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A Two Depth Averaged Numerical Temperature Model of Narragansett Bay

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A TWO DIMENSIONAL DEPTH AVERAGED NUMERICAL
TEMPERATURE MODEL OF NARRAGANSETT BAY

BY

JOHN J. ALFANO

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

OCEAN ENGINEERING

UNIVERSITY OF RHODE ISLAND

1973

MASTER OF SCIENCE THESIS

OF

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1973

ABSTRACT

The numerical temperature model proposed in this thesis approximates the temperature distributions produced by natural or man made conditions in Narragansett Bay. The model approximates the temperature distribution by averaging the vertical structure over depth. A two dimensional, planar coordinate system continuously specifies the temperatures within the bay. A hydrodynamic model calculates the necessary velocities and depths required by the thermal model. The combined thermal-hydraulic model calculates bottom roughness, Coriolis acceleration, non-linear convective terms, astronomical tidal series for Rhode Island Sound, and air-water heat exchange. Known river flow inputs are used as boundary conditions. To simplify the model geometry the Mount Hope Bay structure is replaced by a boundary flow rate at the Mount Hope Bridge grids.

Narragansett Bay has an average depth of 32 feet and a length of approximately 24 nautical miles with a maximum width of six nautical miles. By specifying a total of 325 square grids with eleven boundary grids $1/2$ nautical mile in length the model approximates the features of the estuary.

Verification of the model is achieved through conservation of mass analysis and comparison of predicted temperatures

for given meteorological and water temperature data. The model is used to predict the thermal fields from a proposed power plant near Rome Point in the West Passage of Narragansett Bay. By specifying plant flow rates and dispersion coefficients characteristic temperature field conditions are observed. Under specified plant operating conditions, a maximum temperature rise of 5.5°C above ambient in the discharge grid is predicted. For a temperature rise of 5.5°C the area encompassed by the 1°C excess isotherm is approximately two square miles while the 0.5°C isotherm area is about four square miles. Temperature isotherms over a tidal cycle retain the same general shape, especially in the far field where temperatures fall below 0.4°C excess.

This model can simulate salinity or other non-decaying constituents if appropriate boundary condition changes are made.

In summary, the thermal model gives valuable insight into natural and man-made temperature distributions that will aid the marine scientist in preserving and understanding the dynamics of Narragansett Bay.

ACKNOWLEDGEMENT

Although computer modeling is primarily a struggle between the modeler and the model it would be a grave injustice not to mention the support I received from my committee. In particular Dr. Frank White's encouraging words on the model, this thesis and other related matters deserve commendation. During the darkest days Dr. George Brown's help proved invaluable as well as Professor Warren Hagist's encouraging support.

It is unfortunate that certain ultimate goals were not achieved but the confidence and love of my wife clarified my perspective and stimulated this work. We weathered the storm together.

Mr. Kurt Hess's constant support and patience went beyond the normal bounds of friendship.

Miss Linda Weinreich, showing profitable enthusiasm with the many drafts made the manuscript into a thesis.

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I. INTRODUCTION

A. GENERAL

A model tries to represent the salient characteristics of a system so that the user can gain insight into the governing features of the particular site. This thesis explains the implementation of a model that will predict vertically-averaged temperature distribution in Narragansett Bay. The thermal model, as it is called, uses a tidal model (Hess, 4) to provide the necessary hydrodynamic structure in the bay. The hydrodynamic inputs are velocity, tidal elevation, and bottom friction. The thermal model then predicts the effect of thermal convection and diffusion as well as the heat exchange that takes place at the air-water interface for specified locations or grids. Pertinent meteorological data must be read in for periods of simulation. In essence, the model predicts the movement or mixing of heat subject to eleven known boundary conditions around the bay.

The model is a digital computer program, written in Fortran language, that uses over three hundred $1/2$ by $1/2$ nautical mile cells to represent the characteristic features of the bay. The model is two dimensional in that

it determines a temperature value for each cell volume in both a general north-south and east-west direction.

With this model, marine life behavior and electric generating plant thermal discharges can be studied. Other applications, such as salinity prediction, are possible with minor model modifications.

To begin this study, a breakdown of main model components is shown in Figure 1.1. It can be seen that to understand the convective, diffusive and time varying quantities we must rely on a hydrodynamic model that will simulate the transporting medium accurately. The grouping of these terms, in block diagram form, indicates no interaction of constituent on flow behavior. If the model had a vertical structure, one would couple the hydrodynamic model with constituent model through the vertical buoyancy flux term, creating a much more difficult problem and many more cells.

