27	1	1	1	1	2	4	4	4	4	4	4	4	4	4	4	2	1	1	1
26	1	1	1	1	6	2	4	4	4	4	4	4	4	4	4	2	1	1	1
25	1	1	1	1	6	2	4	4	4	4	10	10	4	4	4	2	1	1	1
24	1	1	1	1	2	4	4	4	4	4	10	10	4	4	4	2	1	1	1
23	1	1	1	1	2	4	4	4	4	4	10	10	4	4	4	2	1	1	1
22	1	1	1	1	2	4	4	4	4	4	10	10	4	4	4	2	1	1	1
21	1	1	1	6	2	4	4	4	4	4	10	10	4	4	4	2	1	1	1
20	1	1	1	2	4	4	4	4	4	4	10	10	4	4	4	2	1	1	1
19	1	1	1	2	4	4	4	4	4	10	10	10	4	4	4	2	1	1	1
18	6	2	2	2	4	4	4	4	4	10	10	10	4	4	4	2	1	1	1
17	2	4	4	4	4	4	4	4	4	4	10	10	4	4	4	2	1	1	1
16	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	1	1	1
15	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	1	1	1
14	6	2	2	4	4	4	4	4	4	4	4	4	4	4	4	2	1	1	1
13	1	1	6	2	2	4	4	4	4	4	4	4	4	4	4	2	1	1	1
12	1	1	1	1	6	2	2	2	4	4	4	4	4	4	4	2	1	1	1
11	1	1	1	1	1	1	1	6	2	2	4	4	4	4	4	4	2	1	1
10	1	1	1	1	1	1	1	1	1	6	2	2	4	4	4	4	2	1	1
9	1	1	1	1	1	1	1	1	1	1	1	6	2	4	4	4	2	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	2	4	4	4	2	6	1
7	1	1	1	1	1	1	1	1	1	1	1	1	2	4	4	4	4	2	1
6	1	1	1	1	1	1	1	1	1	1	1	1	2	4	4	4	4	2	1
5	1	1	1	1	1	1	1	1	1	1	1	1	6	2	4	4	4	2	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	2	4	4	4	2	6
3	1	1	1	1	1	1	1	1	1	1	1	1	1	6	2	4	4	4	2
2	1	1	1	1	1	1	[illegible]	1	1	1	1	1	1	1	2	4	4	4	2
1	1	1	1	1	1	1	1	[illegible]	1	1	1	1	1	1	6	2	2	2	6

APPENDIX C. OUTPUT (continued)

THE DEPTH AT THE CORNER

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10
35									7.500	10.500
34							2.000	5.000	7.500	10.500
33						8.500	2.000	5.000	7.500	10.500
32					8.500	8.500	10.500	10.500	10.500	10.500
31			8.500	8.500	8.500	10.500	9.500	11.000	9.500	8.500
30			8.500	8.500	12.500	11.500	11.500	11.500	11.500	9.500
29			10.500	10.500	12.500	12.500	11.500	10.000	11.500	10.500
28			10.500	10.500	12.500	10.500	11.500	10.000	9.500	10.500
27					9.000	9.000	10.000	10.500	11.000	10.500
26					10.500	9.000	8.500	9.500	9.500	8.000
25					3.000	3.000	3.500	2.000	3.500	2.500
24					3.000	3.000	3.000	2.000	2.000	2.500
23					7.000	7.000	2.500	2.500	2.500	2.500
22					7.500	7.500	2.000	2.500	2.500	2.000
21				4.000	4.000	6.500	2.000	2.000	2.500	2.000
20				4.000	4.000	5.500	2.500	2.500	2.500	2.000
19				3.500	3.500	3.500	2.500	2.500	2.000	2.000
18	2.000	2.000	2.000	6.000	7.500	3.500	2.500	2.500	2.000	2.000
17	2.000	2.000	2.000	6.000	6.500	2.500	2.500	2.500	2.500	2.000
16	10.500	10.500	10.500	11.500	11.500	10.500	8.000	5.500	4.500	2.000
15	10.500	10.500	10.500	11.500	11.500	11.500	11.500	10.500	9.000	9.500
14	10.500	10.500	10.500	10.500	11.500	11.500	11.500	11.500	11.000	10.500
13			10.500	10.500	11.500	11.000	11.500	11.500	11.500	11.500
12					11.250	11.000	11.500	11.500	10.500	11.500
11								11.000	10.500	11.500
10										9.500
9										
8										
7										
6										
5										
4										
3										
2										
1										

ROW	COLUMN 11	12	13	14	15	16	17	18	19
35	11.000	11.500	14.500	5.500	2.000				
34	11.000	11.500	14.500	5.500	2.000	2.000			
33	11.000	11.500	14.500	5.500	12.000	12.000			
32	10.500	11.500	14.500	11.500	11.000	11.000			
31	10.500	11.500	14.500	14.500	10.000	10.000			
30	10.500	11.500	14.500	14.500	12.000	12.000			
29	11.000	11.500	15.000	14.500	12.000	12.000			
28	11.500	10.500	16.000	15.000	12.000	12.000			
27	4.500	10.500	17.500	16.000	12.000	12.000			
26	1.500	9.500	18.000	16.000	16.000	16.000			
25	1.500	9.500	18.000	16.500	10.000	10.000			
24	2.500	19.500	19.500	17.500	10.000	10.000			
23	2.500	18.500	18.500	18.000	8.000	8.000			
22	2.000	17.500	17.500	19.000	2.000	2.000			
21	2.000	17.000	17.000	18.500	2.000	2.000			
20	2.000	16.500	16.500	18.500	2.000	2.000			
19	0.0	17.500	17.500	18.500	2.000	2.000			
18	0.0	18.000	18.000	18.500	2.000	2.000			
17	2.000	5.000	17.500	17.500	2.000	2.000			
16	2.000	5.000	16.000	12.500	8.000	8.000			
15	7.500	7.500	14.500	13.500	10.000	10.000			
14	10.000	11.500	13.500	12.500	10.000	10.000			
13	12.000	13.000	12.500	12.500	10.000	10.000			
12	12.500	13.500	12.500	11.500	10.000	2.000			
11	7.500	13.000	14.500	11.500	10.000	2.000	2.000		
10	7.500	13.000	13.500	11.500	12.000	2.000	2.000		
9		13.250	13.500	15.500	13.000	2.000	2.000		
8			15.500	15.500	14.500	10.000	2.000	2.000	
7			16.500	16.500	14.500	12.500	2.000	2.000	
6			16.500	16.500	14.500	12.500	2.000	2.000	
5			16.500	16.500	15.500	13.000	2.000	2.000	
4				15.500	15.500	14.500	2.000	2.000	2.000
3				15.500	15.500	14.500	12.000	2.000	2.000
2					15.500	15.500	15.500	2.000	2.000
1					15.500	15.500	15.500	2.000	2.000

APPENDIX C. OUTPUT (continued)

DIMENSIONLESS DEPTH AT EACH POINT

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10
35									0.078	0.112
34							0.092	0.087	0.078	0.112
33						0.112	0.092	0.087	0.105	0.122
32					0.119	0.112	0.122	0.130	0.130	0.122
31			0.119	0.119	0.119	0.134	0.134	0.136	0.136	0.122
30			0.119	0.119	0.137	0.153	0.147	0.139	0.139	0.134
29			0.131	0.131	0.144	0.150	0.144	0.134	0.128	0.131
28			0.131	0.131	0.144	0.128	0.128	0.131	0.128	0.130
27					0.117	0.117	0.114	0.120	0.127	0.122
26					0.148	0.117	0.075	0.073	0.077	0.073
25					0.063	0.063	0.039	0.033	0.030	0.033
24					0.063	0.063	0.048	0.031	0.028	0.030
23					0.091	0.091	0.059	0.030	0.031	0.030
22					0.080	0.080	0.056	0.027	0.030	0.028
21				0.047	0.047	0.063	0.052	0.028	0.030	0.028
20				0.047	0.047	0.052	0.044	0.031	0.030	0.027
19				0.064	0.064	0.056	0.037	0.031	0.028	0.027
18	0.078	0.078	0.078	0.094	0.081	0.063	0.034	0.031	0.030	0.034
17	0.078	0.078	0.078	0.094	0.111	0.097	0.073	0.058	0.047	0.034
16	0.131	0.131	0.131	0.137	0.144	0.141	0.130	0.111	0.092	0.078
15	0.131	0.131	0.131	0.134	0.141	0.144	0.144	0.141	0.131	0.125
14	0.131	0.131	0.131	0.131	0.137	0.142	0.142	0.144	0.142	0.139
13			0.131	0.131	0.137	0.140	0.141	0.144	0.141	0.141
12					0.139	0.140	0.141	0.144	0.136	0.137
11								0.140	0.136	0.137
10										0.125
9										
8										
7										
6										
5										
4										
3										
2										
1										

ROW	COLUMN 11	12	13	14	15	16	17	18	19
35	0.134	0.141	0.162	0.125	0.078				
34	0.134	0.141	0.162	0.125	0.078	0.078			
33	0.133	0.139	0.162	0.144	0.125	0.125			
32	0.125	0.137	0.162	0.172	0.147	0.147			
31	0.122	0.137	0.162	0.181	0.159	0.159			
30	0.130	0.139	0.164	0.183	0.166	0.166			
29	0.136	0.139	0.166	0.189	0.167	0.167			
28	0.116	0.116	0.170	0.202	0.172	0.172			
27	0.077	0.081	0.173	0.211	0.188	0.188			
26	0.042	0.069	0.172	0.214	0.183	0.183			
25	0.042	0.065	0.208	0.223	0.169	0.169			
24	0.030	0.237	0.237	0.230	0.167	0.167			
23	0.030	0.225	0.225	0.228	0.147	0.147			
22	0.028	0.216	0.216	0.225	0.130	0.130			
21	0.028	0.209	0.209	0.220	0.128	0.128			
20	0.027	0.212	0.212	0.222	0.128	0.128			
19	0.0	0.222	0.222	0.227	0.128	0.128			
18	0.0	0.183	0.183	0.223	0.125	0.125			
17	0.066	0.069	0.136	0.198	0.125	0.125			
16	0.066	0.069	0.134	0.177	0.137	0.137			
15	0.117	0.114	0.147	0.169	0.144	0.144			
14	0.137	0.145	0.158	0.159	0.141	0.141			
13	0.148	0.159	0.161	0.153	0.137	0.137			
12	0.134	0.145	0.167	0.156	0.138	0.081			
11	0.112	0.128	0.169	0.159	0.141	0.081	0.081		
10	0.112	0.128	0.166	0.169	0.162	0.091	0.091		
9		0.147	0.166	0.188	0.183	0.123	0.123		
8			0.200	0.200	0.191	0.161	0.091	0.091	
7			0.206	0.206	0.194	0.169	0.091	0.091	
6			0.206	0.206	0.197	0.173	0.092	0.092	
5			0.206	0.206	0.197	0.183	0.098	0.098	
4				0.194	0.194	0.188	0.134	0.098	0.098
3				0.194	0.194	0.191	0.180	0.098	0.098
2					0.194	0.194	0.194	0.109	0.109
1					0.194	0.194	0.194	0.109	0.109

APPENDIX C. OUTPUT (continued)

THE BOUNDARY VALUES AND THE INITIAL GUESSES

COLUMN

ROW	1	2	3	4	5	6	7	8	9	10
35									0.926	0.852
34							1.000	1.000	0.0	0.0
33						1.000	0.0	0.0	0.0	0.0
32					1.000	0.0	0.0	0.0	0.0	0.0
31			1.000	1.000	0.0	0.0	0.0	0.0	0.0	0.0
30			0.859	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29			0.719	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28			0.578	0.578	0.578	0.0	0.0	0.0	0.0	0.0
27					0.578	0.0	0.0	0.0	0.0	0.0
26					0.578	0.578	0.0	0.0	0.0	0.0
25					0.578	0.578	0.0	0.0	0.0	0.0
24					0.578	0.0	0.0	0.0	0.0	0.0
23					0.578	0.0	0.0	0.0	0.0	0.0
22					0.578	0.0	0.0	0.0	0.0	0.0
21				0.578	0.578	0.0	0.0	0.0	0.0	0.0
20				0.578	0.0	0.0	0.0	0.0	0.0	0.0
19				0.578	0.0	0.0	0.0	0.0	0.0	0.0
18	0.578	0.578	0.578	0.578	0.0	0.0	0.0	0.0	0.0	0.0
17	0.680	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.782	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.884	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.986	0.986	0.986	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13			0.986	0.986	0.986	0.0	0.0	0.0	0.0	0.0
12					0.986	0.986	0.986	0.986	0.0	0.0
11								0.986	0.986	0.986
10										0.986
9										
8										
7										
6										
5										
4										
3										
2										
1										

COLUMN

ROW	11	12	13	14	15	16	17	18	19
35	0.778	0.704	0.630	0.556	0.482				
34	0.0	0.0	0.0	0.0	0.0	0.422			
33	0.0	0.0	0.0	0.0	0.0	0.436			
32	0.0	0.0	0.0	0.0	0.0	0.450			
31	0.0	0.0	0.0	0.0	0.0	0.464			
30	0.0	0.0	0.0	0.0	0.0	0.477			
29	0.0	0.0	0.0	0.0	0.0	0.491			
28	0.0	0.0	0.0	0.0	0.0	0.505			
27	0.0	0.0	0.0	0.0	0.0	0.519			
26	0.0	0.0	0.0	0.0	0.0	0.533			
25	0.0	0.0	0.0	0.0	0.0	0.533			
24	0.0	0.0	0.0	0.0	0.0	0.533			
23	0.0	0.0	0.0	0.0	0.0	0.533			
22	0.0	0.0	0.0	0.0	0.0	0.533			
21	0.0	0.0	0.0	0.0	0.0	0.533			
20	0.0	0.0	0.0	0.0	0.0	0.533			
19	0.0	0.0	0.0	0.0	0.0	0.533			
18	0.0	0.0	0.0	0.0	0.0	0.533			
17	0.0	0.0	0.0	0.0	0.0	0.533			
16	0.0	0.0	0.0	0.0	0.0	0.533			
15	0.0	0.0	0.0	0.0	0.0	0.533			
14	0.0	0.0	0.0	0.0	0.0	0.533			
13	0.0	0.0	0.0	0.0	0.0	0.533			
12	0.0	0.0	0.0	0.0	0.0	0.533			
11	0.0	0.0	0.0	0.0	0.0	0.0	0.533		
10	0.986	0.986	0.0	0.0	0.0	0.0	0.533		
9		0.986	0.986	0.0	0.0	0.0	0.533		
8			0.986	0.0	0.0	0.0	0.533	0.533	
7			0.986	0.0	0.0	0.0	0.0	0.533	
6			0.986	0.0	0.0	0.0	0.0	0.533	
5			0.986	0.986	0.0	0.0	0.0	0.533	
4				0.986	0.0	0.0	0.0	0.533	0.533
3				0.986	0.986	0.0	0.0	0.0	0.533
2					0.986	0.0	0.0	0.0	0.533
1					0.986	0.873	0.760	0.646	0.533

APPENDIX C. OUTPUT (continued)

THE SOLUTION FOR THE HYDRO MODEL

THE PRESENT NUMERICAL SCHEME IS O. K.
DIFMAX= 0.88767 05E-03 FOR THE 35TH ITERATION OCCURING AT (7,16)

THE STREAM FUNCTION - PSI

COLUMN

ROW	1	2	3	4	5	6	7	8	9	10
35									0.926	0.852
34							1.000	1.000	0.929	0.861
33						1.000	0.972	0.952	0.904	0.840
32					1.000	0.962	0.933	0.902	0.857	0.806
31			1.000	1.000	0.942	0.907	0.875	0.848	0.810	0.773
30			0.859	0.860	0.842	0.822	0.805	0.786	0.764	0.741
29			0.719	0.722	0.718	0.725	0.732	0.732	0.725	0.712
28			0.578	0.578	0.578	0.644	0.674	0.689	0.693	0.689
27					0.578	0.610	0.641	0.660	0.671	0.674
26					0.578	0.578	0.630	0.650	0.663	0.671
25					0.578	0.578	0.633	0.654	0.665	0.677
24					0.578	0.602	0.639	0.657	0.667	0.675
23					0.578	0.614	0.648	0.662	0.669	0.676
22					0.578	0.618	0.651	0.664	0.670	0.677
21				0.578	0.578	0.618	0.651	0.664	0.671	0.677
20				0.578	0.596	0.627	0.653	0.665	0.672	0.676
19				0.578	0.608	0.638	0.658	0.667	0.675	0.671
18	0.578	0.578	0.578	0.578	0.622	0.649	0.663	0.669	0.676	0.671
17	0.600	0.645	0.635	0.639	0.656	0.667	0.672	0.674	0.677	0.677
16	0.782	0.744	0.728	0.723	0.723	0.718	0.709	0.699	0.693	0.686
15	0.884	0.867	0.853	0.831	0.814	0.795	0.776	0.755	0.737	0.721
14	0.986	0.986	0.986	0.927	0.901	0.872	0.849	0.827	0.803	0.779
13			0.986	0.986	0.986	0.941	0.920	0.901	0.873	0.846
12					0.986	0.986	0.986	0.986	0.980	0.914
11								0.986	0.986	0.986
10										0.986
9										
8										
7										
6										
5										
4										
3										
2										
1										

COLUMN

ROW	11	12	13	14	15	16	17	18	19
35	0.778	0.708	0.630	0.556	0.482				
34	0.788	0.709	0.625	0.538	0.473	0.422			
33	0.774	0.708	0.630	0.548	0.485	0.436			
32	0.755	0.702	0.637	0.562	0.499	0.450			
31	0.735	0.693	0.639	0.573	0.513	0.464			
30	0.713	0.681	0.638	0.581	0.525	0.477			
29	0.693	0.670	0.636	0.586	0.535	0.491			
28	0.678	0.666	0.639	0.592	0.545	0.505			
27	0.671	0.667	0.645	0.599	0.555	0.519			
26	0.670	0.669	0.649	0.603	0.561	0.533			
25	0.671	0.671	0.651	0.600	0.560	0.533			
24	0.671	0.671	0.641	0.594	0.557	0.533			
23	0.671	0.671	0.637	0.569	0.554	0.533			
22	0.671	0.671	0.636	0.586	0.551	0.533			
21	0.671	0.671	0.636	0.586	0.550	0.533			
20	0.671	0.671	0.637	0.586	0.550	0.533			
19	0.671	0.671	0.640	0.589	0.551	0.533			
18	0.671	0.671	0.648	0.597	0.554	0.533			
17	0.671	0.671	0.660	0.608	0.560	0.533			
16	0.681	0.677	0.661	0.615	0.568	0.533			
15	0.706	0.691	0.668	0.623	0.574	0.533			
14	0.754	0.729	0.687	0.635	0.581	0.533			
13	0.816	0.776	0.719	0.652	0.588	0.533			
12	0.883	0.840	0.766	0.676	0.592	0.533			
11	0.902	0.907	0.826	0.714	0.612	0.553	0.533		
10	0.986	0.986	0.897	0.764	0.640	0.564	0.533		
9		0.986	0.986	0.818	0.673	0.580	0.533		
8			0.986	0.840	0.702	0.593	0.533	0.533	
7			0.986	0.861	0.730	0.614	0.552	0.533	
6			0.986	0.899	0.766	0.638	0.562	0.533	
5			0.986	0.986	0.821	0.672	0.574	0.533	
4				0.986	0.878	0.724	0.598	0.533	0.533
3				0.986	0.986	0.794	0.643	0.563	0.533
2					0.986	0.836	0.694	0.592	0.533
1					0.986	0.873	0.760	0.646	0.533

APPENDIX C. OUTPUT (continued)

THE X-COMPONENT VELOCITY - U

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10
35									0.016	0.031
34							-0.122	-0.224	-0.058	-0.021
33						-0.135	-0.146	-0.227	-0.139	-0.091
32					-0.199	-0.168	-0.161	-0.168	-0.147	-0.113
31			-0.480	-0.479	-0.270	-0.212	-0.194	-0.174	-0.139	-0.109
30			-0.480	-0.475	-0.330	-0.240	-0.198	-0.164	-0.124	-0.092
29			-0.435	-0.435	-0.372	-0.240	-0.184	-0.147	-0.112	-0.080
28			-0.435	-0.445	-0.395	-0.183	-0.144	-0.111	-0.084	-0.058
27					0.0	-0.115	-0.078	-0.064	-0.048	-0.030
26					-0.027	-0.110	-0.020	-0.018	-0.017	-0.004
25					0.077	0.155	0.045	0.042	0.022	0.025
24					0.0	0.116	0.060	0.054	0.027	0.019
23					0.0	0.036	0.040	0.045	0.023	0.013
22					0.0	0.011	0.011	0.019	0.015	0.006
21				0.076	0.152	0.028	0.008	0.007	0.014	-0.005
20				0.0	0.128	0.077	0.035	0.019	0.029	-0.044
19				0.0	0.085	0.080	0.054	0.029	0.029	-0.074
18	0.530	0.348	0.295	0.262	0.120	0.096	0.079	0.046	0.015	0.066
17	0.530	0.431	0.389	0.314	0.185	0.145	0.126	0.105	0.072	0.088
16	0.315	0.342	0.337	0.283	0.223	0.184	0.162	0.148	0.132	0.115
15	0.315	0.374	0.399	0.307	0.255	0.218	0.198	0.184	0.170	0.151
14	0.315	0.368	0.411	0.240	0.254	0.209	0.206	0.206	0.194	0.183
13			0.297	0.183	0.252	0.165	0.197	0.225	0.198	0.195
12					0.190	0.129	0.191	0.239	0.168	0.206
11								0.190	0.138	0.212
10										0.188
9										
8										
7										
6										
5										
4										
3										
2										
1										