B. HISTORICAL DATA

General historical information consists of data obtained from various cruises and buoy measurements taken in and around the bay area during the last 100 years. Tables 1.1, 1.2, and 1.3 present a summary of temperature informa-

FIGURE 1.1. MODEL COMPONENTS

<u>PERIOD</u>	<u>TIME</u>	<u>PROBE</u>	<u>LOCATION</u>	<u>REFERENCE</u>
1879-1942	Monthly	Surface	Brenton's Reef	31
1881-1883	Monthly	Surface	Newport	31
1905-Dec., 1966	Hourly	Surface (Air)	Weather Data	56
Jan., 1967-Present	3 Hour Interval	Surface (Air)	T.F. Green Airport	56
8/24/51 to 9/18/51 (Not Daily)	Hourly	Variable	Narragansett Bay	32
2/19/52 to 9/16/52 (Not Daily)	Hourly	Variable	Narragansett Bay	32
4/16/50 to 9/28/52	Weekly		Wickford Harbor and Greenwich Bay	33
6/51 to 9/52	Variable	Variable	Narragansett Bay	58
2/1-21/56 (Cr. 14)	Hourly	Variable	Narragansett Bay	34 (mostly isotherms)
4/2-20/56 (CR. 15)	Hourly	Variable	Narragansett Bay	34

TABLE 1.1. TEMPERATURE DATA, 1879-1956

<u>PERIOD</u>	<u>TIME</u>	<u>PROBE</u>	<u>LOCATION</u>	<u>REFERENCE</u>
6/11-28/56 (Cr. 18)	Hourly	Variable	Narragansett Bay	35
8/6-10/56 (CR.19)	Hourly	Variable	Narragansett Bay	35
9/1/56 to 12/31/56	Daily (Max., Min.)	Surface	Narragansett Marine Lab Pier	36
1/22 to 2/6/57 (Cr.1)	Hourly	Variable	Narragansett Bay	37
4/10 to 4/18/57 (Cr.2)	Hourly	Variable	Narragansett Bay	37
7/15 to 7/19/57 (Cr.3)	Hourly	Variable	Narragansett Bay	37
5 11/11 to 11/16/57 (Cr. 4)	Hourly	Variable	Narragansett Bay	37
2/7 to 1/29/58	Weekly	Sfc., Bot.	Narragansett Marine Lab	37
1/1 to 12/31/57	Daily (Max., Min.)	Surface	Narragansett Marine Lab	38
5/18/57 to 3/18/58	Weekly	Surface	Mt. Hope Bay, Fox Island	39

TABLE 1.2. TEMPERATURE DATA, 1956-1958

<u>PERIOD</u>	<u>TIME</u>	<u>PROBE</u>	<u>LOCATION</u>	<u>REFERENCE</u>
8/55 to 12/58	Monthly Daily (Available)	Surface	Newport, R.I.	41
1959	Daily (Average)	Surface	Narragansett Marine Lab	40
Summer 1959	Hourly	Surface- Bottom	Upper Narragansett Bay	42
1960	Daily (Average)	Surface	Narragansett Marine Lab	43
7/19/63 to 7/64	Period	Variable	R.I. Sound (Isotherms)	44
1960 to 1966	Monthly Daily (Available)	Surface	Newport, R.I.	45
1967 to Present	Weekly	Surface	Fox Island, Whale Rock	46
3/71 to 10/71	Continuous Daily (Max., Min.)	Near Bottom	East of Saunderstown (71°25', 41°30'30")	47
6/72 to 8/72	Hourly	Variable	Narragansett Bay	48

TABLE 1.3. TEMPERATURE DATA, 1958-PRESENT

tion for the Narragansett Bay. This compilation of data provides some understanding of boundary conditions and very general spacial variations throughout the bay.

First, the Brenton's Reef Data (31) provides an estimate for the monthly surface temperature for the lower bay boundary condition. The averaged monthly temperature for Brenton's Reef is shown in Figure 1.2. For the thermal model, the average value during the prediction period is read off Figure 1.2 and specified as the Rhode Island Sound boundary condition. Included in reference 31 is a brief temperature record for Newport during the period May, 1881 to March, 1883 and the average values are also seen in Figure 1.2.