ROW	COLUMN 11	12	13	14	15	16	17	18	19
35	0.019	0.015	-0.013	-0.059	-0.048				
34	-0.006	0.005	-0.000	-0.013	0.008	0.072			
33	-0.044	-0.010	0.016	0.035	0.043	0.045			
32	-0.063	-0.022	0.012	0.030	0.039	0.038			
31	-0.070	-0.032	0.001	0.021	0.033	0.035			
30	-0.066	-0.033	-0.003	0.014	0.027	0.034			
29	-0.053	-0.022	0.002	0.013	0.024	0.034			
28	-0.039	-0.006	0.010	0.013	0.023	0.033			
27	-0.020	0.009	0.011	0.010	0.018	0.030			
26	-0.000	0.012	0.008	0.001	0.006	0.031			
25	0.005	0.009	-0.008	-0.008	-0.005	0.0			
24	0.0	0.0	-0.012	-0.010	-0.008	0.0			
23	0.0	0.0	-0.004	-0.006	-0.009	0.0			
22	0.0	0.0	-0.001	-0.003	-0.005	0.0			
21	0.0	0.0	0.001	-0.000	-0.001	0.0			
20	0.0	0.0	0.003	0.003	0.002	0.0			
19	0.0	0.0	0.011	0.010	0.006	0.0			
18	0.0	0.0	0.022	0.017	0.014	0.0			
17	0.064	0.036	0.019	0.019	0.022	0.0			
16	0.108	0.060	0.013	0.018	0.021	0.0			
15	0.125	0.085	0.036	0.023	0.019	0.0			
14	0.162	0.118	0.065	0.037	0.020	0.0			
13	0.177	0.146	0.099	0.055	0.017	0.0			
12	0.190	0.183	0.129	0.080	0.037	0.100			
11	0.186	0.231	0.158	0.112	0.068	0.078	0.0		
10	0.158	0.249	0.195	0.125	0.076	0.062	0.0		
9		0.230	0.216	0.081	0.070	0.047	0.0		
8			0.0	0.044	0.060	0.042	0.084	0.042	
7			0.0	0.058	0.067	0.054	0.066	0.0	
6			0.0	0.123	0.094	0.067	0.058	0.0	
5			0.086	0.172	0.116	0.095	0.072	0.0	
4				0.0	0.172	0.132	0.104	0.125	0.062
3				0.113	0.225	0.120	0.108	0.123	0.0
2					0.0	0.083	0.122	0.153	0.0
1					0.038	0.076	0.139	0.199	0.099

APPENDIX C. OUTPUT (continued)

THE Y-COMPONENT VELOCITY - V

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10
35									-0.384	-0.267
34							0.0	-0.329	-0.362	-0.261
33						-0.100	-0.106	-0.159	-0.216	-0.216
32					-0.128	-0.120	-0.100	-0.119	-0.151	-0.170
31			-0.098	-0.199	-0.159	-0.100	-0.094	-0.098	-0.107	-0.124
30			0.002	-0.029	-0.055	-0.049	-0.050	-0.059	-0.066	-0.077
29			0.010	-0.001	0.005	0.019	0.009	-0.011	-0.032	-0.049
28			0.005	0.0	0.188	0.152	0.070	0.030	0.001	-0.024
27					0.110	0.109	0.089	0.051	0.023	-0.001
26					0.169	0.181	0.196	0.091	0.053	0.019
25					0.257	0.360	0.392	0.195	0.134	0.037
24					0.155	0.198	0.232	0.179	0.125	0.029
23					0.161	0.156	0.164	0.144	0.092	0.015
22					0.203	0.186	0.166	0.147	0.086	0.006
21				0.249	0.346	0.236	0.182	0.145	[illegible]	-0.000
20				0.152	0.211	0.226	0.177	0.124	0.074	-0.009
19				0.187	0.189	0.183	0.160	0.109	0.026	-0.065
18	-0.091	0.0	0.0	0.192	0.177	0.132	0.121	0.085	0.011	-0.061
17	-0.181	-0.117	-0.017	0.045	0.052	0.033	0.020	0.020	0.009	-0.038
16	-0.117	-0.084	-0.033	-0.006	-0.007	-0.021	-0.029	-0.029	-0.029	-0.029
15	-0.053	-0.048	-0.056	-0.059	-0.052	-0.054	-0.055	-0.055	-0.053	-0.051
14	-0.027	0.0	-0.183	-0.132	-0.081	-0.074	-0.065	-0.065	-0.068	-0.072
13			-0.091	0.0	-0.132	-0.096	-0.058	-0.066	-0.080	-0.082
12					-0.065	0.0	0.0	-0.130	-0.107	-0.084
11								-0.067	0.0	-0.129
10										-0.071
9										
8										
7										
6										
5										
4										
3										
2										
1										

ROW	COLUMN 11	12	13	14	15	16	17	18	19
35	-0.223	-0.213	-0.185	-0.240	-0.384				
34	-0.229	-0.230	-0.214	-0.246	-0.300	-0.264			
33	-0.202	-0.210	-0.199	-0.204	-0.182	-0.159			
32	-0.168	-0.175	-0.175	-0.162	-0.155	-0.137			
31	-0.132	-0.141	-0.149	-0.141	-0.139	-0.125			
30	-0.093	-0.110	-0.124	-0.125	-0.127	-0.118			
29	-0.062	-0.083	-0.103	-0.109	-0.115	-0.107			
28	-0.041	-0.068	-0.087	-0.095	-0.103	-0.094			
27	-0.020	-0.065	-0.079	-0.087	-0.087	-0.077			
26	-0.006	-0.063	-0.078	-0.083	-0.078	-0.063			
25	-0.021	-0.116	-0.069	-0.083	-0.081	-0.065			
24	-0.051	-0.051	-0.066	-0.074	-0.074	-0.059			
23	-0.068	-0.060	-0.074	-0.075	-0.078	-0.057			
22	-0.081	-0.065	-0.079	-0.077	-0.084	-0.056			
21	-0.083	-0.068	-0.082	-0.079	-0.084	-0.055			
20	-0.074	-0.065	-0.081	-0.079	-0.085	-0.055			
19	0.0	-0.057	-0.075	-0.079	-0.089	-0.058			
18	0.0	-0.050	-0.082	-0.086	-0.104	-0.069			
17	-0.034	-0.067	-0.094	-0.102	-0.122	-0.088			
16	-0.027	-0.060	-0.093	-0.107	-0.122	-0.102			
15	-0.051	-0.067	-0.094	-0.113	-0.127	-0.116			
14	-0.080	-0.093	-0.116	-0.135	-0.147	-0.138			
13	-0.096	-0.123	-0.156	-0.173	-0.176	-0.162			
12	-0.112	-0.163	-0.198	-0.225	-0.216	-0.296			
11	-0.142	-0.184	-0.232	-0.271	-0.232	-0.198	-0.100		
10	0.0	-0.280	-0.270	-0.310	-0.250	-0.239	-0.140		
9		-0.354	-0.410	-0.338	-0.263	-0.231	-0.156		
8			-0.297	-0.288	-0.262	-0.213	-0.269	-0.177	
7			-0.245	-0.252	-0.259	-0.214	-0.182	-0.084	
6			-0.172	-0.216	-0.269	-0.238	-0.230	-0.130	
5			-0.248	-0.324	-0.324	-0.274	-0.286	-0.171	
4				-0.225	-0.275	-0.304	-0.288	-0.266	-0.195
3				-0.314	-0.402	-0.364	-0.260	-0.227	-0.125
2					-0.313	-0.306	-0.255	-0.298	-0.221
1					-0.237	-0.237	-0.237	-0.420	-0.420

APPENDIX C. OUTPUT (continued)

```
                 PLOTTING COMMENCING
                 -------------------

..... DISSPLA VERSION 7.5 .....
NO. OF FIRST PLOT  1




PLOT NO.   1 WITH THE TITLE
    FIGURE 7 FLOW PATTERNS
HAS BEEN COMPLETED.

PLOT ID. READS
PLOT 1     15.31.57   SAT 20 JAN, 1979   JOB=TGTBT003. .JBL  DISSPLA VER  7.5

DATA FOR PLOT

NO. OF CURVES DRAWN   9
------------------------------
HORIZ. AXIS LENGTH    4.0 INS.
VERT. AXIS LENGTH     9.0 INS.
------------------------------
HORIZ. ORIGIN 0.1000E 01 VERT.  ORIGIN 0.1000E 01
------------------------------
HORIZ. AXI. LINEAR
STEP SIZE 0.3770E 01 UNITS/INCH
------------------------------
VERT.  AXIS LINEAR
STEP SIZE 0.3770E 01 UNITS/INCH
------------------------------

    ......................................
    . LOCATION OF CURRENT PHYSICAL ORIGIN .
    . X=   2.12      Y=   0.55     INCHES .
    .    FROM LOWER LEFT CORNER OF PAGE   .
    ......................................



THE VALUE OF IPEN IS NOT PERMITTED IN THE CALL OF PLOT  X=0.0        Y=0.0         IPEN=                 999
THE VALUE OF  2 IS USED FOR IPEN

END DISSPLA --     3756 VECTORS GENERATED IN     1 PLOT FRAMES.
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APPENDIX C. OUTPUT (continued)

```
                           INPUT DATA FOR THE THERMAL MODEL
NPCW =   7
NRIV =  29
MAXIT =    200
INTPR=  0
EPST= 0.01000000
DIFX =         75.00
DIFY =         75.00
KW =     0.00200
OMEGA =         30.00
KE =     0.0
EAREA =     C.0

                           DISCHARGE FLOW, COORDINATE AND TEMPERATURE
DISCHARG          1      14      265.00       19.60
DISCHARG          1      15      265.00       19.60
DISCHARG          1      16      265.00       19.60
DISCHARG          1      17      265.00       19.60
INTAKE            3      28     -365.00        0.0
INTAKE            3      29     -365.00        0.0
INTAKE            3      30     -365.00        0.0

                           RIVER INFLOW, COORDINATES AND RIVER TEMPERATURE
CB02 OUT         15       1     -293.80        0.0
CB02 OUT         16       1     -293.80        0.0
CB02 OUT         17       1     -293.80        0.0
CB02 OUT         18       1     -293.80        0.0
CB26 OUT         15      26      -40.69        0.0
CB26 OUT         15      27      -40.69        0.0
CB26 OUT         15      28      -40.69        0.0
CB26 OUT         15      29      -40.69        0.0
CB26 OUT         15      30      -40.69        0.0
CB26 OUT         15      31      -40.69        0.0
CB26 OUT         15      32      -40.69        0.0
CB26 OUT         15      33      -40.67        0.0
CB36 IN           8      34      191.98        0.0
CB36 IN           9      34      191.98        0.0
CB36 IN          10      34      191.98        0.0
CB36 IN          11      34      191.98        0.0
CB36 IN          12      34      191.98        0.0
CB36 IN          13      34      191.98        0.0
CB36 IN          14      34      191.98        0.0
CB36 IN          15      34      191.98        0.0

                           BOUNDARY VALUES OF THE TEMPERATURE AND THE COORDINATES
      1          14         19.60
      1          15         19.60
      1          16         19.60
      1          17         19.60
      3          28          0.0
      3          29          0.0
      3          30          0.0
```

APPENDIX C. OUTPUT (continued)

ROW				COLUMN					
	11	12	13	14	15	16	17	18	19
35	0.0	0.0	0.0	0.0	0.0				
34	16.403	13.358	-13.987	-47.460	-23.891	36.336			
33	-27.282	-3.962	13.712	26.779	32.072	36.341			
32	-87.687	-13.778	18.686	36.959	37.125	36.341			
31	-53.033	-24.286	5.577	29.006	35.775	36.341			
30	-56.565	-31.291	-4.301	18.585	30.577	33.745			
29	-52.266	-27.627	-3.022	14.209	26.054	36.341			
28	-39.532	-11.810	7.576	16.167	24.850	36.341			
27	-17.828	3.222	14.382	18.522	26.289	36.341			
26	-1.477	6.536	18.500	9.342	17.128	36.341			
25	1.276	3.799	6.028	-7.465	-2.999	0.0			
24	0.0	0.0	-26.459	-16.701	-7.765	0.0			
23	0.0	0.0	-9.459	-11.810	-9.552	0.0			
22	0.0	0.0	-3.161	-7.075	-6.816	0.0			
21	0.0	0.0	-0.394	-1.532	-1.474	0.0			
20	0.0	0.0	1.830	1.419	0.233	0.0			
19	0.0	0.0	7.630	6.863	2.325	0.0			
18	0.0	0.0	22.502	20.907	7.274	0.0			
17	0.0	0.0	29.096	28.015	15.300	0.0			
16	26.935	15.743	3.871	19.600	19.533	0.0			
15	63.646	36.891	18.573	20.080	17.309	0.0			
14	123.819	87.215	48.963	29.978	17.418	0.0			
13	162.090	132.575	82.882	45.029	18.442	0.0			
12	173.302	165.864	121.573	62.743	11.343	-0.005			
11	154.265	175.124	155.479	98.097	52.167	51.848	-0.005		
10	113.723	204.306	186.259	130.579	70.522	29.582	0.0		
9		0.145	229.6[illegible]	138.342	87.830	41.820	0.0		
8			0.073	57.009	74.827	32.838	-0.005	0.0	
7			0.0	56.382	71.163	54.503	48.896	-0.005	
6			0.0	96.704	94.732	61.132	27.654	0.0	
5			0.071	226.780	142.624	88.611	31.114	0.0	
4				0.073	148.683	134.607	60.045	-0.005	0.0
3				0.071	279.047	181.814	118.709	78.483	-0.005
2					0.073	110.918	130.764	75.874	0.0
1					0.071	94.836	172.069	138.974	0.005

THEX-COMPONENT FLOW RATE

ROW				COLUMN						
	1	2	3	4	5	6	7	8	9	10
35									0.0	0.0
34							0.0	0.0	7.968	22.384
33						0.0	-71.842	-125.598	-66.004	-52.897
32					0.0	-97.376	-190.914	-128.225	-119.902	-88.901
31			0.0	0.0	-151.294	-144.601	-150.739	-150.514	-124.227	-86.764
30			-366.081	-364.332	-259.412	-219.755	-183.415	-152.071	-117.324	-82.950
29			-363.344	-356.994	-320.921	-250.817	-188.552	-140.008	-103.296	-74.709
28			-366.002	-374.107	-363.811	-210.313	-150.886	-112.043	-81.031	-59.545
27					0.005	-90.276	-85.446	-74.412	-57.058	-37.478
26					0.005	-82.302	-27.705	-24.434	-20.468	-9.893
25					0.0	0.0	8.026	7.868	3.905	6.591
24					-0.005	61.822	14.707	9.897	4.343	3.867
23					0.0	31.295	22.220	11.583	5.394	3.211
22					0.0	10.523	8.403	5.609	3.641	1.737
21				0.0	-0.005	0.290	-0.227	1.021	2.183	0.323
20				-0.005	45.662	22.464	5.768	1.596	2.988	-2.280
19				0.0	31.079	28.368	13.808	6.088	7.881	-12.649
18	0.0	0.0	0.0	-0.005	38.610	29.004	11.986	5.406	2.417	0.0
17	264.766	174.230	147.445	157.061	86.358	47.662	22.591	12.860	3.464	14.462
16	264.771	257.236	281.475	219.509	175.975	131.680	96.267	64.676	39.480	24.270
15	264.704	318.116	324.685	279.186	233.967	199.023	173.288	145.405	115.729	90.644
14	264.844	309.438	345.382	289.566	225.831	201.258	190.863	185.071	169.859	150.520
13			0.145	153.703	221.470	179.737	183.766	193.884	182.886	174.584
12					0.145	115.900	171.678	219.854	173.154	176.289
11								0.145	119.767	186.947
10										0.145
9										
8										
7										
6										
5										
4										
3										
2										
1										

APPENDIX C. OUTPUT (continued)

THE Y-COMPONENT FLOW RATE

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10
35									-192.090	-192.022
34							0.0	-184.193	-177.675	-198.003
33						-71.842	-53.757	-124.599	-164.567	-172.388
32					-97.376	-75.380	-81.068	-116.276	-133.565	-131.174
31			0.0	-151.294	-90.682	-81.519	-80.843	-89.988	-96.102	-97.443
30			1.749	-46.375	-51.024	-45.179	-49.499	-55.242	-61.729	-71.057
29			8.099	-10.301	19.080	17.086	-0.955	-18.530	-33.141	-48.554
28			-0.005	-0.005	172.578	76.513	37.887	12.482	-11.656	-28.541
27					82.296	81.343	48.922	29.836	7.925	-8.892
26					-0.011	135.941	52.193	33.802	18.500	-0.476
25					-0.011	143.967	52.035	29.839	21.186	-5.791
24					61.816	96.852	47.225	24.284	20.710	-9.658
23					93.112	87.776	36.589	18.095	18.527	-12.869
22					103.634	85.657	33.794	16.127	16.623	-14.606
21				-0.011	103.930	85.140	35.042	17.289	14.763	-14.929
20				45.657	80.732	68.384	30.929	18.681	9.495	-12.649
19				76.736	78.021	53.824	23.210	20.474	-11.035	0.0
18	-0.005	0.0	-0.005	115.352	68.414	36.806	16.630	17.484	-13.452	0.0
17	-90.541	-26.785	9.611	44.648	29.718	11.735	6.900	8.088	-2.453	-14.462
16	-98.077	-42.546	-12.355	1.114	-14.577	-23.677	-24.692	-17.107	-17.663	-11.798
15	-44.666	-36.017	-57.813	-44.106	-49.521	-49.412	-52.575	-46.783	-42.748	-38.796
14	-0.071	-0.073	-153.629	-67.841	-74.093	-59.808	-58.367	-61.995	-62.087	-65.496
13			-0.071	-0.073	-115.826	-55.779	-48.249	-72.994	-70.389	-77.990
12					-0.071	0.0	-0.073	-119.693	-67.254	-80.977
11								-0.071	-0.073	-113.660
10										-0.071
9										
8										
7										
6										
5										
4										
3										
2										
1										

ROW	COLUMN 11	12	13	14	15	16	17	18	19
35	-192.089	-192.089	-192.089	-192.089	-192.084				
34	-195.134	-219.434	-225.562	-168.520	-131.857	0.0			
33	-171.814	-201.760	-212.495	-163.227	-127.588	0.0			
32	-137.906	-169.295	-194.223	-163.060	-128.372	0.0			
31	-109.159	-139.432	-170.794	-156.286	-127.811	0.0			
30	-83.885	-112.442	-147.908	-144.294	-124.643	0.0			
29	-59.307	-87.837	-130.677	-132.449	-114.355	0.0			
28	-31.585	-68.450	-122.086	-123.766	-102.865	0.0			
27	-10.536	-57.290	-117.946	-115.998	-92.813	0.0			
26	-2.523	-53.326	-119.104	-108.213	-73.600	0.0			
25	0.0	-51.097	-132.596	-103.747	-70.601	0.0			
24	0.0	-77.555	-122.839	-94.810	-62.836	0.0			
23	0.0	-87.015	-125.190	-92.552	-53.284	0.0			
22	0.0	-90.175	-129.104	-92.293	-46.468	0.0			
21	0.0	-90.569	-130.242	-92.234	-44.995	0.0			
20	0.0	-88.739	-130.653	-93.421	-45.227	0.0			
19	0.0	-81.109	-131.420	-97.958	-47.552	0.0			
18	0.0	-58.607	-133.015	-111.592	-54.826	0.0			
17	0.0	-29.511	-134.096	-124.307	-70.127	0.0			
16	-11.191	-41.382	-118.367	-124.374	-89.660	0.0			
15	-37.947	-59.700	-116.860	-127.145	-106.969	0.0			
14	-74.552	-97.951	-135.846	-139.713	-124.379	0.0			
13	-104.067	-147.644	-173.698	-166.300	-142.821	0.0			
12	-111.505	-191.935	-232.529	-217.701	-154.169	0.011			
11	-90.646	-211.580	-289.910	-263.631	-154.487	-51.843	0.0		
10	-0.073	-229.626	-345.591	-323.688	-195.427	-81.425	0.0		
9		-0.145	-435.875	-374.199	-241.437	-123.245	0.0		
8			-379.940	-356.382	-283.426	-156.089	0.011	0.0	
7			-323.558	-341.601	-300.086	-161.695	-48.891	0.0	
6			-226.854	-343.573	-333.686	-195.173	-76.545	0.0	
5			-0.145	-427.729	-387.699	-252.670	-107.660	0.0	
4				-279.120	-401.774	-327.232	-167.710	0.011	0.0
3				-0.145	-499.007	-390.337	-207.936	-78.478	0.0
2					-388.162	-370.491	-262.826	-154.352	0.0
1					-293.399	-293.258	-295.921	-293.320	0.0

APPENDIX C. OUTPUT (continued)

THE NUMERICAL FOR THERMAL MODEL IS O. K.
NO. OF ITERATION = 136 MAX DIF = 0.996E-02 OCCURS AT I = 15 J = 34

THE DISTRIBUTION OF EXCESS TEMP

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10
35									0.0	0.0
34							0.0	0.638	0.601	0.578
33						1.486	1.306	0.989	0.846	0.762
32					1.851	1.680	1.501	1.280	1.106	0.980
31			0.0	2.198	2.055	1.912	1.742	1.556	1.387	1.237
30			2.484	2.390	2.321	2.217	2.064	1.884	1.708	1.535
29			2.615	2.630	2.660	2.603	2.467	2.277	2.067	1.856
28			2.740	2.853	3.112	3.118	2.991	2.778	2.510	2.223
27					3.758	3.843	3.670	3.382	3.040	2.670
26					4.322	4.848	4.552	4.196	3.660	3.221
25					0.0	6.696	6.065	5.308	4.676	4.128
24					10.790	9.788	8.806	7.704	6.828	6.169
23					11.667	11.291	10.589	9.554	8.759	8.170
22					12.483	12.260	11.782	10.897	10.223	9.719
21				0.0	13.486	13.270	12.854	12.082	11.451	10.985
20				15.633	14.884	14.367	13.821	13.078	12.418	11.919
19				16.296	15.889	15.333	14.638	13.882	13.174	12.505
18	0.0	0.0	0.0	17.027	16.628	16.074	15.296	14.531	13.907	0.0
17	19.600	19.176	18.554	17.761	17.174	16.574	15.803	14.937	14.028	13.152
16	19.600	19.210	18.655	18.007	17.389	16.738	15.984	15.095	14.014	12.543
15	19.600	19.220	18.683	18.070	17.431	16.756	15.999	15.117	14.045	12.730
14	19.600	19.208	18.599	18.005	17.360	16.686	15.934	15.066	14.045	12.852
13			18.250	17.843	17.173	16.586	15.820	14.957	13.992	12.904
12					16.786	16.369	15.697	14.753	13.858	12.873
11								14.226	13.638	12.719
10										12.225
9										
8										
7										
6										
5										
4										
3										
2										
1										

ROW	COLUMN 11	12	13	14	15	16	17	18	19
35	0.0	0.0	0.0	0.0	0.0				
34	0.555	0.534	0.514	0.487	0.475	0.0			
33	0.708	0.672	0.654	0.649	0.651	0.0			
32	0.896	0.842	0.816	0.807	0.801	0.0			
31	1.120	1.039	0.994	0.972	0.960	0.0			
30	1.378	1.261	1.191	1.155	[illegible]	0.0			
29	1.654	1.497	1.406	1.357	1.328	0.0			
28	1.939	1.738	1.631	1.574	1.540	0.0			
27	2.247	1.968	1.856	1.796	1.761	0.0			
26	2.580	2.206	2.084	2.017	1.978	0.0			
25	2.908	2.444	2.323	2.253	2.211	0.0			
24	0.0	2.624	2.553	2.501	2.467	0.0			
23	0.0	2.831	2.800	2.769	2.740	0.0			
22	0.0	3.133	3.116	3.098	3.079	0.0			
21	0.0	3.527	3.515	3.508	3.505	0.0			
20	0.0	4.016	4.003	3.998	4.000	0.0			
19	0.0	4.588	4.573	4.568	4.569	0.0			
18	0.0	5.232	5.219	5.219	5.220	0.0			
17	0.0	6.124	6.045	6.000	5.982	0.0			
6	10.529	7.989	7.212	6.947	6.843	0.0			
15	11.096	9.282	8.309	7.860	7.651	0.0			
14	11.492	10.121	9.167	8.623	8.350	0.0			
13	11.737	10.634	9.779	9.220	8.923	0.0			
12	11.846	10.898	10.165	9.639	9.337	0.0			
11	11.809	10.957	10.339	9.881	9.622	9.573	0.0		
10	11.636	10.839	10.317	9.929	9.698	9.567	0.0		
9		10.461	10.091	9.806	9.618	9.487	0.0		
8			9.695	9.572	9.444	9.351	0.0	0.0	
7			9.402	9.335	9.242	9.145	8.971	0.0	
6			9.176	9.121	9.045	8.965	8.861	0.0	
5			9.031	8.937	8.860	8.789	8.709	0.0	
4				8.731	8.676	8.609	8.540	0.0	0.0
3				8.595	8.516	8.443	8.366	8.241	0.0
2					8.348	8.309	8.261	8.194	0.0
1					8.255	8.232	8.206	8.159	0.0

APPENDIX D. INPUT AND OUTPUT OF AN ARTIFICIAL IMPOUNDMENT APPLICATION

INPUT