The data collected by Wehe (32) is given in chart form with longitude and latitude, date, time in minutes, various depths, temperature of water ($^{\circ}\text{F}$), salinity, oxygen, sound velocity, Secchi Disk measurements, sea state, wind direction and magnitude, and weather conditions. The report has 91 pages of data with measurements taken on August 24, 27-31, September 5, 10-12, 14, 17, 18 in 1951, and February 2, 19-22, March 25-27, August 13, 27-29, September 4, 9, 11, 15, 16 in 1952.

The weekly temperature variations of surface water in

FIGURE 1.2. MONTHLY SURFACE WATER TEMPERATURE FOR NEWPORT,
RHODE ISLAND AND BRENTON'S REEF (31)

Wickford Harbor and bottom water in Greenwich Bay for May through March of 1951 and 1952 can be found in Reference 33. Figure 11 in Reference 33 shows the seasonal variation of temperature from approximately 16°C in late May to 25°C at the beginning of August and then a decrease to 17°C for the end of September.

Hicks et al (58) report made an unexpected appearance this fall after being classified for twenty years. This report, which encompasses the period summer of 1951 through the summer of 1952 was undertaken to increase the overall physical data available on Narragansett Bay. The report has over 25 tables and figures that are a cornucopia of important bay temperature distribution information throughout the year. It is highly recommended for workers interested in Bay modeling.

Hicks (34) in Chapter III discusses the distribution of temperature and salinity in Narragansett Bay at the surface and the bottom of water column for the tidal period, slack before ebb. For the February 1956 period, (Cruise, 14) the bottom temperature increases from 1°C at Rhode Island Sound to 3°C half way up the bay and down to 2°C in Providence River area. Surface temperatures for Cruise 14 remain at 2°C for the entire bay. The isothermal pattern

for the April 1956 period (Cruise 15) is very irregular, with variations in bottom water from 1°C to 7°C while the surface water is 3°C in Rhode Island Sound and increases to 10°C in the Providence River.

Hicks (34) undertook two more cruises one in June (Cruise 18) and another in August, 1956 (Cruise 19). The isothermal pattern for the June cruise shows a surface temperature variation of 19°C at Rhode Island Sound to 20°C in the Providence River while the bottom water changes from 11°C to 17°C respectively. For the second cruise, the temperature variation in the surface water was about 4°C or the difference between 23°C in the Providence River compared with 19°C in the lowest portions of the bay. The bottom water varied from 20°C in the upper portion of the bay to about 17°C in the Rhode Island Sound.

Continuous temperature readings were taken at the Narragansett Marine Laboratory on a Bristol Recorder. These temperature readings were reduced into maximum and minimum values (36, 38) and then to just a daily average (40, 43). The average values for each month are listed and these are plotted against the Brenton's Reef data (31) to estimate how weather conditions affect general bay behavior.

Hicks (37), in a comprehensive report, presents temper-

ature data in four quarterly cruises. In this report are tables estimating seasonal temperature trends and ranges as well as vertical distribution of temperature during the various cruises. In addition, his Figure 14 (37) shows the surface and bottom temperature variation at Narragansett Marine Lab Pier for the period February, 1957 through June, 1958. The information for this figure is contained in Appendix Table 5 (37) for which temperature data is taken about once a week.

Weekly surface water temperatures for Mt. Hope Bay and Fox Island for the interval May 18, 1957 to March 18, 1958 were taken by Herman (39). The general temperature pattern can be seen in Figure 1.3.

Since August, 1955, surface water temperature data (41, 45) has been gathered at Newport, Rhode Island. The surface water temperatures are measured several times a week and these data sheets (available) are compiled into monthly maximum, mean maximum, mean, mean minimum, and minimum temperatures. The temperature variations for Narragansett Marine Lab Pier and Newport are shown in Figure 1.4.

The Corps of Engineer Survey (42) did extensive measurements during the summer of 1959 in the portion of Narragansett

FIGURE 1.3. SURFACE WATER TEMPERATURE, MT. HOPE BAY AREA
AND FOX ISLAND (39)

FIGURE 1.4. MONTHLY WATER SURFACE TEMPERATURE AVERAGES FOR
NEWPORT AND NARRAGANSETT MARINE LAB PIER (41, 38)

Bay north of Prudence Island. The report includes average isotherms that are compared with a physical model that was built to simulate bay dynamics during hurricane conditions.