```
                SEWER EMERGENCY COOLING STUDY                        2
1.0     98.4285  42.37  0.0     0.0     6.43      1.93     0.00237.000001 0.005
&CONTRL NX=20,NY=29,NUMMAX=41,NUNMAX=29,MAXIT=100,NPRIN=10,EPS=0.001,INTER=0,
NUMAXT=42,NUNAXT=30,MAXITT=5000,NPRINT=10,EPST=0.00100,INTERT=0,IRPC=0,JOPT=1,
&END
&BOUND MBD=2,3,4,5,6,7,8,9,10,11,11,12,12,13,13,14,14,14,15,15,16,17,17,18,18,
        18,19,19,19,  70*0,
      NBDB=6,5, 3, 4, 4, 4, 4, 5, 5, 5, 15,5, 16,5, 17,4, 18,25,3, 24,3, 2,16,
        2,16,26,2,15,26,  70*0,
      NBDE=9,10,10,11,14,15,15,15,16,12,16,13,18,14,23,15,22,25,16,25,26,9,26,
        6,21,28,5,15,27,  70*0,
       NBD=2, 3, 3, 4, 4, 5, 6, 7, 8, 9, 10,11,12,13,13,14,14,15,15,15,16,16,
        17,17,18,18,19,19,20,20,21,21,22,22,23,23,24,25,26,27,28,   58*0,
      MBDB=17,4,15,4,14,3, 2, 2, 2, 2, 3, 5, 6, 6, 12,6, 13,7, 14,19,10,15,12,
        16,12,16,13,16,13,16,13,16,13,16,13,16,15,14,16,18,18,      58*0,
      MBDE=19,4,19,8,19,19,18,17,17,17,16,16,16,10,16,10,16,11,16,19,12,18,13,
        18,14,18,14,18,14,18,14,18,14,17,13,17,17,17,19,19,18, 58*0,  &END
&OBND NOBD=2,NPTOBD=2,2,97*0, IBXOBD=12,17,97*0, IEXCBD=12,17,97*0,
      JBYOBD=23,28,97*0, JEYOBD=24,29,97*0, INDOBD=0,1,97*0, &END
&CBND NCBD=69,BXCBD=16,3,14,5,13,2,9,1,19,18,1,17,2,4,11,18,5,12,17,6,13,19,
        9,14,11,18,14,13,12,18,13,15,19,17,  1,2,2,3,4,5,5,6,9,9,11,11,
        12,12,12,13,13,13,14,14,14,15,15,16,17,17,18,18,18,19,19,19,20,20,
        20, 30*0,  BYCBD=1,2,2,3,3,4,4,5,6,7,10,10,11,12,14,14,15,15,15,
        16,16,16,17,17,19,22,23,24,25,25,26,27,28,29,  5,4,10,2,11,2,12,15,
3,16,13,17,14,19,24,3,15,24,2,16,23,17,26,1,10,27,7,14,22,6,16,28,1,14,25,30*0,
EXCBD=20,5,16,9,14,3,13,2,20,19,2,18,4,5,12,20,6,13,18,9,14,20,11,15,12,19,15,
14,13,20,15,17,20,19,  1,2,2,3,4,5,5,6,9,9,11,11,12,12,12,13,13,13,14,14,14,
15,15,16,17,17,18,18,18,19,19,19,20,20,20, 30*0,
EYCBD=1,2,2,3,3,4,4,5,6,7,10,10,11,12,14,14,15,15,15,16,16,16,17,17,19,22,23,
24,25,25,26,27,28,29,  10,5,11,4,12,3,15,16,4,17,14,19,15,23,25,4,16,26,3,17,
24,23,27,2,15,28,10,15,25,7,22,29,6,16,28,  30*0,  &END
&HBNV BV=99*1.0,0.0,27*0.0,1.0,171*0.0, IBV=4*12,3*11,10,2*9,8,7,2*6,4*5,2*4,3,
2*2,6*1,2*2,3*3,4,2*5,6,7,8,2*9,10,11,12,2*13,2*14,15,2*16,17,18,19,6*20,2*19,
4*18,6*17,2*18,19,3*20,7*19,4*18,19,4*20,2*19,18,3*17,16,2*15,14,3*13,2*14,
7*15,2*14,2*13,2*12,2*11,3*12,171*0,          JBV=22,21,20,2*19,18,3*17,4*16,
2*15,14,13,2*12,3*11,2*10,9,8,7,6,2*5,2*4,3,3*2,5*3,5*4,2*3,3*2,5*1,2,3,4,5,
2*6,2*7,8,9,2*10,11,12,13,14,2*15,3*14,15,2*16,17,18,19,20,21,2*22,23,24,3*25,
26,27,2*28,3*29,28,3*27,3*26,25,2*24,2*23,22,21,20,19,18,2*17,2*16,2*15,2*14,
13,25,24,23,171*0,          NBV=128,  &END
&PATCH IN(1,5)=6,IN(1,10)=6,IN(2,11)=6,IN(4,12)=6,IN(5,15)=6,IN(6,16)=6,
IN(9,17)=6,IN(11,19)=6,IN(12,25)=6,IN(13,26)=6,IN(15,27)=6,IN(17,29)=6,
IN(19,29)=6,IN(20,28)=6,IN(20,25)=6,IN(19,22)=6,IN(20,16)=6,IN(20,14)=6,
IN(18,14)=6,IN(18,10)=6,IN(19,7)=6,IN(20,6)=6,IN(20,1)=6,IN(16,1)=6,
IN(14,2)=6,IN(13,3)=6,IN(9,3)=6,IN(5,2)=6,IN(3,2)=6,IN(2,4)=6,IN(12,24)=6, &END
&HIGHT HIN=580*6.43, &END
   2    0
50.0      50.0      30.0      124.8     0.002     0.0       0.0
&BOUNDT MBDT=1,2,3,4,5,6,7,8,9,10,11,11,12,12,13,13,13,14,14,14,15,16,17,17,18,
18,18,3*19,69*0,  NBDBT=5,4,2,2,4*3,3*4,14,4,15,3,16,24,2,17,23,2,1,1,15,1,14,
25,1,14,25,69*0,  NBDET=9,10,10,11,14,3*15,2*16,13,18,14,23,15,23,25,16,22,25,
26,26,9,28,6,21,28,5,15,27,69*0,       MBDIND=13*11,10,16*11,69*0,
NBDT=1,2,2,3,3,4,5,6,7,
8,9,10,11,12,13,13,14,14,14,15,15,16,16,17,17,18,18,19,19,20,20,21,21,22,22,23,
23,  24,25,26,27,28,57*0,  MBDBT=16,3,14,3,13,2,1,1,1,1,1,2,4,5,5,11,5,12,18,
6,13,9,14,11,15,11,15,12,15,12,15,12,15,12,15,12,14,    13,13,15,17,17,57*0,
MBDET=19,4,19,8,19,19,19,18,17,17,17,16,16,16,10,16,11,16,19,12,19,13,18,14,18,
14,18,14,18,14,18,14,18,14,17,13,17,    17,19,19,19,18,57*0,
NBDIND=35*11,1,6*11,57*0,    &END
&TBNV QBVT=42.345, 42.375, 97*0.0,  BVT=40.0, 0.0, 97*0.0,  IBVT=12,17,
 97*0,  JBVT=23,28, 97*0,  INDBT=1, 0, 97*0,  NBVT=2,    &END
DISCHARGE     12    23 42.370             40.0
INTAKE        17    28 -42.370             0.0
```

APPENDIX D. OUTPUT

SEWER EMERGENCY COOLING STUDY

INPUT DATA FOR HYDRO MODEL

```
VELOCITY SCALE   =  1.00 FT/SEC      LENGTH SCALE    =  98.4 FT
TOTAL DISCHARGE  =   42.4 CFS        WIND SPEED      =  0.0  FT/SEC
WIND DIRECTION   =   0.0 DEGREE      AVERAGE DEPTH   =  6.43 FT
WATER DENSITY    = 1.930 SLUG/FT3    AIR DENSITY     = 0.0024 SLUG/FT3
WIND STRESS COEF =0.0000010           BOTTOM STRESS COEF = 0.005000
```

THE INDEX OF EACH POINT

	COLUMN																			
ROW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	6	2	6	1
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	4	2	6
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	6	2	2	4	4	2
26	1	1	1	1	1	1	1	1	1	1	1	1	6	2	2	4	4	4	4	2
25	1	1	1	1	1	1	1	1	1	1	1	6	2	4	4	4	4	2	2	6
24	1	1	1	1	1	1	1	1	1	1	1	6	2	2	4	4	4	2	1	1
23	1	1	1	1	1	1	1	1	1	1	1	2	4	2	2	4	4	2	1	1
22	1	1	1	1	1	1	1	1	1	1	1	2	4	4	2	4	4	2	6	1
21	1	1	1	1	1	1	1	1	1	1	1	2	4	4	2	4	4	4	2	1
20	1	1	1	1	1	1	1	1	1	1	1	2	4	4	2	4	4	4	2	1
19	1	1	1	1	1	1	1	1	1	1	6	2	4	4	2	4	4	4	2	1
18	1	1	1	1	1	1	1	1	1	1	2	4	4	4	2	4	4	4	2	1
17	1	1	1	1	1	1	1	1	6	2	2	4	4	2	2	4	4	4	2	1
16	1	1	1	1	1	6	2	2	2	4	4	4	2	2	4	4	4	4	2	6
15	1	1	1	1	6	2	4	4	4	4	4	2	2	4	4	4	2	2	4	2
14	1	1	1	1	2	4	4	4	4	4	2	2	4	4	4	4	2	6	2	6
13	1	1	1	1	2	4	4	4	4	4	2	4	4	4	4	4	2	1	1	1
12	1	1	1	6	2	4	4	4	4	4	4	4	4	4	4	4	2	1	1	1
11	1	6	2	2	4	4	4	4	4	4	4	4	4	4	4	4	2	1	1	1
10	6	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	6	1	1
9	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	1	1
8	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	1	1
7	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	6	1
6	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	6
5	6	[illegible]	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
4	1	6	2	4	4	4	4	4	2	2	2	2	2	4	4	4	4	4	4	2
3	1	1	2	4	2	2	2	2	6	1	1	1	6	2	4	4	4	4	4	2
2	1	1	6	2	6	1	1	1	1	1	1	1	1	6	2	2	4	4	4	2
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	6	2	2	2	6

APPENDIX D. OUTPUT (continued)

THE DEPTH AT THE CCRNER

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10
29										
28										
27										
26										
25										
24										
23										
22										
21										
20										
19										
18										
17									6.430	6.430
16						6.430	6.430	6.430	6.430	6.430
15					6.430	6.430	6.430	6.430	6.430	6.430
14					6.430	6.430	5.430	6.430	6.430	6.430
13					6.430	6.430	6.430	6.430	6.430	6.430
12				6.430	6.430	6.430	6.430	6.430	6.430	6.430
11		6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
10	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
9	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
8	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
7	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
6	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
5	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
4		6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
3			6.430	6.430	6.430	6.430	6.430	6.430	6.430	
2			6.430	6.430	6.430					
1										

ROW	COLUMN 11	12	13	14	15	16	17	18	19	20
29							6.430	6.430	6.430	
28							6.430	6.430	6.430	6.430
27					6.430	6.430	6.430	6.430	6.430	6.430
26			6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
25		6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
24		6.430	6.430	6.430	6.430	6.430	6.430	6.430		
23		6.430	6.430	6.430	6.430	6.430	6.430	6.430		
22		6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	
21		6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	
20		6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	
19	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	
18	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	
17	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	
16	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
15	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
14	6.430	6.430	6.430	6.430	6.430	6.430	6.430	9.645	6.430	6.430
13	6.430	6.430	6.430	6.430	6.430	6.430	6.430			
12	6.430	6.430	6.430	6.430	6.430	6.430	6.430			
11	6.430	6.430	6.430	6.430	6.430	6.430	6.430			
10	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430		
9	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430		
8	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430		
7	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	
6	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
5	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
4	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
3			6.430	6.430	6.430	6.430	6.430	6.430	6.430	6.430
2				6.430	6.430	6.430	6.430	6.430	6.430	6.430
1						6.430	6.430	6.430	6.430	6.430

APPENDIX D. OUTPUT (continued)

DIMENSIONLESS DEPTH AT EACH POINT

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10
29										
28										
27										
26										
25										
24										
23										
22										
21										
20										
19										
18										
17									0.065	0.065
16						0.065	0.065	0.065	0.065	0.065
15					0.065	0.065	0.065	0.065	0.065	0.065
14					0.065	0.065	0.065	0.065	0.065	0.065
13					0.065	0.065	0.065	0.065	0.065	0.065
12				0.065	0.065	0.065	0.065	0.065	0.065	0.065
11		0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
10	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
9	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
8	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
7	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
6	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
5	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
4		0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
3			0.065	0.065	0.065	0.065	0.065	0.065	0.065	
2			0.065	0.065	0.065					
1										

ROW	COLUMN 11	12	13	14	15	16	17	18	19	20
29							0.065	0.065	0.065	
28							0.065	0.065	0.065	0.065
27					0.065	0.065	0.065	0.065	0.065	0.065
26			0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
25		0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
24		0.065	0.065	0.065	0.065	0.065	0.065	0.065		
23		0.065	0.065	0.065	0.065	0.065	0.065	0.065		
22		0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	
21		0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	
20		0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	
19	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	
18	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	
17	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	
16	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.073	0.073
15	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.073	0.073
14	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.102	0.073	0.073
13	0.065	0.065	0.065	0.065	0.065	0.065	0.065			
12	0.065	0.065	0.065	0.065	0.065	0.065	0.065			
11	0.065	0.065	0.065	0.065	0.065	0.065	0.065			
10	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065		
9	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065		
8	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065		
7	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	
6	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
5	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
4	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
3			0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
2				0.065	0.065	0.065	0.065	0.065	0.065	0.065
1						0.065	0.065	0.065	0.065	0.065

APPENDIX D. OUTPUT (continued)

THE BOUNDARY VALUES AND THE INITIAL GUESSES

COLUMN

ROW	1	2	3	4	5	6	7	8	9	10
29										
28										
27										
26										
25										
24										
23										
22										
21										
20										
19										
18										
17									1.000	1.000
16						1.000	1.000	1.000	1.000	0.0
15					1.000	1.000	0.0	0.0	0.0	0.0
14					1.000	0.0	0.0	0.0	0.0	0.0
13					1.000	0.0	0.0	0.0	0.0	0.0
12				1.000	1.000	0.0	0.0	0.0	0.0	0.0
11		1.000	1.000	1.000	0.0	0.0	0.0	0.0	0.0	0.0
10	1.000	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	1.000	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4		1.000	1.000	0.0	0.0	0.0	0.0	0.0	1.000	1.000
3			1.000	0.0	1.000	1.000	1.000	1.000	1.000	
2			1.000	1.000	1.000					
1										

COLUMN

ROW	11	12	13	14	15	16	17	18	19	20
29							1.000	1.000	1.000	
28							0.0	0.0	1.000	1.000
27					0.0	0.0	0.0	0.0	0.0	1.000
26			0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000
25		0.0	0.0	0.0	0.0	0.0	0.0	1.000	1.000	1.000
24		0.0	0.0	0.0	0.0	0.0	0.0	1.000		
23		1.000	0.0	0.0	0.0	0.0	0.0	1.000		
22		1.000	0.0	0.0	0.0	0.0	0.0	1.000	1.000	
21		1.000	0.0	0.0	0.0	0.0	0.0	0.0	1.000	
20		1.000	0.0	0.0	0.0	0.0	0.0	0.0	1.000	
19	1.000	1.000	0.0	0.0	0.0	0.0	0.0	0.0	1.000	
18	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000	
17	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000	
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000	1.000
15	0.0	0.0	0.0	0.0	0.0	0.0	1.000	1.000	0.0	1.000
14	0.0	0.0	0.0	0.0	0.0	0.0	1.000	1.000	1.000	1.000
13	0.0	0.0	0.0	0.0	0.0	0.0	1.000			
12	0.0	0.0	0.0	0.0	0.0	0.0	1.000			
11	0.0	0.0	0.0	0.0	0.0	0.0	1.000			
10	0.0	0.0	0.0	0.0	0.0	0.0	1.000	1.000		
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000		
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000		
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000	1.000	
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000	1.000
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000
4	1.000	1.000	1.000	0.0	0.0	0.0	0.0	0.0	0.0	1.000
3			1.000	1.000	0.0	0.0	0.0	0.0	0.0	1.000
2				1.000	1.000	1.000	0.0	0.0	0.0	1.000
1						1.000	1.000	1.000	1.000	1.000

APPENDIX D. <u>OUTPUT</u> (continued)

THE SOLUTION FOR THE HYDRO MODEL

THE PRESENT NUMERICAL SCHEME IS O. K.
DIFMAX= 0.8497452E-03 FOR THE 22TH ITERATION OCCURING AT (18,27)

THE STREAM FUNCTION - PSI

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10
29										
28										
27										
26										
25										
24										
23										
22										
21										
20										
19										
18										
17									1.000	1.000
16						1.000	1.000	1.000	1.000	0.787
15					1.000	1.000	0.937	0.871	0.765	0.557
14					1.000	0.952	0.879	0.780	0.632	0.389
13					1.030	0.930	0.847	0.741	0.591	0.367
12				1.000	1.000	0.919	0.838	0.743	0.627	0.488
11		1.000	1.000	1.000	0.964	0.908	0.843	0.768	0.686	0.602
10	1.000	1.000	0.990	0.976	0.948	0.906	0.857	0.802	0.745	0.694
9	1.000	0.994	0.983	0.968	0.944	0.913	0.876	0.837	0.799	0.767
8	1.000	0.992	0.981	0.967	0.948	0.925	0.898	0.871	0.846	0.826
7	1.000	0.993	0.983	0.971	0.956	0.939	0.921	0.904	0.838	0.876
6	1.000	0.995	0.987	0.978	0.967	0.956	0.9[illegible]	0.934	0.926	0.919
5	1.000	1.000	0.993	0.986	0.979	0.971	0.965	0.962	0.962	0.960
4		1.000	1.000	0.994	0.989	0.986	0.985	0.987	1.000	1.000
3			1.000	0.998	1.000	1.000	1.000	1.000	1.000	
2			1.000	1.000	1.000					
1										

ROW	COLUMN 11	12	13	14	15	16	17	18	19	20
29							1.000	1.000	1.000	
28							0.0	0.637	1.000	1.000
27					0.0	0.0	0.0	0.549	0.860	1.000
26			0.0	0.0	0.0	0.165	0.360	0.700	0.890	1.000
25		0.0	0.0	0.028	0.110	0.299	0.576	1.030	1.000	1.000
24		0.0	0.0	0.0	0.114	0.346	0.644	1.000		
23		1.000	0.388	0.0	0.0	0.328	0.652	1.000		
22		1.000	0.552	0.207	0.0	0.315	0.637	1.000	1.000	
21		1.000	0.613	0.278	0.0	0.295	0.582	0.844	1.000	
20		1.000	0.621	0.290	0.0	0.282	0.551	0.795	1.000	
19	1.000	1.000	0.581	0.262	0.0	0.283	0.546	0.784	1.000	
18	1.000	0.754	0.441	0.176	0.0	0.302	0.568	0.795	1.000	
17	1.000	0.575	0.254	0.0	0.0	0.357	0.627	0.828	1.000	
16	0.591	0.292	0.0	0.0	0.225	0.500	0.755	0.892	1.000	1.000
15	0.287	0.0	0.0	0.183	0.399	0.662	1.000	1.000	1.000	1.000
14	0.0	0.0	0.163	0.335	0.527	0.749	1.000	1.000	1.000	1.000
13	0.0	0.176	0.319	0.464	0.626	0.806	1.000			
12	0.354	0.387	0.470	0.579	0.706	0.848	1.000			
11	0.501	0.507	0.597	0.674	0.771	0.881	1.000			
10	0.662	0.664	0.696	0.750	0.822	0.905	1.000	1.000		
9	0.749	0.750	0.772	0.810	0.860	0.917	0.971	1.000		
8	0.815	0.817	0.832	0.858	0.892	0.931	0.969	1.000		
7	0.870	0.871	0.881	0.897	0.920	0.946	0.973	1.000	1.000	
6	0.916	0.917	0.923	0.931	0.944	0.960	0.977	0.992	1.000	1.000
5	0.959	0.959	0.960	0.961	0.965	0.973	0.982	0.991	0.997	1.000
4	1.000	1.000	1.000	0.985	0.982	0.984	0.988	0.993	0.997	1.000
3			1.000	1.000	0.994	0.993	0.994	0.996	0.998	1.000
2				1.000	1.000	1.000	0.998	0.998	0.999	1.000
1						1.000	1.000	1.000	1.000	1.000

APPENDIX D. OUTPUT (continued)

THE X-COMPONENT VELOCITY - U

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10
29										
28										
27										
26										
25										
24										
23										
22										
21										
20										
19										
18										
17									-0.015	-0.014
16						-0.004	-0.004	-0.009	-0.016	-0.015
15					-0.002	-0.003	-0.004	-0.007	-0.012	-0.013
14					0.0	-0.002	-0.003	-0.004	-0.006	-0.006
13					0.0	-0.001	-0.001	-0.001	-0.000	0.003
12				-0.002	-0.002	-0.001	-0.000	0.001	0.003	0.008
11		-0.001	-0.001	-0.002	-0.002	-0.000	0.001	0.002	0.004	0.007
10	-0.000	-0.000	-0.001	-0.001	-0.001	0.000	0.001	0.002	0.004	0.006
9	0.0	-0.000	-0.000	-0.000	0.000	0.001	0.001	0.002	0.003	0.004
8	0.0	-0.000	-0.000	0.000	0.000	0.001	0.002	0.002	0.003	0.004
7	0.0	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.003	0.003
6	0.0	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.003
5	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.002	0.002	0.003
4		0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.003	0.003
3			0.0	0.000	0.001	0.001	0.001	0.001	0.002	
2			0.000	0.000	0.000					
1										

ROW	COLUMN 11	12	13	14	15	16	17	18	19	20
29							-0.067	-0.024	-0.017	
28							-0.067	-0.015	-0.009	-0.005
27					0.009	0.011	0.024	0.002	-0.004	0.0
26			0.001	0.002	0.007	0.010	0.019	0.015	0.005	0.0
25		0.006	0.0	0.0	0.004	0.006	0.009	0.020	0.007	0.004
24		0.067	0.026	-0.002	-0.004	0.001	0.003	0.0		
23		0.067	0.018	0.014	-0.008	-0.001	-0.000	0.0		
22		0.0	0.008	0.009	0.0	-0.001	-0.002	-0.010	-0.005	
21		0.0	0.002	0.003	0.0	-0.001	-0.003	-0.007	0.0	
20		0.0	-0.001	-0.001	0.0	-0.000	-0.001	-0.002	0.0	
19	-0.008	-0.016	-0.006	-0.004	0.0	0.001	0.001	-0.000	0.0	
18	0.0	-0.014	-0.011	-0.009	0.0	0.002	0.003	0.001	0.0	
17	-0.027	-0.015	-0.015	-0.012	0.015	0.007	0.006	0.003	0.0	
16	-0.024	-0.019	-0.017	0.012	0.013	0.010	0.012	0.006	-0.000	-0.000
15	-0.020	-0.020	0.011	0.011	0.010	0.008	0.016	0.007	0.0	0.0
14	-0.019	0.012	0.011	0.009	0.008	0.005	0.0	0.002	0.000	0.000
13	0.024	0.013	0.010	0.008	0.006	0.003	0.0			
12	0.018	0.012	0.009	0.007	0.005	0.003	0.0			
11	0.010	0.009	0.008	0.006	0.004	0.002	0.0			
10	0.007	0.007	0.006	0.005	0.003	0.001	-0.002	-0.001		
9	0.005	0.005	0.005	0.004	0.002	0.001	-0.001	0.0		
8	0.004	0.004	0.004	0.003	0.002	0.001	0.000	0.0		
7	0.003	0.003	0.003	0.002	0.002	0.001	0.000	-0.001	-0.000	
6	0.003	0.003	0.003	0.002	0.001	0.001	0.000	-0.000	-0.000	-0.000
5	0.003	0.003	0.003	0.002	0.001	0.001	0.000	0.000	-0.000	0.0
4	0.003	0.003	0.003	0.001	0.001	0.001	0.000	0.000	0.000	0.0
3			0.002	0.001	0.001	0.001	0.000	0.000	0.000	0.0
2				0.001	0.000	0.000	0.000	0.000	0.000	0.0
1						0.000	0.000	0.000	0.000	0.000

APPENDIX D. OUTPUT (continued)

THE Y-COMPONENT VELOCITY - V

ROW	1	2	3	4	5	6	7	8	9	10
29										
28										
27										
26										
25										
24										
23										
22										
21										
20										
19										
18										
17									-0.007	0.0
16						-0.002	0.0	0.0	-0.014	-0.014
15					-0.004	-0.004	-0.004	-0.006	-0.011	-0.016
14					-0.003	-0.004	-0.006	-0.008	-0.013	-0.021
13					-0.005	-0.005	-0.006	-0.009	-0.013	-0.020
12				-0.004	-0.005	-0.005	-0.006	-0.007	-0.009	-0.009
11		-0.000	0.0	-0.002	-0.003	-0.004	-0.005	-0.005	-0.006	-0.005
10	-0.001	-0.001	-0.001	-0.001	-0.002	-0.003	-0.003	-0.004	-0.004	-0.003
9	-0.000	-0.001	-0.001	-0.001	-0.002	-0.002	-0.003	-0.003	-0.002	-0.002
8	-0.001	-0.001	-0.001	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002	-0.001
7	-0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
6	-0.000	-0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.000	-0.000
5	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
4		-0.000	-0.000	-0.000	-0.000	-0.000	0.000	0.001	0.001	0.0
3			-0.000	0.0	0.000	0.0	0.0	0.0	0.000	
2			-0.000	0.0	0.000					
1										

ROW	11	12	13	14	15	16	17	18	19	20
29							0.021	0.0	0.012	
28							0.043	0.033	0.024	0.017
27					0.006	0.0	0.037	0.029	0.015	0.009
26			0.001	0.0	0.011	0.012	0.018	0.018	0.010	0.007
25		-0.009	0.002	0.004	0.009	0.016	0.023	0.028	0.0	0.004
24		-0.020	0.0	0.008	0.012	0.018	0.022	0.024		
23		-0.041	-0.033	-0.026	0.022	0.022	0.022	0.023		
22		-0.030	-0.027	-0.018	0.021	0.021	0.023	0.024	0.017	
21		-0.026	-0.024	-0.021	0.020	0.019	0.018	0.014	0.010	
20		-0.025	-0.024	-0.021	0.019	0.018	0.017	0.015	0.014	
19	-0.022	-0.028	-0.025	-0.019	0.019	0.018	0.017	0.015	0.014	
18	-0.016	-0.019	-0.019	-0.015	0.020	0.019	0.017	0.014	0.014	
17	-0.028	-0.025	-0.019	-0.017	0.024	0.021	0.016	0.012	0.011	
16	-0.017	-0.020	-0.020	0.015	0.017	0.018	0.013	0.008	0.006	0.003
15	-0.019	-0.019	0.012	0.013	0.016	0.020	0.023	-0.000	0.0	0.000
14	-0.026	0.011	0.011	0.012	0.014	0.016	0.017	0.005	0.0	0.000
13	0.012	0.011	0.010	0.010	0.011	0.013	0.013			
12	-0.003	0.004	0.006	0.008	0.009	0.010	0.010			
11	-0.002	0.002	0.004	0.006	0.007	0.008	0.008			
10	-0.001	0.001	0.003	0.004	0.005	0.006	0.006	0.004		
9	-0.001	0.001	0.002	0.003	0.004	0.004	0.003	0.002		
8	-0.000	0.001	0.001	0.002	0.002	0.003	0.002	0.002		
7	-0.000	0.000	0.001	0.001	0.002	0.002	0.002	0.002	0.001	
6	-0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.000
5	-0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000
4	0.0	0.0	-0.001	-0.001	-0.000	0.000	0.000	0.000	0.000	0.000
3			-0.001	-0.000	-0.000	0.000	0.000	0.000	0.000	0.000
2				-0.000	0.0	-0.000	-0.000	0.000	0.000	0.000
1						-0.000	0.0	0.0	0.0	0.000

APPENDIX D. OUTPUT (continued)

```
                    PLOTTING COMMENCING
                    ...................

..... DISSPLA VERSION 7.5 .....
NO. OF FIRST PLOT  1




PLOT NO.    1 WITH THE TITLE
     FIGURE 7 FLOW PATTERNS
HAS BEEN COMPLETED.

PLOT ID. READS
PLOT 1      01.31.22   WED 24 JAN, 1979    JOB=TGYHT004. ORNL  DISSPLA VER  7.5


DATA FOR PLOT

NO. OF CURVES DRAWN  0
-----------------------------
HORIZ. AXIS LENGTH   6.1 INS.
VERT. AXIS LENGTH    9.0 INS.
-----------------------------
HORIZ. ORIGIN 0.1000E 01 VERT.  ORIGIN 0.1000E 01
-----------------------------
HORIZ. AXIS LINEAR
STEP SIZE 0.3111E 01 UNITS/INCH
-----------------------------
VERT.  AXIS LINEAR
STEP SIZE 0.3111E 01 UNITS/INCH
-----------------------------

     ......................................
     . LOCATION OF CURRENT PHYSICAL ORIGIN .
     . X=    1.45      Y=    0.55     INCHES .
     .    FROM LOWER LEFT CORNER OF PAGE   .
     ......................................



THE VALUE OF IPEN IS NOT PERMITTED IN THE CALL OF PLOT  X=0.0          Y=0.0          IPEN=
THE VALUE OF  2 IS USED FOR IPEN


END DISSPLA --     3321 VECTORS GENERATED IN     1 PLOT FRAMES.
```

APPENDIX D. <u>OUTPUT</u> (continued)

```
                         INPUT DATA FOR THE THERMAL MODEL
NPCW =    2
NRIV =    0
MAXITT =  5000
INTER=  0
EPST= 0.00100000
DIFX =        50.00
DIFY =        50.00
KH =     0.00200
OMEGA =        30.00
KW =     0.0
LAMADA =     0.0

                         DISCHARGE FLOW, COORDINATE AND TEMPERATURE
DISCHARG          12    23        42.37        40.00
INTAKE            17    28       -42.37         0.0

                         BOUNDARY VALUES OF THE TEMPERATURE AND THE COORDINATES
    12          23          40.00
    17          28           0.0
```

APPENDIX D. OUTPUT (continued)

THEX-COMPONENT FLOW RATE

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10
29										
28										
27										
26										
25										
24										
23										
22										
21										
20										
19										
18										
17									0.0	0.0
16						0.0	0.0	0.0	0.0	-9.023
15					0.0	0.0	-2.653	-5.473	-9.973	-9.745
14					0.0	-2.033	-2.455	-3.835	-5.639	-7.131
13					0.0	-0.949	-1.389	-1.679	-1.697	-0.923
12				0.0	0.0	-0.459	-0.363	0.120	1.507	5.108
11		0.0	0.0	0.0	-1.537	-0.451	0.196	1.057	2.485	4.854
10	0.0	0.0	-0.431	-1.011	-0.674	-0.097	0.598	1.414	2.515	3.893
9	0.0	-0.273	-0.279	-0.363	-0.168	0.288	0.819	1.490	2.273	3.086
8	0.0	-0.068	-0.091	-0.025	0.175	0.498	0.939	1.450	1.999	2.505
7	0.0	0.026	0.072	0.174	0.354	0.628	0.974	1.371	1.771	2.108
6	0.0	0.090	0.199	0.274	0.454	0.680	0.965	1.279	1.618	1.852
5	0.0	0.226	0.239	0.348	0.485	0.675	0.904	1.205	1.523	1.725
4		0.0	0.291	0.329	0.463	0.637	0.917	1.035	1.618	1.690
3			0.0	0.201	0.448	0.573	0.647	0.569	0.0	
2			0.0	0.073	0.0					
1										

ROW	COLUMN 11	12	13	14	15	16	17	18	19	20
29							0.0	0.0	0.0	
28							-42.370	-15.370	0.0	0.0
27					0.0	0.0	0.0	-3.721	-5.950	0.0
26			0.0	0.0	0.0	6.983	15.264	6.364	1.292	0.0
25		0.0	0.0	1.168	4.672	5.701	9.139	12.727	4.658	0.0
24		0.0	0.0	-1.168	0.166	1.992	2.878	0.0		
23		42.370	16.439	0.0	-4.837	-0.759	0.370	0.0		
22		0.0	6.950	8.785	0.0	-0.562	-0.638	0.0	0.0	
21		0.0	2.567	2.972	0.0	-0.868	-2.349	-6.606	0.0	
20		0.0	0.352	0.529	0.0	-0.529	-1.307	-2.079	0.0	
19	0.0	0.0	-1.696	-1.198	0.0	0.013	-0.203	-0.466	0.0	
18	0.0	-10.427	-5.914	-3.648	0.0	0.815	0.894	0.865	0.0	
17	0.0	-7.581	-7.938	-7.441	0.0	2.339	2.518	1.417	0.0	
16	-17.308	-12.007	-10.759	0.0	9.518	6.043	5.406	2.689	0.0	0.0
15	-12.900	-12.355	0.0	7.771	7.401	6.871	10.400	4.578	-0.003	0.0
14	-12.162	0.0	6.917	6.402	5.410	3.678	0.0	0.0	0.003	0.0
13	0.0	7.473	6.579	5.500	4.180	2.413	0.0			
12	14.996	8.922	6.227	4.841	3.392	1.799	0.0			
11	7.940	6.791	5.365	4.046	2.746	1.390	0.0			
10	5.111	4.942	4.193	3.232	2.160	1.013	0.0	0.0		
9	3.674	3.670	3.234	2.533	1.635	0.518	-1.217	0.0		
8	2.827	2.831	2.537	2.025	1.363	0.586	-0.100	0.0		
7	2.299	2.287	2.065	1.671	1.156	0.641	0.162	0.0	0.0	
6	1.978	1.947	1.771	1.419	1.023	0.581	0.173	-0.350	0.0	0.0
5	1.802	1.780	1.600	1.264	0.873	0.555	0.216	-0.021	-0.138	0.0
4	1.743	1.728	1.683	1.047	0.747	0.472	0.264	0.067	0.015	0.0
3			0.0	0.618	0.488	0.378	0.238	0.116	0.036	0.0
2				0.0	0.268	0.307	0.172	0.117	0.042	0.0
1						0.0	0.092	0.072	0.046	0.0

APPENDIX D. OUTPUT (continued)

THET-COMPONENT FLOW RATE

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10
29										
28										
27										
26										
25										
24										
23										
22										
21										
20										
19										
18										
17									0.0	0.0
16						0.0	0.0	0.0	-9.023	-8.286
15					0.0	-2.653	-2.820	-4.500	-8.794	-11.441
14					-2.033	-3.075	-4.200	-6.304	-10.286	-16.471
13					-2.983	-3.515	-4.491	-6.322	-9.511	-15.549
12				0.0	-3.442	-3.419	-4.008	-4.934	-5.911	-5.661
11		0.0	0.0	-1.537	-2.355	-2.771	-3.148	-3.507	-3.541	-2.575
10	0.0	-0.431	-0.580	-1.200	-1.768	-2.086	-2.332	-2.406	-2.163	-1.357
9	-0.273	-0.437	-0.664	-1.005	-1.313	-1.555	-1.662	-1.622	-1.350	-0.769
8	-0.341	-0.460	-0.598	-0.804	-0.990	-1.114	-1.151	-1.073	-0.844	-0.447
7	-0.315	-0.413	-0.497	-0.625	-0.715	-0.768	-0.754	-0.672	-0.507	-0.256
6	-0.226	-0.304	-0.421	-0.445	-0.489	-0.483	-0.441	-0.333	-0.273	-0.130
5	0.0	-0.291	-0.311	-0.308	-0.299	-0.253	-0.140	-0.015	-0.071	-0.053
4		0.0	-0.274	-0.174	-0.125	-0.074	0.078	0.569	0.0	0.0
3			-0.073	0.073	0.0	0.0	0.0	0.0	0.0	
2			0.0	0.0	0.0					
1										

ROW	COLUMN 11	12	13	14	15	16	17	18	19	20
29							0.0	0.0	0.0	
28							27.000	15.370	0.0	0.0
27					0.0	0.0	23.279	13.141	5.950	0.0
26			0.0	0.0	6.983	8.280	14.379	8.069	4.658	0.0
25		0.0	1.168	3.504	8.012	11.710	17.976	0.0	0.0	0.0
24		0.0	0.0	4.837	9.839	12.596	15.098	0.0		
23		-25.931	-16.439	0.0	13.917	13.725	14.728	0.0		
22		-18.981	-14.603	-8.785	13.355	13.649	15.366	0.0	0.0	
21		-16.415	-14.197	-11.758	12.487	12.176	11.101	6.606	0.0	
20		-16.063	-14.020	-12.287	11.958	11.398	10.329	8.684	0.0	
19	0.0	-17.758	-13.523	-11.089	11.971	11.181	10.067	9.150	0.0	
18	-10.427	-13.246	-11.256	-7.441	12.786	11.261	9.638	8.685	0.0	
17	-18.008	-13.603	-10.759	0.0	15.125	11.439	8.538	7.268	0.0	
16	-12.707	-12.355	0.0	9.518	11.650	10.802	5.821	4.578	0.0	0.0
15	-12.162	0.0	7.771	9.148	11.120	14.331	0.0	-0.003	0.003	0.0
14	0.0	6.917	7.256	8.156	9.388	10.653	0.0	0.0	0.0	0.0
13	7.473	6.023	6.177	6.836	7.621	8.240	0.0			
12	1.399	3.528	4.591	5.387	6.028	6.441	0.0			
11	0.250	2.102	3.272	4.087	4.672	5.051	0.0			
10	0.081	1.352	2.312	3.015	3.524	4.038	0.0	0.0		
9	0.077	0.917	1.611	2.116	2.407	2.303	1.217	0.0		
8	0.081	0.623	1.099	1.454	1.630	1.617	1.318	0.0		
7	0.068	0.402	0.705	0.949	1.105	1.138	1.156	0.0	0.0	
6	0.037	0.225	0.353	0.553	0.664	0.730	0.632	0.350	0.0	0.0
5	0.015	0.045	0.018	0.162	0.346	0.390	0.395	0.234	0.138	0.0
4	0.0	0.0	-0.618	-0.138	0.071	0.183	0.198	0.181	0.123	0.0
3			0.0	-0.268	-0.029	0.043	0.075	0.102	0.087	0.0
2				0.0	0.0	-0.092	0.020	0.026	0.046	0.0
1						0.0	0.0	0.0	0.0	0.0

APPENDIX D. OUTPUT (continued)

THE NUMERICAL FOR THERMAL MODEL IS O. K.
NO. OF ITERATION = 1278 MAX DIF = 0.999E-03 OCCURS AT I = 18 J = 28

THE DISTRIBUTION OF EXCESS TEMP

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10
29										
28										
27										
26										
25										
24										
23										
22										
21										
20										
19										
18										
17									0.0	0.0
16						0.0	0.0	0.0	19.687	21.030
15					0.0	15.306	15.782	16.725	18.338	19.842
14					14.474	14.858	15.335	16.049	17.046	18.214
13					14.120	14.339	14.671	15.095	15.551	15.882
12				0.0	13.573	13.731	13.935	14.120	14.168	13.803
11		0.0	0.0	12.512	12.893	13.103	13.241	13.296	13.197	12.823
10	0.0	11.713	11.855	12.159	12.409	12.570	12.653	12.646	12.515	12.220
9	11.509	11.602	11.722	11.890	12.042	12.144	12.183	12.146	12.018	11.791
8	11.447	11.495	11.572	11.667	11.754	11.808	11.816	11.765	11.649	11.466
7	11.366	11.390	11.432	11.483	11.527	11.549	11.536	11.479	11.373	11.220
6	11.293	11.298	11.314	11.336	11.353	11.355	11.330	11.271	11.174	11.039
5	11.244	11.226	11.220	11.224	11.226	11.217	11.188	11.132	11.042	10.917
4		11.171	11.148	11.142	11.141	11.130	11.104	11.057	10.974	10.854
3			11.087	11.088	11.096	11.088	11.070	11.048	0.0	
2			11.057	11.057	0.0					
1										

ROW	COLUMN 11	12	13	14	15	16	17	18	19	20
29							0.0	0.0	0.0	
28							6.714	6.707	0.0	0.0
27					0.0	0.0	6.747	6.728	6.719	0.0
26			0.0	0.0	6.919	6.892	6.824	6.767	6.738	0.0
25		0.0	6.966	6.979	6.974	6.958	6.910	6.803	6.757	0.0
24		0.0	6.981	7.025	7.065	7.080	7.076	0.0		
23		40.000	38.174	7.102	7.207	7.244	7.257	0.0		
22		37.112	36.2[illegible]2	35.240	7.436	7.453	7.470	0.0	0.0	
21		34.891	34.57[illegible]	34.197	7.667	7.682	7.719	7.820	0.0	
20		32.912	32.855	32.776	7.903	7.907	7.921	7.948	0.0	
19	0.0	30.927	31.122	31.258	8.155	8.143	8.131	8.128	0.0	
18	27.308	28.669	29.411	29.858	8.437	8.400	8.355	8.327	0.0	
17	25.937	26.940	27.961	28.903	8.774	8.685	8.584	8.523	0.0	
16	23.494	25.128	26.551	9.514	9.211	8.998	8.797	8.682	0.0	0.0
15	21.715	23.438	10.135	9.837	9.565	9.315	8.947	8.749	8.706	0.0
14	19.981	10.806	10.455	10.149	9.908	9.754	0.0	8.704	8.691	0.0
13	11.717	11.180	10.745	10.413	10.181	10.055	0.0			
12	12.272	11.465	10.950	10.598	10.368	10.252	0.0			
11	12.081	11.469	11.01[illegible]	10.685	10.468	10.358	0.0			
10	11.775	11.338	10.970	10.687	10.490	10.383	0.0	0.0		
9	11.484	11.163	10.871	10.631	10.451	10.331	10.25[illegible]	0.0		
8	11.235	10.986	10.749	10.544	10.382	10.268	10.204	0.0		
7	11.031	10.825	10.624	10.444	10.297	10.187	10.121	0.0	0.0	
6	10.873	10.690	10.507	10.342	10.203	10.092	10.003	9.910	0.0	0.0
5	10.762	10.586	10.401	10.243	10.112	10.006	9.920	9.846	9.789	0.0
4	10.702	10.519	10.298	10.146	10.028	9.931	9.855	9.797	9.762	0.0
3			10.156	10.044	9.951	9.866	9.801	9.755	9.730	0.0
2				9.955	9.896	9.811	9.758	9.722	9.703	0.0
1						9.755	9.729	9.703	9.688	0.0

APPENDIX E. LISTING OF COMPUTER SOURCE PROGRAM