Jeffries (46) has maintained a weekly surface temperature record for Fox Island and Whale Rock that complements historically the data obtained from Herman (39). This data for 1967 can be seen in Figure 1.5.

The Environmental Protection Agency, National Water Quality Lab, Kingston, has obtained continuous temperature readings from a data buoy. Mr. Rick Lapan kindly supplied the averaged and raw data showing the response of water temperature measured 8 feet from bottom in water 30 feet deep near Saunderstown, Rhode Island (Reference 47).

The Ocean Engineering Department has taken water temperature measurements in conjunction with other studies during the summer of 1972. The surface and bottom temperatures were determined by a thermistor probe at seven stations in bay. Temperature versus depth plots are provided for each run and clearly show the vertical structure with a thermocline below the ten foot depth for most stations.

Having reviewed the data, a decision to use the period, Summer 1957, was made because it represents the best collection of published data in the bay for use in

FIGURE 1.5. SURFACE WATER TEMPERATURES AT FOX ISLAND
AND WHALE ROCK, 1967, (46)

verifying the model.

C. APPLICATIONS

The model calculates the movement of thermal energy in the bay and specifies the average temperature in each grid as well as the depth and average velocity components in the x and y direction. The thermal model is designed to realistically model two dimensional, vertically averaged heat content in the bay. Other conservative properties, such as salinity, can be suitably modeled by changing physical values specified at boundaries and negating the effect of the air-water interface. For instance, instead of specifying a heat content in a grid by tagging the grid with a value of T, ($^{\circ}\text{C}$) you could have used S ($^{\circ}/\text{oo}$) for salinity where the formulation would be the same with regard to a non-reacting substance.

To what purpose might this information be used? Biological modeling requires an understanding of ambient temperature and salinity, and provides one general use of the model. A second use would be to model a source of heat, such as a power plant, to determine thermal structure around an outfall area. An analysis of re-entrainment of heated effluent would be a valuable aid in determining de-

sirable site locations from both a power plant operation and biological viewpoint.

One of the important physical parameters of the bay that determines the mixing of heat is the dispersive term. This dispersive term has a dispersion coefficient that can be varied to simulate various bay conditions. Since most biologists are interested in mixing patterns in the aquatic environment the thermal model and its dispersion coefficient effects would be enlightening for large scale effects.

D. APPROACH

Kurt Hess (4) has adapted Leendertse's (1) [pronounced: lee an der' see] two-dimensional, depth averaged model to simulate hydrodynamics of bay. The hydrodynamic model is a computer program that formulates the fluid equations of linear momentum and continuity into a usable finite difference scheme applicable for use on a high speed computer.

The fundamental equations of motion and energy can be formulated into a general finite difference scheme. The specific technique for arranging spatial and time variables are many in number. Anyone is free to choose a method that he feels will work satisfactorily, but the burden of proof

is on him. Grimsrud (6) conducted an investigation of various methods as well as this author to see if better methods were available for modeling Narragansett Bay. A general summary for hydrodynamic, non-reacting concentration models is presented in Table 1.4.

Masch et al (57) have followed an approach similar to Leendertse (3) with a slightly different spatial arrangement for grid depth specification. The governing equations are explicitly formulated using forward difference substitutions for the partial derivatives in the time varying concentration-salinity model.

Pritchard (5, Chapter II) develops the equations for a three dimensional dynamic concentration model for an estuary, which includes isobaric slope for the pressure force term. The equations of linear momentum, continuity, salt and energy when applied with phenomenological relations can only be solved by an iterative numerical approach given reasonable spatial distributions of velocity, energy and salt. Hess (59) is developing a three dimensional time averaged model that uses tidally averaged values from the two dimensional vertically averaged hydraulic model. This model has six levels that are equally spaced for all grid depth specifications to determine vertical structure.