```
C
C         MAIN: TRANSPORT AND DISPERSION OF POLLUTANTS IN SURFACE
C         IMPOUNDMENTS - A FINITE DIFFERENCE MODEL
C         DEVELOPED BY G. T. YEH OF OAK RIDGE NATIONAL LAB
C         FOR ANY QUESTION CALL (615) 483-7285 OR
C         WRITE P. O. BOX X, BLDG 1505, ROOM 203
C               OAK RIDGE NATIONAL LABORATORY
C               OAK RIDGE, TN. 37830
C
C
      REAL*8 RNAME(99), PNAME(99)
      DIMENSION TITLE(20)
      DIMENSION CDPH(25,40),HIGH(25,40),DHCT(25,40),DHRT(25,40),
     1 DHLT(25,40),DHUP(25,40),DHBT(25,40),HIN(1000),TAUX(25,40),
     2 TAUY(25,40),PSI(25,40),PSIO(25,40),UU(25,40),VV(25,40),
     3 TO(25,40),T1(25,40),T2(25,40),EX(25,40),EY(25,40),IN(25,40)
C
C
      COMMON /CONTRL/ NX,NY,MUMMAX,NUMMAX,NUMAXT,MUMAXT
      COMMON /HYDR/ EPS,MAXIT,NPRIN,INTER
      COMMON /YEH/ NBD(99),NBDB(99),NBDE(99),MBD(99),MBDB(99),MBDE(99)
      COMMON /COBND/ NOBD,NPTOBD(99),IBXOBD(99),JBYOBD(99),
     1               IEXOBD(99), JEYOBD(99),INDOBD(99)
      COMMON /CCBND/ NCBD,  BXCBD(99), BYCBD(99),  EXCBD(99), EYCBD(99)
      COMMON /CHBNV/ BV(299),IBV(299),JBV(299),NBV
      COMMON /PARAM/ CV,CL,Q,WINS,WINANG,AVH,RHOW,RHOA,CKWIN,CKWAT
      COMMON/THEM/TURHOW,RKH,RKM,RAMADA,TINC,EPST,MAXITT,NPRINT,INTERT
     1 NBDT(99),NBDBT(99),NBDET(99),NBDIND(99)
      COMMON /THEM1/ QRIV(99),TRIV(99),QPOW(99),TPOW(99),NRIV,NPOW,
     1 IRIV(99),JRIV(99),IPOW(99),JPOW(99)
      COMMON /CTBNV/ QBVT(99),BVT(99),IBVT(99),JBVT(99),INDBT(99),NBVT
      COMMON /OPT/ JOPT,IREC
      COMMON /THOM/ A(99),B(99),C(99),D(99)
C
      NAMELIST /CONTRL/ NX,NY,NUMMAX,MUMMAX,MAXIT,NPRIN,INTER,EPS,
     1 NUMAXT,MUMAXT,MAXITT,NPRINT,INTERT,EPST,JOPT,IREC
      NAMELIST /BOUND/ NBD,NBDB,NBDE, MBD,MBDB,MBDE
      NAMELIST /OBND/ NOBD,NPTOBD,IBXOBD,JBYOBD,IEXOBD,JEYOBD,INDOBD
      NAMELIST /CBND/ NCBD, BXCBD, BYCBD, EXCBD, EYCBD
      NAMELIST /HIGHT/ HIN
      NAMELIST /PATCH/ IN
      NAMELIST /HBNV/ BV,IBV,JBV,NBV
      NAMELIST /TBNV/ QBVT,BVT,IBVT,JBVT,INDBT,NBVT
C
      DATA MAXNX,MAXNY,MAXNXY /25,40,1000/
C
CC
      CALL ECHO2
C
C
C          INITIALIZE ALL STORAGE AREA
      DO 98 I=1,MAXNX
      DO 98 J=1,MAXNY
      CDPH(I,J)=0.0
      HIGH(I,J)=0.0
      DHCT(I,J)=0.0
      DHRT(I,J)=0.0
      DHLT(I,J)=0.0
      DHUP(I,J)=0.0
      DHBT(I,J)=0.0
      TAUX(I,J)=0.0
      TAUY(I,J)=0.0
      PSI(I,J)=0.0
      PSIO(I,J)=0.0
      UU(I,J)=0.0
      VV(I,J)=0.0
      TO(I,J)=0.0
      T1(I,J)=0.0
      T2(I,J)=0.0
```

APPENDIX E. (continued)

```
          EX(I,J)=0.0                                               MAIN 350
          EY(I,J)=0.0                                               MAIN 355
       98 IN(I,J)=0                                                 MAIN 360
C                                                                   MAIN 365
          DO 99 I=1,MAXNXY                                          MAIN 370
       99 HIN(I)=0.0                                                MAIN 375
C                                                                   MAIN 380
          READ(5,10,END=999) (TITLE(I),I=1,15), IMODEL              MAIN 385
          WRITE(6,6000) (TITLE(I),I=1,15)                           MAIN 390
          READ(5,20) CV,CL,Q,WINS,WINANG,AVH,RHOW,RHOA,CKWIN,CKWAT  MAIN 395
          READ(5,CONTRL)                                            MAIN 400
          READ(5,BCUND)                                             MAIN 405
          READ(5,OBND)                                              MAIN 410
          READ(5,CEND)                                              MAIN 415
          READ(5,HENV)                                              MAIN 420
C                                                                   MAIN 425
C             TO CLASIFY THE GRID PCINTS                            MAIN 430
C             FOR EXTERIOR POINTS IN(I,J)=1                         MAIN 435
C             FOR INTERIOR POINTS IN(I,J)=4                         MAIN 440
C             FOR DIRICHLET BOUNDARY POINTS IN(I,J)=2               MAIN 445
C             FOR NEUMANN BOUNDARY POINTS IN(I,J)=8                 MAIN 450
C             FOR BOUNDARY CORNER POINTS IN(I,J)=6                  MAIN 455
C             FOR ISLAND POINTS IN(I,J)=10,18,26,34, ....           MAIN 460
C             FOR ISLAND CORNER POINTS IN(I,J)=14,22,30,38,46, ....... MAIN 465
C                                                                   MAIN 470
          DO 100 I=1,NX                                             MAIN 475
          DO 100 J=1,NY                                             MAIN 480
      100 IN(I,J)=1                                                 MAIN 485
          DO 101 NUM=1,NUMMAX                                       MAIN 490
          I=NBD(NUM)                                                MAIN 495
          NB=NBDB(NUM) - 1                                          MAIN 500
          NE=NBDE(NUM) + 1                                          MAIN 505
          DO 101 J=NB,NE                                            MAIN 510
          IN(I,J)=4                                                 MAIN 515
      101 IF(J .EQ. NB .OR. J.EQ. NE) IN(I,J)=2                     MAIN 520
          DO 103 NUM=1,NUMMAX                                       MAIN 525
          J=NBD(NUM)                                                MAIN 530
          I=NBDB(NUM) - 1                                           MAIN 535
          IN(I,J)=2                                                 MAIN 540
          I=NBDE(NUM) + 1                                           MAIN 545
      103 IN(I,J)=2                                                 MAIN 550
C                                                                   MAIN 555
          READ(5,PATCH)                                             MAIN 560
          WRITE(6,7000)                                             MAIN 565
          WRITE(6,8000) CV,CL,Q,WINS,WINANG,AVH,RHOW,RHOA,CKWIN,CKWAT MAIN 570
          WRITE(6,1000)                                             MAIN 575
C                                                                   MAIN 580
          CALL ALLOUT(NX,NY,IN,MAXNX,MAXNY)                         MAIN 585
C                                                                   MAIN 590
C                                                                   MAIN 595
          READ(5,HIGHT)                                             MAIN 600
C                                                                   MAIN 605
          CALL DEPTH(CDPH,HIGH,HIN,IN,MAXNX,MAXNY,MAXNXY)           MAIN 610
          CALL WINDS(TAUX,TAUY,MAXNX,MAXNY)                         MAIN 615
C                                                                   MAIN 620
          WRITE(6,1100)                                             MAIN 625
          CALL OUTPRT(NX,NY,CDPH,2,MAXNX,MAXNY,IN)                  MAIN 630
          WRITE(6,1200)                                             MAIN 635
          CALL OUTPRT(NX,NY,HIGH,2,MAXNX,MAXNY,IN)                  MAIN 640
C                                                                   MAIN 645
          CALL HYDRO(HIGH,TAUX,TAUY,PSI,PSIO,UU,VV,IN,MAXNX,MAXNY)  MAIN 650
C                                                                   MAIN 655
          CALL VELPLT(UU,VV,MAXNX,MAXNY)                            MAIN 660
C                                                                   MAIN 665
          IF(IMODEL .EQ. 1) GO TO 999                               MAIN 670
          READ(5,30) NPOW,NRIV                                      MAIN 675
          READ(5,35) DIFX,DIFY,TINC,TURHOW,RKH,RKN,RAMADA           MAIN 680
          READ(5,BOUNDT)                                            MAIN 685
          READ(5,TENV)                                              MAIN 690
          IF(NPOW .GE. 1) READ(5,40) (PNAME(K),IPOW(K),JPOW(K),QPOW(K), MAIN 695
```

APPENDIX E. (continued)

```
      1         TPOW(K),K=1,NPOW)                                       MAIN 700
       IF(NRIV.GE.1) READ(5,40) (RNAME(K),IRIV(K),JRIV(K),QRIV(K),      MAIN 705
      1      TRIV(K),K=1,NRIV)                                          MAIN 710
C                                                                       MAIN 715
       WRITE(6,5000) NPOW,NRIV,MAXITT,INTERT, EPST,DIXA,DIFY,RKH,TINC,  MAIN 720
      1 RKM,RAMADA                                                      MAIN 725
       IF(NPOW.GE.1) WRITE(6,5002) (PNAME(K),IPOW(K),JPOW(K),QPOW(K),   MAIN 730
      1  TPOW(K),K=1,NPOW)                                              MAIN 735
       IF(NRIV.GE.1) WRITE(6,5001) (RNAME(K),IRIV(K),JRIV(K),QRIV(K),   MAIN 740
      1 TRIV(K),K=1,NRIV)                                               MAIN 745
       WRITE(6,5100) (IBVT(K),JBVT(K),BVT(K),K=1,NBVT)                  MAIN 750
C                                                                       MAIN 755
       CALL QEXY(HIGH,PSI,UU,VV,EX,EY,DIFX,DIFY,MAXNX,MAXNY)            MAIN 760
C                                                                       MAIN 765
       WRITE(6,9100)                                                    MAIN 770
       CALL OUTPRT(NX,NY,UU,2,MAXNX,MAXNY,IN)                           MAIN 775
       WRITE(6,9500)                                                    MAIN 780
       CALL OUTPRT(NX,NY,VV,2,MAXNX,MAXNY,IN)                           MAIN 785
C                                                                       MAIN 790
      1 MAXNX,MAXNY)                                                    MAIN 795
C                                                                       MAIN 800
   999 CONTINUE                                                         MAIN 805
C                                                                       MAIN 810
    10 FORMAT(15A4,I5)                                                  MAIN 815
    20 FORMAT(8F8.3,2F8.6)                                              MAIN 820
    30 FORMAT(2I5)                                                      MAIN 825
    35 FORMAT(8F10.0)                                                   MAIN 830
    40 FORMAT(A8,2X,2I5,2F20.4)                                         MAIN 835
  1000 FORMAT(1H1,25X,'THE INDEX OF EACH POINT')                        MAIN 840
  1100 FORMAT(1H1,20X,'THE DEPTH AT THE CORNER')                        MAIN 845
  1200 FORMAT(1H1,20X,'DIMENSIONLESS DEPTH AT EACH POINT')              MAIN 850
  5000 FORMAT(1H1,20X,'INPUT DATA FOR THE THERMAL MODEL'/1X,            MAIN 855
      1 'NPOW = ',I3/1X,'NRIV = ',I3/1X,'MAXITT = ',I5/1X,'INTER=',I3,/1XMAIN 860
      2,'EPST= ',F10.[illegible]/1X,'DIFX = ',F10.2/1X,'DIFY = ',F10.2/1X,       MAIN 865
      3 'KH = ',F10.5/1X,'OMEGA = ',F10.2/1X,'KM = ',F10.5/1X,          MAIN 870
      4 'RAMADA = ',F10.5)                                              MAIN 875
  5001 FORMAT(1H0,20X,'RIVER INFLOW, COORDINATES AND RIVER TEMPERATURE', MAIN 880
      1 1X/(1X,A8,4X,I5,2X,I5,2X,F10.2,2X,F10.[illegible]))                      MAIN 885
  5002 FORMAT(1H0,20X,'DISCHARGE FLOW, COORDINATE AND TEMPERATURE',     MAIN 890
      1 1X/(1X,A8,4X,I5,2X,I5,2X,F10.2,2X,F10.2))                       MAIN 895
  5100 FORMAT(1H0,20X,'BOUNDARY VALUES OF THE TEMPERATURE AND THE COORDINMAIN 900
      1ATES '/(1X,1X,I5,5X,I5,5X,F10.2))                                MAIN 905
  6000 FORMAT(1H1,20X,15A4)                                             MAIN 910
  7000 FORMAT(1H0,20X,'INPUT DATA FOR HYDRO MODEL')                     MAIN 915
  8000 FORMAT(1H0,9X,'VELOCITY SCALE    =',F6.2,' FT/SEC',5X,           MAIN 920
      1          'LENGTH SCALE    =',F6.1,' FT'/10X,'TOTAL DISCHARGE  =', MAIN 925
      2          F7.1,' CFS',7X,'WIND SPEED       =',F6.2,' FT/SEC'/10X, MAIN 930
      3          'WIND DIRECTION   =',F6.1,' DEGREE',5X,'AVERAGE DEPTH  =', MAIN 935
      4          F6.2,' FT'/10X,'WATER DENSITY     =',F6.3,' SLUG/FT3',3X, MAIN 940
      5          'AIR DENSITY     =',F7.4,' SLUG/FT3'/10X,               MAIN 945
      6          'WIND STRESS COEF =',F9.7,10X,'BOTOM STRESS COEF =',F9.6) MAIN 950
  9000 FORMAT(1H0)                                                      MAIN 955
  9100 FORMAT(1H1,20X,'THEX-COMPONENT FLOW RATE')                       MAIN 960
  9500 FORMAT(1H1,20X,'THEY-COMPONENT FLOW RATE')                       MAIN 965
       STOP                                                             MAIN 970
       END                                                              MAIN 975
```

APPENDIX E. (continued)

```
      SUBROUTINE  ECHO2                                                 ECHO 005
      REAL*8      CM,CMT                                                ECHO 010
C                                                                       ECHO 015
      DIMENSION  A(20)                                                  ECHO 020
C                                                                       ECHO 025
      DATA        CMT / 'COMMENT ' /                                    ECHO 030
C                                                                       ECHO 035
      IPG = 0                                                           ECHO 040
      LINE = 0                                                          ECHO 045
      ICK = 0                                                           ECHO 050
      ICM = 0                                                           ECHO 055
   10 READ (55,100,END=99)  (A(I),I=1,20),CM                            ECHO 060
      ICK = ICK+1                                                       ECHO 065
      IF(ICK.LT.56 .AND. ICK.NE.1) GO TO 20                             ECHO 070
      ICK = 11                                                          ECHO 075
      IPG = IPG+1                                                       ECHO 080
      WRITE (6,200)  IPG,(I,I=1,8)                                      ECHO 085
   20 IF (CM.EQ.CMT)  GO TO 40                                          ECHO 090
      LINE = LINE+1                                                     ECHO 095
      IF (ICM.NE.1)  GO TO 30                                           ECHO 100
      WRITE (6,300)                                                     ECHO 105
      ICK = ICK+1                                                       ECHO 110
   30 ICM = 0                                                           ECHO 115
      WRITE (6,400)  LINE,(A(I),I=1,20)                                 ECHO 120
      WRITE (5,500)  (A(I),I=1,20)                                      ECHO 125
      GO TC 10                                                          ECHO 130
   40 IF (ICM.EQ.1)  GO TO 50                                           ECHO 135
      WRITE (6,300)                                                     ECHO 140
      ICK = ICK+1                                                       ECHO 145
   50 WRITE (6,600)  (A(I),I=3,20)                                      ECHO 150
      ICM = 1                                                           ECHO 155
      GO TC 10                                                          ECHO 160
   99 REWIND 5                                                          ECHO 165
      RETURN                                                            ECHO 170
C                                                                       ECHO 175
  100 FORMAT (20A4,T1,A8)                                               ECHO 180
  200 FORMAT (1H1///3X,'I N P U T   D A T A',75X,'PAGE',I4///3X,        ECHO 185
     2  'COLUMN NUMBER ----->  ',8I10,3X/17X,'----->  123456789012345', ECHO 190
     3  '67890123456789012345678901234567890123456789012345',           ECHO 195
     4  '67890'/3X,'LINE',3X,'NUMBER',9X,'|',8X,8('|',9X)/15X,'|',9X,   ECHO 200
     5  '|',8X,8('|',9X)/15X,'V',9X,'V',8X,8('V',9X)/)                  ECHO 205
  3C0 FORMAT (1H )                                                      ECHO 210
  400 FORMAT (3X,I13,' ----->  ',20A4)                                  ECHO 215
  500 FORMAT (20A4)                                                     ECHO 220
  6C0 FORMAT (25X,'******* ',18A4)                                      ECHO 225
      END                                                               ECHO 230
```

APPENDIX E. (continued)

```
      SUBROUTINE ALLOUT(NX,NY,IN,MAXNX,MAXNY)
C
      DIMENSION IN(MAXNX,MAXNY),NCOL(20)
C
      ISTART=1
  110 IEND=ISTART + 19
      IF(IEND .GT. NX) IEND=NX
      DO 120 I=1,20
  120 NCOL(I)=I-1+ISTART
      WRITE(6,1001) (NCOL(I+1-ISTART),I=ISTART,IEND)
      DO 130 JJ=1,NY
      J=NY+1-JJ
  130 WRITE(6,1002) J, (IN(I,J),I=ISTART,IEND)
      ISTART=IEND + 1
      IF(IEND .LT. NX) GO TO 110
C
 1001 FORMAT(1H0,45X,'COLUMN',/,3X,'ROW',' ' 20I4/)
 1002 FORMAT(1H ,1X,I3,4X,20I4)
C
      RETURN
      END
```

APPENDIX E. (continued)

```
      SUBROUTINE HYDRO(HIGH,TAUX,TAUY,PSI,PSIO,UU,VV,IN,MAXNX,MAXNY)
C
      DIMENSION TONE(99),HIGH(MAXNX,MAXNY),TAUX(MAXNX,MAXNY),
     1 TAUY(MAXNX,MAXNY),PSI(MAXNX,MAXNY),PSIO(MAXNX,MAXNY),
     2 UU(MAXNX,MAXNY),VV(MAXNX,MAXNY),IN(MAXNX,MAXNY)
C
      COMMON /CCNTRL/ NX,NY,NUMPAX,NUMMAX,NUMAXT,NUMAXT
      COMMON /HYDR/ EPS,MAXIT,NPRIN,INTER
      COMMON /TEN/ NBD(99),NBDB(99),NBDE(99),MBD(99),MBDB(99),MBDE(99)
      COMMON /CHBNV/ BV(299),IBV(299),JBV(299),NBV
      COMMON /PARAM/ CD,CL,Q,WINS,WINANG,AVH,RHOW,RHOA,CKWIN,CKWAT
      COMMON /THOM/ A(99),B(99),C(99),D(99)
C
      NX1=NX-1
      NY1=NY-1
      DIF=0.0
C
C          SET UP BOUNDARY VALUES AND MAKE INITIAL GUESS AND
C          INITIALIZE UU, VV, WW
C
      DO 100 IB=1,NBV
      I=IBV(IB)
      J=JBV(IB)
      PSI(I,J)=BV(IB)
  100 CONTINUE
      DO 110 I=1,NX
      DO 110 J=1,NY
  110 PSIO(I,J)=PSI(I,J)
      WRITE (6,1100)
      MAXMN=NX
      IF(MAXMN.LT.NY) MAXMN=NY
      ARG=3.14159/(2.0*MAXMN)
      ROIT=4.0*SIN(ARG)*COS(ARG)
C
C          START MAIN LOOP OF ITERATION
C
      DO 800 ITER=1,MAXIT
      INTOUT=(ITER-1)/NPRIN*NPRIN+1-ITER
C
C          X-IMPLICIT
C
      ISLAND=0
      DO 290 NUM=1,NUMMAX
C
C          LEFT BOUNDARY GRID POINT
C
      J=NBD(NUM)
      I=NBDB(NUM) - 1
      IF(IN(I,J).GE.10) GO TO 210
      IF(IN(I,J).EQ.8) GO TO 209
C
C          DIRICHLET BOUNDARY POINT
C
C
      A(I)=0.0
      B(I)=1.0 + ROIT
      C(I)=0.0
      D(I)=PSI(I,J)*(1.0+ROIT)
      GO TO 215
C          NEUMANN BOUNDARY POINT
C
  209 B(I)=1.0
      A(I)=0.0
      D(I)=0.0
      C(I)=-1.0
      GO TO 215
C
C          ISLAND BOUNDARY POINTS
C
```

APPENDIX E. (continued)

```
  210 ISLAND=ISLAND+1                                                   HYDR 350
      IF(ISLAND.NE.1) GO TO 213                                         HYDR 355
      IP1=I+1                                                           HYDR 360
      IM1=I-1                                                           HYDR 365
      JP1=J+1                                                           HYDR 370
      JM1=J-1                                                           HYDR 375
      IF(IN(I-1,J).GE.10) IM1=I                                         HYDR 380
      IF(IN(I+1,J).GE.10) IP1=I                                         HYDR 385
      IF(IN(I,J+1).GE.10) JP1=J                                         HYDR 390
      IF(IN(I,J-1).GE.10) JM1=J                                         HYDR 395
      HIP1=HIGH(IP1,J)                                                  HYDR 400
      HIM1=HIGH(IM1,J)                                                  HYDR 405
      HJP1=HIGH(I,JP1)                                                  HYDR 410
      HJM1=HIGH(I,JM1)                                                  HYDR 415
      HIJ=HIGH(I,J)                                                     HYDR 420
      A(I)=0.0                                                          HYDR 425
      B(I)=1.0 - 0.5*(HIP1-HIM1)/HIJ + ROIT                             HYDR 430
      C(I)=-1.0 + 0.5*(HIP1-HIM1)/HIJ                                   HYDR 435
      D(I)=(1.0+0.5*(HJP1-HJM1)/HIJ)*PSIO(I,JM1) - 2.0*PSIO(I,J) +      HYDR 440
     1 (1.0-0.5*(HJP1-HJM1)/HIJ)*PSIO(I,JP1) - 0.5*HIJ*HIJ*(TAUY(IP1,J)/HYDR 445
     2 HIP1-TAUY(IM1,J)/HIM1-TAUX(I,JP1)/HJP1+TAUX(I,JM1)/HJM1) +       HYDR 450
     3 PCIT*PSIO(I,J)                                                   HYDR 455
      GO TO 215                                                         HYDR 460
  213 A(I)=0.0                                                          HYDR 465
      B(I)=1.0 + ROIT                                                   HYDR 470
      C(I)=0.0                                                          HYDR 475
      D(I)=PSIIL*(1.0+ROIT)                                             HYDR 480
C                                                                       HYDR 485
C          RIGHT BOUNDARY GRID POINT                                    HYDR 490
C                                                                       HYDR 495
  215 IB=I                                                              HYDR 500
      IBP1=IB+1                                                         HYDR 505
      I=NBDE(NUM) + 1                                                   HYDR 510
      IF(IN(I,J).GE.10) GO TO 220                                       HYDR 515
      IF(IN(I,J).EQ.8) GO TO 219                                        HYDR 520
C                                                                       HYDR 525
C          DIRICHLET BOUNDARY POINT                                     HYDR 530
C                                                                       HYDR 535
      A(I)=0.0                                                          HYDR 540
      B(I)=1.0 + ROIT                                                   HYDR 545
      C(I)=0.0                                                          HYDR 550
      D(I)=PSI(I,J)*(1.0+ROIT)                                          HYDR 555
      GO TO 225                                                         HYDR 560
C                                                                       HYDR 565
C          NEUMANN BOUNDARY POINT                                       HYDR 570
C                                                                       HYDR 575
  219 A(I)=-1.0                                                         HYDR 580
      B(I)=1.0                                                          HYDR 585
      C(I)=0.0                                                          HYDR 590
      D(I)=0.0                                                          HYDR 595
      GO TO 225                                                         HYDR 600
C                                                                       HYDR 605
C          ISLAND BOUNDARY POINTS                                       HYDR 610
C                                                                       HYDR 615
  220 ISLAND=ISLAND+1                                                   HYDR 620
      IF(ISLAND.NE.1) GO TO 223                                         HYDR 625
      IP1=I+1                                                           HYDR 630
      IM1=I-1                                                           HYDR 635
      JP1=J+1                                                           HYDR 640
      JM1=J-1                                                           HYDR 645
      IF(IN(I+1,J).GE.10) IP1=I                                         HYDR 650
      IF(IN(I-1,J).GE.10) IM1=I                                         HYDR 655
      IF(IN(I,J+1).GE.10) JP1=J                                         HYDR 660
      IF(IN(I,J-1).GE.10) JM1=J                                         HYDR 665
      HIP1=HIGH(IP1,J)                                                  HYDR 670
      HIM1=HIGH(IM1,J)                                                  HYDR 675
      HJP1=HIGH(I,JP1)                                                  HYDR 680
      HJM1=HIGH(I,JM1)                                                  HYDR 685
```

APPENDIX E. (continued)

```
          HIJ=HIGH(I,J)                                                 HYDR 690
          A(I)=-1.0-0.5*(HIP1-HIM1)/HIJ                                 HYDR 695
          B(I)= 1.0 + 0.5*(HIP1-HIM1)/HIJ + ROIT                        HYDR 700
          C(I)=0.0                                                      HYDR 705
          D(I)=(1.0+0.5*(HJP1-HJM1)/HIJ)*PSIO(I,JM1) - 2.0*PSIO(I,J) +  HYDR 710
         1 (1.0-0.5*(HJP1-HJM1)/HIJ)*PSIO(I,JP1) - 0.5*HIJ*HIJ*(TAUY(IP1,J)/HYDR 715
         2 HIP1-TAUY(IM1,J)/HIM1-TAUX(I,JP1)/HJP1+TAUX(I,JM1)/HJM1) +   HYDR 720
         3 RCIT*PSIO(I,J)                                               HYDR 725
          GO TO 225                                                     HYDR 730
      223 A(I)=0.0                                                      HYDR 735
          B(I)=1.0+ROIT                                                 HYDR 740
          C(I)=0.0                                                      HYDR 745
          D(I)=PSIIL*(1.0+ROIT)                                         HYDR 750
      225 IE=I                                                          HYDR 755
          IEM1=IE-1                                                     HYDR 760
C                                                                       HYDR 765
C             INTERIOR POINTS                                           HYDR 770
C                                                                       HYDR 775
          DO 230 I=IBP1,IEM1                                            HYDR 780
          HIP1=HIGH(I+1,J)                                              HYDR 785
          HIM1=HIGH(I-1,J)                                              HYDR 790
          HJP1=HIGH(I,J+1)                                              HYDR 795
          HJM1=HIGH(I,J-1)                                              HYDR 800
          HIJ=HIGH(I,J)                                                 HYDR 805
          A(I)=-1.0-0.5*(HIP1-HIM1)/HIJ                                 HYDR 810
          B(I)=2.0 + ROIT                                               HYDR 815
          C(I)=-1.0+0.5*(HIP1-HIM1)/HIJ                                 HYDR 820
          D(I)=(1.0+0.5*(HJP1-HJM1)/HIJ)*PSIO(I,J-1) - 2.0*PSIO(I,J) +  HYDR 825
         1 (1.0-0.5*(HJP1-HJM1)/HIJ)*PSIO(I,J+1) - 0.5*HIJ*HIJ*(TAUY(I+1,J)/HYDR 830
         2 HIP1-TAUY(I-1,J)/HIM1-TAUX(I,J+1)/HJP1+TAUX(I,J-1)/HJM1) +   HYDR 835
         3 RCIT*PSIO(I,J)                                               HYDR 840
      230 CONTINUE                                                      HYDR 845
C                                                                       HYDR 850
          CALL THOMAS(IB,IE,TONE)                                       HYDR 855
C                                                                       HYDR 860
          IF(ISLAND.NE.1) GO TO 240                                     HYDR 865
          IF(IN(IB,J).GE.10) PSIIL=TONE(IB)                             HYDR 870
          IF(IN(IE,J).GE.10) PSIIL=TONE(IE)                             HYDR 875
      240 DO 250 I=IB,IE                                                HYDR 880
      250 PSI(I,J)=TONE(I)                                              HYDR 885
      290 CONTINUE                                                      HYDR 890
C                                                                       HYDR 895
          DO 300 I=1,NX                                                 HYDR 900
          DO 300 J=1,NY                                                 HYDR 905
          IF(IN(I,J).GE.10) PSI(I,J)=PSIIL                              HYDR 910
      300 PSIO(I,J)=PSI(I,J)                                            HYDR 915
C                                                                       HYDR 920
C             Y-IMPLICIT                                                HYDR 925
C                                                                       HYDR 930
          ISLAND=0                                                      HYDR 935
          DO 390 NUM=1,NUMMAX                                           HYDR 940
C                                                                       HYDR 945
C             BOTTOM BOUNDARY GRID POINT                                HYDR 950
C                                                                       HYDR 955
          I=MBD(NUM)                                                    HYDR 960
          J=MBDB(NUM)-1                                                 HYDR 965
          IF(IN(I,J).GE.10) GO TO 310                                   HYDR 970
          IF(IN(I,J).EQ.8) GO TO 309                                    HYDR 975
C                                                                       HYDR 980
C             DIRICHLET BOUNDARY POINT                                  HYDR 985
C                                                                       HYDR 990
          A(J)=0.0                                                      HYDR 995
          B(J)=1.0+ROIT                                                 HYDR1000
          C(J)=0.0                                                      HYDR1005
          D(J)=PSI(I,J)*(1.0+ROIT)                                      HYDR1010
          GO TO 315                                                     HYDR1015
C                                                                       HYDR1020
C             NEUMANN BOUNDARY POINT                                    HYDR1025
C                                                                       HYDR1030
      309 A(J)=0.0                                                      HYDR1035
```

APPENDIX E. (continued)

```
      B(J)=1.0
      C(J)=-1.0
      D(J)=0.0
      GO TO 315
C
C          ISLAND BOUNDARY POINTS
C
  310 ISLAND=ISLAND+1
      IF(ISLAND.NE.1) GO TO 313
      IP1=I+1
      IM1=I-1
      JP1=J+1
      JM1=J-1
      IF(IN(I+1,J).GE.10) IP1=I
      IF(IN(I-1,J).GE.10) IM1=I
      IF(IN(I,J+1).GE.10) JP1=J
      IF(IN(I,J-1).GE.10) JM1=J
      HIP1=HIGH(IP1,J)
      HIM1=HIGH(IM1,J)
      HJP1=HIGH(I,JP1)
      HJM1=HIGH(I,JM1)
      HIJ=HIGH(I,J)
      A(J)=0.0
      B(J)=1.0 - 0.5*(HJP1-HJM1)/HIJ + ROIT
      C(J)=-1.0 + 0.5*(HJP1-HJM1)/HIJ
      D(J)=(1.0+0.5*(HIP1-HIM1)/HIJ)*PSIO(IM1,J) - 2.0*PSIO(I,J) +
     1 (1.0-0.5*(HIP1-HIM1)/HIJ)*PSIO(IP1,J) - 0.5*HIJ*HIJ*(TAUY(IP1,J)/
     2 HIP1-TAUY(IM1,J)/HIM1-TAUX(I,JP1)/HJP1+TAUX(I,JM1)/HJM1) +
     3 ROIT*PSIO(I,J)
      GO TO 315
  313 A(J)=0.0
      B(J)=1.0+ROIT
      C(J)=0.0
      D(J)=PSIIL*(1.0+ROIT)
  315 JB=J
      JBP1=JB+1
C
C
C          TOP BOUNDAR GRID POINTS
C
      J=NBDZ(NUM) + 1
      IF(IN(I,J).GE.10) GO TO 320
      IF(IN(I,J).EQ.8) GO TO 319
C
C          DIRICHLET BOUNDARY POINT
C
      A(J)=0.0
      B(J)=1.0+ROIT
      C(J)=0.0
      D(J)=PSI(I,J)*(1.0+ROIT)
      GO TO 325
C
C          NEUMANN BOUNDARY POINT
C
  319 A(J)=-1.0
      B(J)=1.0
      C(J)=0.0
      D(J)=0.0
      GO TO 325
C
C          ISLAND BOUNDARY POINTS
C
  320 ISLAND=ISLAND+1
      IF(ISLAND.NE.1) GO TO 323
      IP1=I+1
      IM1=I-1
      JP1=J+1
      JM1=J-1
      IF(IN(I+1,J).GE.10) IP1=I
      IF(IN(I-1,J).GE.10) IM1=I
```

APPENDIX E. (continued)

```
      IF(IN(I,J+1).GE.10) JP1=J                                         HYDR1390
      IF(IN(I,J-1).GE.10) JM1=J                                         HYDR1395
      HIP1=HIGH(IP1,J)                                                  HYDR1400
      HIM1=HIGH(IM1,J)                                                  HYDR1405
      HJP1=HIGH(I,JP1)                                                  HYDR1410
      HJM1=HIGH(I,JM1)                                                  HYDR1415
      HIJ=HIGH(I,J)                                                     HYDR1420
      A(J)=-1.0 - 0.5*(HJP1-HJM1)/HIJ                                   HYDR1425
      B(J)= 1.0 + 0.5*(HJP1-HJM1)/HIJ + ROIT                            HYDR1430
      C(J)=0.0                                                          HYDR1435
      D(J)=(1.0+0.5*(HIP1-HIM1)/HIJ)*PSIO(IM1,J) - 2.0*PSIO(I,J) +      HYDR1440
     1 (1.0-0.5*(HIP1-HIM1)/HIJ)*PSIO(IP1,J) - 0.5*HIJ*HIJ*(TAUY(IP1,J)/HYDR1445
     2 HIP1-TAUY(IM1,J)/HIM1-TAUX(I,J+P)/HJP1+TAUX(I,JM1)/HJM1) +       HYDR1450
     3 ROIT*PSIO(I,J)                                                   HYDR1455
      GO TO 325                                                         HYDR1460
  323 A(J)=0.0                                                          HYDR1465
      B(J)=1.0+ROIT                                                     HYDR1470
      C(J)=0.0                                                          HYDR1475
      D(J)=PSIIL*(1.0+ROIT)                                             HYDR1480
  325 JE=J                                                              HYDR1485
      JEM1=JE-1                                                         HYDR1490
C                                                                       HYDR1495
C          INTERIOR POINTS                                              HYDR1500
C                                                                       HYDR1505
      DO 330 J=JBP1,JEM1                                                HYDR1510
      HIP1=HIGH(I+1,J)                                                  HYDR1515
      HIM1=HIGH(I-1,J)                                                  HYDR1520
      HJP1=HIGH(I,J+1)                                                  HYDR1525
      HJM1=HIGH(I,J-1)                                                  HYDR1530
      HIJ=HIGH(I,J)                                                     HYDR1535
      A(J)=-1.0-0.5*(HJP1-HJM1)/HIJ                                     HYDR1540
      B(J)=2.0 + ROIT                                                   HYDR1545
      C(J)=-1.0+0.5*(HJP1-HJM1)/HIJ                                     HYDR1550
      D(J)=(1.0+0.5*(HIP1-HIM1)/HIJ)*PSIO(I-1,J) - 2.0*PSIO(I,J) +      HYDR1555
     1 (1.0-0.5*(HIP1-HIM1)/HIJ)*PSIO(I+1,J) - 0.5*HIJ*HIJ*(TAUY(I+1,J)/HYDR1560
     2 HIP1-TAUY(I-1,J)/HIM1-TAUX(I,J+1)/HJP1+TAUX(I,J-1)/HJM1) +       HYDR1565
     3 ROIT*PSIO(I,J)                                                   HYDR1570
  330 CONTINUE                                                          HYDR1575
C                                                                       HYDR1580
      CALL THOMAS(JB,JE,TONE)                                           HYDR1585
C                                                                       HYDR1590
      IF(ISLAND.NE.1) GO TO 340                                         HYDR1595
      IF(IN(I,JB).GE.10) PSIIL=TONE(JB)                                 HYDR1600
      IF(IN(I,JE).GE.10) PSIIL=TONE(JE)                                 HYDR1605
  340 DO 350 J=JB,JE                                                    HYDR1610
  350 PSI(I,J)=TONE(J)                                                  HYDR1615
  390 CONTINUE                                                          HYDR1620
C                                                                       HYDR1625
      IMAX=0                                                            HYDR1630
      JMAX=0                                                            HYDR1635
      DIFMAX=0.0                                                        HYDR1640
      DO 420 NUM=1,NUMMAX                                               HYDR1645
      I=NBD(NUM)                                                        HYDR1650
      NB=NEDB(NUM)                                                      HYDR1655
      NE=NEDE(NUM)                                                      HYDR1660
      DO 420 J=NB,NE                                                    HYDR1665
      IF(PSIO(I,J) .EQ.0.0) GO TO 420                                   HYDR1670
      DIF=ABS((PSI(I,J)-PSIO(I,J))/PSIO(I,J))                           HYDR1675
      IF(DIF-DIFMAX)420,420,410                                         HYDR1680
  410 DIFMAX=DIF                                                        HYDR1685
      IMAX=I                                                            HYDR1690
      JMAX=J                                                            HYDR1695
  420 CONTINUE                                                          HYDR1700
C                                                                       HYDR1705
      DO 450 I=1,NX                                                     HYDR1710
      DO 450 J=1,NY                                                     HYDR1715
      IF(IN(I,J).GE.10) PSI(I,J)=PSIIL                                  HYDR1720
  450 PSIO(I,J)=PSI(I,J)                                                HYDR1725
C                                                                       HYDR1730
      IF(ITER.LE.2) GO TO 500                                           HYDR1735
```

APPENDIX E. (continued)

```
      IF(DIFMAX-EPS) 900,900,500
  500 IF(INTER.EQ.0) GO TO 800
C
      WRITE(6,1300) ITER,DIFMAX,IMAX,JMAX
      IF(INTOUT.EQ.0) CALL OUTPRT(NX,NY,PSI,2,MAXNX,MAXNY,IN)
  800 CONTINUE
      WRITE(6,1900) ITER, MAXIT, DIFMAX, EPS
      GO TO 999
C
C          A CONVERGENT SOLUTION HAS BEEN OBTAINED
C
  900 WRITE(6,1200) DIFMAX,ITER,IMAX,JMAX
C
      WRITE(6,1400)
      CALL OUTPRT(NX,NY,PSI,2,MAXNX,MAXNY,IN)
C
      CALL INFVEL(PSI,UU,VV,IN,MAXNX,MAXNY)
      CALL OBDVEL(PSI,UU,VV,MAXNX,MAXNY)
C
      DO 920 I=1,NX
      DO 920 J=1,NY
      IF(HIGH(I,J).EQ.0.0) GO TO 920
      HIGH(I,J)=HIGH(I,J)*CL
      UU(I,J)=UU(I,J)*Q/(HIGH(I,J)*CL)
      VV(I,J)=VV(I,J)*Q/(HIGH(I,J)*CL)
  920 CONTINUE
      WRITE(6,2000)
      CALL OUTPRT(NX,NY,UU,2,MAXNX,MAXNY,IN)
      WRITE(6,3000)
      CALL OUTPRT(NX,NY,VV,2,MAXNX,MAXNY,IN)
C
  999 RETURN
C
 1100 FORMAT(1H1,25X,'THE BOUNDARY VALUES AND THE INITIAL GUESSES')
 1200 FORMAT(1H1,30X,'THE SOLUTION FOR THE HYDRO MODEL'///1X,
     1       20X,'THE PRESENT NUMERICAL SCHEME IS O. K. '/1X,
     2            10X,'DIFMAX=',E15.7,'    FOR THE',I4,'TH ITERATION',
     3       '     OCCURING AT (',I2,',',I2,')')
 1300 FORMAT(1H0,'NO. OF ITER = ',I4,'  MAX DIF = ',E10.3,'  OCCURS AT I
     1 = ',I3,' J = ',I3)
 1400 FORMAT(1H0,25X,'THE STREAM FUNCTION -  PSI')
 1900 FORMAT(1H1,5X,'ITER=',I4,5X,'IMAX=',I4,5X,'DIFMAX=',E12.5,
     1      5X,'EPS=',E12.5,5X,'ITER .GT. MAXIT NG')
 2000 FORMAT(1H1,20X,'THE X-COMPONENT VELOCITY - U ')
 3000 FORMAT(1H1,20X,'THE Y-COMPONENT VELOCITY - V')
      END
```

APPENDIX E. (continued)

```
      SUBROUTINE OUTPRT(NX,NY,PCT,LTEST,MAXNX,MAXNY,IN)
      DIMENSION PCT(MAXNX,MAXNY),IN(MAXNX,MAXNY),NCOL(20)
      REAL VFORM(4) /'(1H+', 'TXX', ',10F', '8.3)'/,
     1    TAB(10) /',T10', ',T18', ',T26', ',T34', ',T42', ',T50',
     2              ',T58', ',T66', ',T74', ',T82'/
C
      ISTART=1
  900 IEND=ISTART + 9
      IF(IEND .GT. NX) IEND=NX
      DO 100 I=1,10
  100 NCOL(I)=I-1+ISTART
      WRITE(6,2000) (NCOL(I+1-ISTART),I=ISTART,IEND)
      DO 200 JJ=1,NY
      J=NY+1-JJ
      WRITE(6,3000) J
      II=ISTART
  300 IF(IN(II,J)/LTEST*LTEST .EQ. IN(II,J)) GO TO 400
      II=II+1
      IF(II .LE. IEND) GO TO 300
      GO TO 200
  400 IM=II
  600 IF(IM.EQ.IEND.OR.IN(IM+1,J)/LTEST*LTEST.NE.IN(IM+1,J)) GO TO 700
      IM=IM+1
      GO TO 600
  700 VFORM(2)=TAB(II-ISTART+1)
      WRITE(6,VFORM) (PCT(I,J),I=II,IM)
      II=IM+1
      IF(IM .LT. IEND) GO TO 300
  200 CONTINUE
      ISTART=IEND+1
      WRITE(6,1000)
      IF(IEND .LT. NX) GO TO 900
C
 1000 FORMAT(1H1)
 2000 FORMAT(1H0,38X,'COLUMN'/1X,3X,'ROW',10I8/)
 3000 FORMAT(4X,I3)
C
      RETURN
      END
```

APPENDIX E. (continued)

```
      SUBROUTINE DEPTH(CDPH,HIGH,HIN,IN,MAXNX,MAXNY,MAXNXY)
      DIMENSION CDPH(MAXNX,MAXNY),HIGH(MAXNX,MAXNY),HIN(MAXNXY),
     1 IN(MAXNX,MAXNY)
      COMMON /CONTRL/ NX,NY,NOMMAX,NUMMAX,NOMAXT,NUMAXT
      COMMON /YEH/ NBD(99),NBDB(99),NBDE(99),MBD(99),MBDB(99),MBDE(99)
      COMMON /PARAM/ CV,CL,Q,WINS,WINANG,AVH,RHOW,RHOA,CKWIN,CKWAT
C
      DO 100 I=1,NX
      DO 100 J=1,NY
      HIGH(I,J)=0.0
  100 CDPH(I,J)=0.0
      NPT=0
      DO 210 NUM=1,NUMMAX
      J=NBD(NUM)
      NB=NBDB(NUM)
      NE=NBDE(NUM)
      DO 200 I=NB,NE
      NPT=NPT+1
      CDPH(I,J)=HIN(NPT)
  200 CONTINUE
      CDPH(NB-1,J)=CDPH(NB,J)
      CDPH(NE+1,J)=CDPH(NE,J)
  210 CONTINUE
      DO 220 MOM=1,NOMMAX
      I=MBD(MOM)
      JB=MBDB(MOM)
      JE=MBDE(MOM)
      CDPH(I,JB-1)=CDPH(I,JB)
      CDPH(I,JE+1)=CDPH(I,JE)
  220 CONTINUE
      DO 240 I=1,NX
      IP1=I+1-I/NX
      IM1=I-1+1/I
      DO 240 J=1,NY
      LL=IN(I,J)
      ICOR=(LL-6)/8*8+6-LL
      IF(ICOR.NE.0) GO TO 240
      JP1=J+1-J/NY
      JM1=J-1+1/J
      CDPH(I,J)=0.5*(CDPH(IP1,J)+CDPH(IM1,J)+CDPH(I,JP1)+CDPH(I,JM1))
  240 CONTINUE
      DO 260 NUM=1,NUMMAX
      J=NBD(NUM)
      NB=NBDB(NUM)
      NE=NBDE(NUM)
      DO 250 I=NB,NE
      HIGH(I,J)=0.25*(CDPH(I,J)+CDPH(I-1,J)+CDPH(I,J-1)+CDPH(I-1,J-1))
  250 CONTINUE
      HIGH(NB-1,J)=HIGH(NB,J)
      HIGH(NE+1,J)=HIGH(NE,J)
  260 CONTINUE
      DO 270 MOM=1,NOMMAX
      I=MBD(MOM)
      JB=MBDB(MOM)
      JE=MBDE(MOM)
      HIGH(I,JB-1)=HIGH(I,JB)
      HIGH(I,JE+1)=HIGH(I,JE)
  270 CONTINUE
      DO 280 I=1,NX
      IP1=I+1-I/NX
      IM1=I-1+1/I
      DO 280 J=1,NY
      LL=IN(I,J)
      ICOR=(LL-6)/8*8+6-LL
      IF(ICOR.NE.0) GO TO 280
      JP1=J+1-J/NY
      JM1=J-1+1/J
      HIGH(I,J)=0.5*(HIGH(IP1,J)+HIGH(IM1,J)+HIGH(I,JP1)+HIGH(I,JM1))
  280 CONTINUE
      DO 300 I=1,NX
      DO 300 J=1,NY
      HIGH(I,J)=HIGH(I,J)/CL
  300 CONTINUE
      RETURN
      END
```

APPENDIX E. (continued)

```
      SUBROUTINE WINDS(TAUX,TAUY,MAXNX,MAXNY)                          WIND 005
      DIMENSION TAUX(MAXNX,MAXNY),TAUY(MAXNX,MAXNY)                    WIND 010
      COMMON /CONTRL/ NX,NY,NUMMAX,NUMMAX,NUMAXT,NUMAXT                WIND 015
      COMMON /PARAM/ CV,CL,Q,WINS,WINANG,AVH,RHOW,RHOA,CKWIN,CKWAT     WIND 020
C                                                                      WIND 025
      TAU=RHOA*CKWIN*WINS**2                                           WIND 030
      TAUDVD=RHOW*Q*CKWAT*CV/CL**2                                     WIND 035
      TAUVX=(TAU/TAUDVD)*COS(WINANG/3.14159)                           WIND 040
      TAUVY=(TAU/TAUDVD)*SIN(WINANG/3.14159)                           WIND 045
      DO 100 J=1,NY                                                    WIND 050
      DO 100 I=1,NX                                                    WIND 055
      TAUX(I,J)=TAUVX                                                  WIND 060
      TAUY(I,J)=TAUVY                                                  WIND 065
  100 CONTINUE                                                         WIND 070
      RETURN                                                           WIND 075
      END                                                              WIND 080
```

APPENDIX E. (continued)

```
      SUBROUTINE INPVEL(PSI,UU,VV,IN,MAXNX,MAXNY)                       INPV 005
      DIMENSION PSI(MAXNX,MAXNY),UU(MAXNX,MAXNY),VV(MAXNX,MAXNY),       INPV 010
     1 IN(MAXNX,MAXNY)                                                  INPV 015
      COMMON /CONTRL/ NX,NY,NUMMAX,NUMMAX,NUMAXT,NUMAXT                 INPV 020
C                                                                       INPV 025
      DO 900 NUM=1,NUMMAX                                               INPV 030
      I=NBD(NUM)                                                        INPV 035
      NB=NBDE(NUM) - 1                                                  INPV 040
      NE=NBDE(NUM) + 1                                                  INPV 045
      DO 900 J=NB,NE                                                    INPV 050
      IF(J .EQ. NB .OR. J .EQ. NE) GO TO 901                            INPV 055
      UU(I,J)=-(PSI(I,J+1)-PSI(I,J-1))/2.0                              INPV 060
      GO TO 900                                                         INPV 065
  901 IF(J .EQ. NB) UU(I,J)=-(PSI(I,J+1)-PSI(I,J))/1.0                  INPV 070
      IF(J.EQ.NE) UU(I,J)=-(PSI(I,J)-PSI(I,J-1))/1.0                    INPV 075
  900 CONTINUE                                                          INPV 080
      DO 910 NUM=1,NUMMAX                                               INPV 085
      J=NBD(NUM)                                                        INPV 090
      NB=NBDE(NUM)-1                                                    INPV 095
      NE=NBDE(NUM)+1                                                    INPV 100
      DO 910 I=NB,NE                                                    INPV 105
      IF(I.EQ.NB .OR. I.EQ.NE) GO TO 911                                INPV 110
      VV(I,J)=(PSI(I+1,J)-PSI(I-1,J))/2.0                               INPV 115
      GO TO 910                                                         INPV 120
  911 IF(I .EQ. NB) VV(I,J)=(PSI(I+1,J)-PSI(I,J))/1.0                   INPV 125
      IF(I .EQ. NE) VV(I,J)=(PSI(I,J)-PSI(I-1,J))/1.0                   INPV 130
  910 CONTINUE                                                          INPV 135
      DO 940 I=1,NX                                                     INPV 140
      IP1=I+1-I/NX                                                      INPV 145
      IM1=I-1+1/I                                                       INPV 150
      DO 940 J=1,NY                                                     INPV 155
      LL=IN(I,J)                                                        INPV 160
      ICOR=(LL-6)/8*8+6-LL                                              INPV 165
      IF(ICOR.NE.0) GO TO 940                                           INPV 170
      JP1=J+1-J/NY                                                      INPV 175
      JM1=J-1+1/J                                                       INPV 180
      UU(I,J)=0.5*(UU(IP1,J)+UU(I,JP1)+UU(IM1,J)+UU(I,JM1))             INPV 185
      VV(I,J)=0.5*(VV(IP1,J)+VV(I,JP1)+VV(IM1,J)+VV(I,JM1))             INPV 190
  940 CONTINUE                                                          INPV 195
      RETURN                                                            INPV 200
      END                                                               INPV 205
```

APPENDIX E. (continued)

```
      SUBROUTINE OBDVEL(PSI,UU,VV,MAXNX,MAXNY)
      DIMENSION PSI(MAXNX,MAXNY),UU(MAXNX,MAXNY),VV(MAXNX,MAXNY)
      COMMON /CONTRL/ NX,NY,NUMPAX,NUMMAX,NUMAXT,NUMAXT
      COMMON /COBND/ NOBD,NPTOBD(99),IBXOBD(99),IEYOBD(99),
     1              IEXOBD(99), JBYOBD(99),INDOBD(99)
C
      DO 940 IB=1,NOBD
      IBX=IBXOBD(IB)
      JBY=JBYOBD(IB)
      IEX=IEXOBD(IB)
      JEY=JEYOBD(IB)
      NTPTS=NPTOBD(IB)
      IF(IEX .EQ. IBX) GO TO 941
      IF(JEY .EQ. JBY) GO TO 942
      VELY=    -(PSI(IEX,JEY)-PSI(IBX,JBY))*
     1         ((JEY-JBY)/((IEX-IBX)**2+(JEY-JBY)**2))
      VELX=    (PSI(IEX,JEY)-PSI(IBX,JBY))*
     1       ((IEX-IBX)/((IEX-IBX)**2+(JEY-JBY)**2))
      DO 950 IPT=1,NTPTS
      I=IBX+IPT-1
      J=JBY+IPT-1
      IF(JEY .LT. JBY) J=JBY-IPT+1
      UU(I,J)=VELX
      VV(I,J)=VELY
  950 CONTINUE
      GO TO 940
  941 VELX=-(PSI(IEX,JEY)-PSI(IBX,JBY))/(JEY-JBY)
      I=IBX
      DO 960 IPT=1,NTPTS
      J=JBY + IPT - 1
      IF(JEY .LT. JBY) J=JBY-IPT+1
      UU(I,J)=VELX
  960 CONTINUE
      GO TO 940
  942 VELY=(PSI(IEX,JEY)-PSI(IBX,JBY))/(IEX-IBX)
      J=JBY
      DO 970 IPT=1,NTPTS
      I=IBX+IPT-1
      VV(I,J)=VELY
  970 CONTINUE
  940 CONTINUE
      RETURN
      END
```

APPENDIX E. (continued)

```
      SUBROUTINE VELPLT(UU,VV,MAXNX,MAXNY)
C
      DIMENSION UU(MAXNX,MAXNY),VV(MAXNX,MAXNY)
      COMMON /CCNTRL/ NX,NY,NUMPAX,NUMMAX,NUMAXT,NUMAXT
      COMMON /CCBND/ NCBD,  BXCBD(99), BYCBD(99),  EXCBD(99), EYCBD(99)
C
      CALL CALCMP(0)
      CALL BGNPL(1)
C
      YAXIS=9.0
      XAXIS=YAXIS*(NX-1)/(NY-1)
      XORIGN=1.0
      YORIGN=1.0
      XSTP=2.0
      YSTP=2.0
      XMAX=NX
      YMAX=NY
      SCALE=YAXIS/(YMAX-YORIGN)
      CALL TITLE('FIGURE 7 FLOW PATTERN$',100,' ',0,' ',0,XAXIS,YAXIS)
      CALL GRAF(XORIGN,XSTP,XMAX,YORIGN,YSTP,YMAX)
C
C        DRAW BOUNDARIES
C
      DO 100 I=1,NCBD
      XFROM=(BXCBD(I)-1.0)*SCALE
      YFROM=(BYCBD(I)-1.0)*SCALE
      XTO=(EXCBD(I)-1.0)*SCALE
      YTO=(EYCBD(I)-1.0)*SCALE
      CALL VECTOR(XFROM,YFROM,XTO,YTO,0)
  100 CONTINUE
C
C        CALCULATE SCALE FOR THE VELOCITY
C
      SCAL=1.0E6
      DO 280 NUM=1,NUMMAX
      J=NBD(NUM)
      IB=NBDB(NUM)
      IE=NBDE(NUM)
      DO 250 I=IB,IE
      IF(ABS(UU(I,J)).LT.1.0E-6) GO TO 225
      USCALE=1.0/ABS(UU(I,J))
      GO TO 230
  225 USCALE=1.0E6
  230 IF(ABS(VV(I,J)).LT.1.0E-6) GO TO 245
      VSCALE=1.0/ABS(VV(I,J))
      GO TO 249
  245 VSCALE=1.0E6
  249 SCAL=AMIN1(SCAL,USCALE,VSCALE)
  250 CONTINUE
  280 CONTINUE
C
C        DRAW VELOCITY VECTOR
C
      DO 400 NUM=1,NUMMAX
      J=NBD(NUM)
      IB=NBDB(NUM)
      IE=NBDE(NUM)
      DO 300 I=IB,IE
      XFROM=(I-1)*SCALE
      YFROM=(J-1)*SCALE
      XTO=XFROM+UU(I,J)*SCALE*SCAL
      YTO=YFROM+VV(I,J)*SCALE*SCAL
      CALL VECTOR(XFROM,YFROM,XTO,YTO,101)
  300 CONTINUE
  400 CONTINUE
C
      CALL ENDPL(1)
      CALL DONEPL
C
      RETURN
      END
```

APPENDIX E. (continued)

```
      DIMENSION HIGH(MAXNX,MAXNY),PSI(MAXNX,MAXNY),UU(MAXNX,MAXNY),      QEXY 005
     1 VV(MAXNX,MAXNY),EX(MAXNX,MAXNY),EY(MAXNX,MAXNY)                   QEXY 010
      COMMON /CONTRL/ NX,NY,NUMBAX,NUMMAX,NUMAXT,NUMAXT                  QEXY 015
      COMMON /PARAM/ CV,CL,Q,WINS,WINANG,AVH,RHOW,RHOA,CKWIN,CKWAT       QEXY 020
      COMMON /GT/ NBD(99),NBDB(99),NBDE(99),NBDIND(99),MBD(99),MBDB(99),QEXY 025
     1 MBDE(99),MBDIND(99)                                               QEXY 030
C                                                                        QEXY 035
      DO 100 I=1,NX                                                      QEXY 040
      DO 100 J=1,NY                                                      QEXY 045
      UU(I,J)=0.0                                                        QEXY 050
      VV(I,J)=0.0                                                        QEXY 055
      EX(I,J)=0.0                                                        QEXY 060
      EY(I,J)=0.0                                                        QEXY 065
  100 CONTINUE                                                           QEXY 070
C                                                                        QEXY 075
      DO 200 NUM=1,NUMAXT                                                QEXY 080
      J=NBD(NUM)                                                         QEXY 085
      J2=J+1                                                             QEXY 090
      IB=NBDB(NUM)                                                       QEXY 095
      IE2=NBDE(NUM)+1                                                    QEXY 100
      DO 200 I=IB,IE2                                                    QEXY 105
  200 UU(I,J)=-Q*(PSI(I,J2)-PSI(I,J))                                    QEXY 110
C                                                                        QEXY 115
C                                                                        QEXY 120
      DO 300 NUM=1,NUMAXT                                                QEXY 125
      I=MBD(NUM)                                                         QEXY 130
      I2=I+1                                                             QEXY 135
      JB=MBDB(NUM)                                                       QEXY 140
      JE2=MBDE(NUM)+1                                                    QEXY 145
      DO 300 J=JB,JE2                                                    QEXY 150
  300 VV(I,J)=Q*(PSI(I2,J)-PSI(I,J))                                     QEXY 155
C                                                                        QEXY 160
C                                                                        QEXY 165
      DO 400 I=1,NX                                                      QEXY 170
      IP1=I+1-I/NX                                                       QEXY 175
      DO 400 J=1,NY                                                      QEXY 180
      JP1=J+1-J/NY                                                       QEXY 185
      AHIGH=0.5*(HIGH(I,JP1)+HIGH(I,J))*CL                               QEXY 190
      UX=UU(I,J)                                                         QEXY 195
      IF(AHIGH.LE.0.000001) GO TO 401                                    QEXY 200
      UX=UU(I,J)/AHIGH                                                   QEXY 205
  401 BHIGH=0.5*(HIGH(IP1,J)+HIGH(I,J))*CL                               QEXY 210
      VY=VV(I,J)                                                         QEXY 215
      IF(BHIGH .LE. 0.000001) GO TO 402                                  QEXY 220
      VY=VV(I,J)/BHIGH                                                   QEXY 225
  402 VEL=SQRT(UX*UX+VY*VY)                                              QEXY 230
      IF(VEL.LE.0.000001) GO TO 400                                      QEXY 235
      EX(I,J)=DIFY*VEL + (DIFX-DIFY)*UX*UX/VEL                           QEXY 240
      EX(I,J)=DIFY                                                       QEXY 245
      EY(I,J)=DIFY*VEL + (DIFX-DIFY)*VY*VY/VEL                           QEXY 250
      EY(I,J)=DIFY                                                       QEXY 255
  400 CONTINUE                                                           QEXY 260
C                                                                        QEXY 265
      RETURN                                                             QEXY 270
      END                                                                QEXY 275
```

APPENDIX E. (continued)

```
      SUBROUTINE THODEL(HIGH,DHCT,DHRT,DHLT,DHUP,DHBT,UU,VV,EX,EY,T0,    THOD 005
     1 T1,T2,IN,MAXNX,MAXNY)                                              THOD 010
      DIMENSION HIGH(MAXNX,MAXNY),DHCT(MAXNX,MAXNY),DHRT(MAXNX,MAXNY),   THOD 015
     1 DHLT(MAXNX,MAXNY),DHUP(MAXNX,MAXNY),DHBT(MAXNX,MAXNY),             THOD 020
     3 T0(MAXNX,MAXNY),T1(MAXNX,MAXNY),T2(MAXNX,MAXNY),IN(MAXNX,MAXNY)   THOD 025
      DIMENSION TONE(99)                                                  THOD 030
      COMMON /CCNTRL/ NX,NY,NUMMAX,NUMMAX,NUMAXX,NUMAXY                   THOD 035
      COMMON /PARAM/ CV,CL,Q,WINS,WINANG,AVE,RHOW,RHOA,CKWIN,CKWAT        THOD 040
      COMMON/THEM/TURNOW,RKH,RKM,RAMADA,TINC,EPST,MAXITT,NPRINT,INTERT    THOD 045
      COMMON /GT/ NBD(99),NBDB(99),NBDE(99),NBDIND(99),MBD(99),MBDB(99),THOD 050
     1 MBDE(99),MBDIND(99)                                                THOD 055
      COMMON /THEM1/ QRIV(99),TRIV(99),QPOW(99),TPOW(99),NRIV,NPOW,       THOD 060
     1 IRIV(99),JRIV(99),IPOW(99),JPOW(99)                                THOD 065
      COMMON /CTBNV/ QBVT(99),BVT(99),IBVT(99),JBVT(99),INDBT(99),NBVT    THOD 070
      COMMON /OPT/ JOPT,IREC                                              THOD 075
      COMMON /THOM/ A(99),B(99),C(99),D(99)                               THOD 080
C                                                                         THOD 085
      TINCI=2.0/TINC                                                      THOD 090
      DO 100 I=1,NX                                                       THOD 095
      DO 100 J=1,NY                                                       THOD 100
      T0(I,J)=0.0                                                         THOD 105
      T1(I,J)=0.0                                                         THOD 110
      T2(I,J)=0.0                                                         THOD 115
  100 CONTINUE                                                            THOD 120
      KOUNT=0                                                             THOD 125
      QKOUNT=0.0                                                          THOD 130
      DO 110 IPT=1,NBVT                                                   THOD 135
      I=IBVT(IPT)                                                         THOD 140
      J=JBVT(IPT)                                                         THOD 145
      IND=INDBT(IPT)                                                      THOD 150
      IF(IND.EQ.1)  QKOUNT=QKOUNT+QBVT(IPT)                               THOD 155
      IF(IND.EQ.1)  KOUNT=KOUNT+1                                         THOD 160
      T0(I,J)=BVT(IPT)                                                    THOD 165
      T1(I,J)=BVT(IPT)                                                    THOD 170
  110 T2(I,J)=BVT(IPT)                                                    THOD 175
C                                                                         THOD 180
      DO 150 I=1,NX                                                       THOD 185
      I2=I+1-I/NX                                                         THOD 190
      DO 150 J=1,NY                                                       THOD 195
      J2=J+1-J/NY                                                         THOD 200
      DHCT(I,J)=0.25*(HIGH(I,J)+HIGH(I2,J)+HIGH(I,J2)+HIGH(I2,J2))        THOD 205
      DHRT(I,J)=0.5*(HIGH(I2,J)+HIGH(I2,J2))                              THOD 210
      DHLT(I,J)=0.5*(HIGH(I,J)+HIGH(I,J2))                                THOD 215
      DHUP(I,J)=0.5*(HIGH(I,J2)+HIGH(I2,J2))                              THOD 220
      DHBT(I,J)=0.5*(HIGH(I,J)+HIGH(I2,J))                                THOD 225
  150 CONTINUE                                                            THOD 230
C                                                                         THOD 235
                                                                          THOD 240
C                                                                         THOD 245
C         START THE ITERATION LOOP OR TIME MARCHING                       THOD 250
C                                                                         THOD 255
      DO 900 IJK=1,MAXITT                                                 THOD 260
      INTOUT=IJK/NPRINT*NPRINT-IJK                                        THOD 265
C                                                                         THOD 270
      DO 201 I=1,NX                                                       THOD 275
      DO 201 J=1,NY                                                       THOD 280
      T1(I,J)=T2(I,J)                                                     THOD 285
  201 T0(I,J)=T2(I,J)                                                     THOD 290
C                                                                         THOD 295
C         X-DIRECTION IMPLICIT                                            THOD 300
C                                                                         THOD 305
      HREC=0.0                                                            THOD 310
      TREC=0.0                                                            THOD 315
      IF(IREC.EQ.0) GO TO 208                                             THOD 320
      DO 205 IPT=1,NBVT                                                   THOD 325
      I=IBVT(IPT)                                                         THOD 330
      J=JBVT(IPT)                                                         THOD 335
      IND=INDBT(IPT)                                                      THOD 340
      IF(IND.EQ.1) GO TO 205                                              THOD 345
```

APPENDIX E. (continued)

```
          HREC=HREC + T1(I,J)*QBVT(IPT)
      205 CONTINUE
          TREC=HREC/QKOUNT
          HREC=HREC/KOUNT
C
      208 DO 299 NUH=1,NUNAXT
          J=NBD(NUH)
          J1=J-1+1/J
          J2=J+1-J/NY
          NUNIND=NBDIND(NUH)
          IF(NUNIND.EQ.99 .AND. JOPT.EQ.1) GO TO 299
          IB=NBDB(NUH)
          IE=NBDE(NUH)
C
          DO 250 I=IB,IE
          I2=I+1-I/NX
          I1=I-1+1/I
          HCT=DHCT(I,J)
          HRT=DHRT(I,J)
          HLT=DHLT(I,J)
          HUP=DHUP(I,J)
          HBT=DHBT(I,J)
          EXRT=HRT*EX(I2,J)
          UURT=UU(I2,J)*0.5
          EXLT=HLT*EX(I,J)
          UULT=UU(I,J)*0.5
          EYUP=HUP*EY(I,J2)
          VVUP=VV(I,J2)*0.5
          EYBT=HBT*EY(I,J)
          VVBT=VV(I,J)*0.5
          IF(IN(I,J).EQ.4 .OR. IN(I,J+1).EQ.4) GO TO 210
C
C             LEFT SIDE OF THE GRID CELL IS THE BOUNDARY
C
          EXLT=0.0
          UULT=0.0
      210 IF(IN(I+1,J).EQ.4 .OR. IN(I+1,J+1).EQ.4) GO TO 215
C
C             RIGHT SIDE OF THE GRID CELL IS THE BOUNDARY
C
          EXRT=0.0
          UURT=0.0
      215 IF(IN(I,J).EQ.4 .OR. IN(I+1,J).EQ.4) GO TO 220
C
C             BOTTOM SIDE OF THE GRID CELL IS THE BOUNDARY
C
          EYBT=0.0
          VVBT=0.0
      220 IF(IN(I,J+1).EQ.4 .OR. IN(I+1,J+1).EQ.4) GO TO 225
C
C             TOP SIDE OF THE GRID CELL IS THE BOUNDARY
C
          EYUP=0.0
          VVUP=0.0
C
C             BOTH BOTTOM AND TOP SIDES OF THE GRID CELL ARE IN THE INTERIOR
C
      225 A(I)=-UULT-EXLT
          B(I)=UURT-UULT+EXRT+EXLT+CL*CL*(RKH/TURNOV+0.5*HCT*(TINCI+RKH+
         1 RAMADA))
          C(I)=UURT-EXRT
          D(I)=EYUP*(T1(I,J2)-T1(I,J))-EYBT*(T1(I,J)-T1(I,J1))-
         1 VVUP*(T1(I,J2)+T1(I,J)) + VVBT*(T1(I,J1)+T1(I,J)) -
         2 CL*CL*T1(I,J)*(RKH/TURNOV-0.5*HCT*(TINCI+RKK+RAMADA))
C
          IF(NRIV.EQ.0) GO TO 245
C
C             LOAD BY INFLOWS OR OUTFLOWS
C
          DO 242 IR=1,NRIV
```

APPENDIX E. (continued)

```
      IF(IRIV(IR).NE.I .OR. JRIV(IR).NE.J) GO TO 242
      IF(QRIV(IR).LE.0.0) D(I)=D(I)+QRIV(IR)*T1(I,J)
      IF(QRIV(IR).GT.0.0) D(I)=D(I)+QRIV(IR)*TRIV(IR)
  242 CONTINUE
C
  245 IF(NPOW.EQ.0) GO TO 250
C
C          LOAD B: DISCHARGES OR INTAKES
C
      DO 248 IPW=1,NPOW
      IF(IPOW(IPW).NE.I .OR. JPOW(IPW).NE.J) GO TO 248
      IF(QPOW(IPW).LT.0.0) D(I)=D(I)+QPOW(IPW)*T1(I,J)
      IF(QPOW(IPW).GT.0.0) D(I)=D(I)+QPOW(IPW)*TPOW(IPW) + NREC*IREC
  248 CONTINUE
  250 CONTINUE
C
      IF(JOPT.NE.1) GO TO 255
      IF(NUNIND.GE.10) GO TO 254
C
C          DIRICHLET BOUNDARY CONDITION IMPOSED ON THE LEFT CELL
C
      I=IB
      B(I)=1.0
      A(I)=0.0
      C(I)=0.0
      D(I)=T1(I,J) + TREC*IREC
C
  254 IF(NUNIND.EQ.1 .OR. NUNIND.EQ.11) GO TO 255
C
C          DIRICHLET BOUNDARY CONDITION IMPOSED ON THE RIGHT CELL
C
      I=IE
      B(I)=1.0
      A(I)=0.0
      C(I)=0.0
      D(I)=T1(I,J) + TREC*IREC
C
  255 CALL THOMAS(IB,IE,TONE)
C
      DO 260 I=IB,IE
  260 T2(I,J)=TONE(I)
  259 CONTINUE
C
      DO 301 I=1,NX
      DO 301 J=1,NY
      T1(I,J)=T2(I,J)
  301 CONTINUE
C
C            Y-DIRECTION IMPLICIT
C
      TREC=0.0
      NREC=0.0
      IF(NRECIRC.EQ.0) GO TO 308
      DO 305 IPT=1,NBVT
      I=IBVT(IPT)
      J=JBVT(IPT)
      IND=INDBT(IPT)
      IF(IND.EQ.1) GO TO 305
      NREC=NREC + T1(I,J)*QBVT(IPT)
  305 CONTINUE
      TREC=NREC/QKOUNT
      NREC=NREC/KOUNT
C
  308 DO 399 NUM=1,NUMAXT
      I=NBD(NUM)
      I1=I-1+1/I
      I2=I+1-I/NX
      NUNIND=NBDIND(NUM)
      IF(NUMIND.EQ.99 .AND. JOPT.EQ.1) GO TO 399
      JB=NBDB(NUM)
```

APPENDIX E. (continued)

```
      JE=NBDE(NUN)
C
      DO 350 J=JB,JE
      J1=J-1+1/J
      J2=J+1-J/NY
      HCT=DHCT(I,J)
      HRT=DHRT(I,J)
      HLT=DHLT(I,J)
      HBT=DHBT(I,J)
      HUP=DHUP(I,J)
      EXRT=HRT*EX(I2,J)
      UURT=UU(I2,J)*0.5
      EXLT=HLT*EX(I,J)
      UULT=UU(I,J)*0.5
      EYUP=HUP*EY(I,J2)
      VVUP=VV(I,J2)*0.5
      EYBT=HBT*EY(I,J)
      VVBT=VV(I,J)*0.5
      IF(IN(I,J).EQ.4 .OR. IN(I+1,J).EQ.4) GO TO 310
C
C          BOTTOM SIDE OF THE GRID IS THE BOUNDARY
C
      EYBT=0.0
      VVBT=0.0
  310 IF(IN(I,J+1).EQ.4 .OR. IN(I+1,J+1).EQ.4) GO TO 315
C
C          THE TOP SIDE OF THE GRID CELL IS THE BOUNDARY
C
      EYUP=0.0
      VVUP=0.0
  315 IF(IN(I,J).EQ.4 .OR. IN(I,J+1).EQ.4) GO TO 320
C
C          LEFT SIDE OF THE GRID CELL IS THE BOUNDARY
C
      EXLT=0.0
      UULT=0.0
  320 IF(IN(I+1,J).EQ.4 .OR. IN(I+1,J+1).EQ.4) GO TO 325
C
C          RIGHT SIDE OF THE GRID CELL IS THE BOUNDARY
C
      EXRT=0.0
      UURT=0.0
C
  325 A(J)=-VVBT-EYBT
      B(J)=VVUP-VVBT+EYUP+EYBT+CL*CL*(HCH/TURNON+0.5*HCT*(TINCI+RKH+
     1 RAMADA))
      C(J)=VVUP-EYUP
      D(J)=EXRT*(T1(I2,J)-T1(I,J))-EXLT*(T1(I,J)-T1(I1,J)) -
     1      UURT*(T1(I2,J)+T1(I,J))+UULT*(T1(I1,J)+T1(I,J)) -
     2 CL*CL*T1(I,J)*(HCH/TURNON-0.5*HCT*(TINCI+RKH+RAMADA))
C
      IF(NRIV.EQ.0) GO TO 345
C
C          LOAD BY INFLOWS OR  OUTFLOWS
C
      DO 342 IR=1,NRIV
      IF(IRIV(IR).NE.I .OR. JRIV(IR).NE.J) GO TO 342
      IF(QRIV(IR).LE.0.0) D(J)=D(J)+QRIV(IR)*T1(I,J)
      IF(QRIV(IR).GT.0.0) D(J)=D(J)+QRIV(IR)*TRIV(IR)
  342 CONTINUE
C
  345 IF(NPOW.EQ.0) GO TO 350
C
C          LOAD BY DISCHARGES OR  INTAKES
C
      DO 348 IPW=1,NPOW
      IF(IPOW(IPW).NE.I .OR. JPOW(IPW).NE.J) GO TO 348
      IF(QPOW(IPW).LT.0.0) D(J)=D(J)+QPOW(IPW)*T1(I,J)
      IF(QPOW(IPW).GT.0.0) D(J)=D(J)+QPOW(IPW)*TPOW(IPW) + HREC*IREC
  348 CONTINUE
```

APPENDIX E. (continued)

```
  350 CONTINUE                                                         THOD1400
C                                                                      THOD1405
      IF(JOPT.NE.1) GO TO 355                                          THOD1410
      IF(NUMIND.GE.10) GO TO 354                                       THOD1415
C                                                                      THOD1420
C         DIRICHLET BOUNDARY CONDITION IMPOSED ON THE BOTTOM CELL      THOD1425
C                                                                      THOD1430
      J=JB                                                             THOD1435
      E(J)=1.0                                                         THOD1440
      A(J)=0.0                                                         THOD1445
      C(J)=0.0                                                         THOD1450
      D(J)=T1(I,J) + TREC*IREC                                         THOD1455
  354 IF(NUMIND.EQ.1 .OR. NUMIND.EQ.11) GO TO 355                      THOD1460
C                                                                      THOD1465
C         DIRICHLET BOUNDARY CONDITION IMPOSED ON THE TOP CELL         THOD1470
C                                                                      THOD1475
      J=JE                                                             THOD1480
      E(J)=1.0                                                         THOD1485
      A(J)=0.0                                                         THOD1490
      C(J)=0.0                                                         THOD1495
      D(J)=T1(I,J) + TREC*IREC                                         THOD1500
C                                                                      THOD1505
  355 CALL THOMAS(JB,JE,TONE)                                          THOD1510
C                                                                      THOD1515
      DO 360 J=JB,JE                                                   THOD1520
  360 T2(I,J)=TONE(J)                                                  THOD1525
  399 CONTINUE                                                         THOD1530
C                                                                      THOD1535
C                                                                      THOD1540
      DTMAX=0.0                                                        THOD1545
      IMAX=0                                                           THOD1550
      JMAX=0                                                           THOD1555
C                                                                      THOD1560
C         CALCULATE MAXIMUM DIFFERENCE                                 THOD1565
C                                                                      THOD1570
      DO 499 NUM=1,NUMAXT                                              THOD1575
      I=NBD(NUM)                                                       THOD1580
      JB=NBDB(NUM)                                                     THOD1585
      JE=NBDE(NUM)                                                     THOD1590
      DO 480 J=JB,JE                                                   THOD1595
      IF(T0(I,J).EQ.0.0) GO TO 480                                     THOD1600
      DTMA=ABS((T2(I,J)-T0(I,J))/T0(I,J))                              THOD1605
      IF(DTMAX.GT.DTMA) GO TO 480                                      THOD1610
      DTMAX=DTMA                                                       THOD1615
      IMAX=I                                                           THOD1620
      JMAX=J                                                           THOD1625
  480 CONTINUE                                                         THOD1630
  499 CONTINUE                                                         THOD1635
C                                                                      THOD1640
      IF(DTMAX.LE.EPST .AND. IJK.GE.2) GO TO 910                       THOD1645
      IF(INTERT.EQ.0) GO TO 900                                        THOD1650
      WRITE(6,1000) IJK,DTMAX,IMAX,JMAX                                THOD1655
      IF(IJK.EQ.1) CALL OUTPRT(NX,NY,T1,2,MAXNX,MAXNY,IW)              THOD1660
      IF(INTOUT.NE.0) GO TO 900                                        THOD1665
      CALL OUTPRT(NX,NY,T1,2,MAXNX,MAXNY,IW)                           THOD1670
  900 CONTINUE                                                         THOD1675
C                                                                      THOD1680
C         END OF ITERATION LOOP OR TIME MARCHING LOOP                  THOD1685
C                                                                      THOD1690
      WRITE(6,3000) IJK,MAXITT,DTMAX, EPST                             THOD1695
      CALL OUTPRT(NX,NY,T1,2,MAXNX,MAXNY,IW)                           THOD1700
C                                                                      THOD1705
      RETURN                                                           THOD1710
C                                                                      THOD1715
  910 CONTINUE                                                         THOD1720
      WRITE(6,2000) IJK,DTMAX,IMAX,JMAX                                THOD1725
      CALL OUTPRT(NX,NY,T1,2,MAXNX,MAXNY,IW)                           THOD1730
C                                                                      THOD1735
```

APPENDIX E. (continued)

```
C          FORMAT                                                      TMOD1740
C                                                                      TMOD1745
C                                                                      TMOD1750
 1000 FORMAT(1H0,'ITER NO. = ',I5,'  MAX DIF = ',E10.3,' OCCURS AT I= ',TMOD1755
     1 I3,'  J = ',I3)                                                 TMOD1760
 3000 FORMAT(1H1,5X,'ITER=',I5,5X,'IMAX=',I4,5X,'DIFMAX=',E12.5,       TMOD1765
     1       5X,'EPS=',E12.5,5X,'ITER .GT. MAXIT NG')                  TMOD1770
 2000 FORMAT(1H1,20X,'THE NUMERICAL FOR THERMAL MODEL IS O. K.'/1X,    TMOD1775
     1 20X,'NO. OF ITERATION = ',I5,'  MAX DIF = ',E10.3,' OCCURS AT I =TMOD1780
     2 ',I3,'  J = ',I3//1X,20X,'THE DISTRIBUTION OF EXCESS TEMP'//)   TMOD1785
       RETURN                                                          TMOD1790
       END                                                             TMOD1795
```

APPENDIX E. (continued)

```
      SUBROUTINE THOMAS(K1, KN, E)                    THOM 005
      DIMENSION E(99)                                 THOM 010
      COMMON /THOM/ A(99),B(99),C(99),D(99)           THOM 015
      K1P1 = K1 + 1                                   THOM 020
      KNM1 = KN - 1                                   THOM 025
      KSUM = KNM1 + K1                                THOM 030
      C(K1) = C(K1)/B(K1)                             THOM 035
      D(K1) = D(K1)/B(K1)                             THOM 040
      C(KN) = 0.0                                     THOM 045
      DO 10 K=K1P1,KN                                 THOM 050
      DEN = B(K) - A(K)*C(K-1)                        THOM 055
      C(K) = C(K)/DEN                                 THOM 060
      D(K) = (D(K) - A(K)*D(K-1))/DEN                 THOM 065
   10 CONTINUE                                        THOM 070
      E(KN) = D(KN)                                   THOM 075
      DO 15 KK=K1,KNM1                                THOM 080
      K = KSUM - KK                                   THOM 085
      E(K) = D(K) - C(K)*E(K+1)                       THOM 090
   15 CONTINUE                                        THOM 095
      RETURN                                          THOM 100
      END                                             THOM 105

IHC002I STOP      0
```