MODEL CHARACTERISTICS	MASCH ET AL (57)	PRITCHARD (5)	LEENDERTSE (3)
Assumptions	Uniformly vertically mixed water conditions	Vertically averaged with relative pressure surface slope and cross product of turbulent velocity fluctuation	Vertically averaged components using distribution functions for vertical column
Application	Estuary-fresh and tidal inlets	Estuary-fresh and tidal inlets	Estuary-fresh and tidal inlets
Influence	Wind included	Wind included	Wind included
19 Time Scale	Long Term Lasting Effect	Short or Long Term	Short or Long Term
Comments	Steady state and time varying salinity capability, 300 grid, prototype available for verification	No application presented	Jamaica Bay, 2000 Grids

TABLE 1.4.a. HYDRODYNAMIC CONCENTRATION MODELS

MODEL CHARACTERISTICS	MASCH ET AL (57)	PRITCHARD (5)	LEENDERTSE (3)
Boundary Condition	Reflective boundary condition for zero concentration gradient at fixed boundary	Not Applicable	Computational scheme formulates grids next to land as boundary value for row or column
Computer Time	2 min./tidal cycle	Not Applicable	30 min./tidal cycle
Dispersion Coefficient	2,500 ft ² /sec (Very High)	Realistic (5-40 ft ² /sec)	Realistic (5-40 ft ² /sec)
Verification Error Magnitude	2-3 ppt, 10-20% tidal estimation	Not Applicable	1-2°C, 10% tidal estimation

TABLE 1.4.b. - HYDRODYNAMIC CONCENTRATION MODELS

Taking a more conservative approach, Pritchard, reduced the three dimensional problem to a two dimensional vertically averaged model that calculates the horizontal velocity components and a time varying slope.

The conservation of dissolved constituent equation is presented and interfaced in development of a solution technique.

The two dimensional formulations are similar to equations used by Leendertse (3) and by Masch et al (57) with two significant differences. The first variance is the inclusion of the slope term for the pressure surfaces due to horizontal variation in density (salinity). The second is the ensemble average of the turbulent velocity fluctuations time averaged for the squared velocity components, $(u')^2$ in x and $(v')^2$ in y direction, and also their cross product $(u'v')$. According to Pritchard, the inclusion of these terms will improve model accuracy for a velocity field with a predominant sign.

Since Leendertse (3) had proven workability of a two-dimensional, depth averaged water quality model with realistic dispersion, it was decided to convert this into a thermal model that required the hydrodynamic input currently available. This coordination between hydrodynamic and thermal models greatly facilitated implementation and

eventually led to improvements in boundary condition formulation for the hydrodynamic model.

If a pioneering effort had been undertaken in the development of a different hydrodynamic-thermal model formulations it would have taken considerably more time and effort just to prove feasibility, not to mention prediction ability. One of the major problems in model development is turn around time of one day and slow computational speed of the present computer system at the University of Rhode Island.

It should be made quite clear that the depth averaged model does have limitations if one is very concerned with near field buoyant plumes. The physical dimensions of the bay necessitated a large grid size of about 1000 yards which, in general, makes the input box the entire near field. Yet, with temperature rises of several degrees around the source one would expect stratification in the surrounding grids. This stratification is mixed into the entire depth and the grid displays the average temperature required by the total heat content in the box for any tidal condition.

E. VERIFICATION

As previously mentioned, the year 1957 was chosen for verification purposes. The model will be run under identical meteorological and boundary conditions for an initial constant temperature field of 21°C during the period of verification. In most instances, the data was taken at isolated points either at or near surface water at various times during the day. Keeping this in mind, grid temperature discrepancies between the data points are to be expected, but spatial agreements should be reasonable.

Ideally, a dozen continuous temperature recorders could be dispersed around the bay to measure both vertical and horizontal temperature distributions to verify validity of model beyond question.

F. CONCLUDING REMARKS

The lengthy discourse on the temperature data for Narragansett Bay provides information for future development of model predictive ability.

The work presented in the following sections will elaborate on the various inputs of model development and implementation. The power plant site was chosen at Rome Point because it appears to be a reasonable first choice

even though the proposed atomic plant seems doubtful at this time. The experimental runs for the various boundary conditions and siting variables are an outline of the procedure to be followed in making an environmental impact judgement. A comprehensive investigation of power plant siting throughout the bay is beyond the scope of this work. Other applications of the model, such as the salt modeling or biological studies are discussed, but no computer modeling was attempted.

In summary, the thermal model is a very valuable tool that allows the engineer to graphically display natural, natural plus man made and man made temperature fields to serve some useful estuarine requirement. The thermal model, in essence, provides the spatial arrangement of water temperatures subject to boundary conditions and source inputs.

II. MODEL DEVELOPMENT

A. INTRODUCTION

Any modeling procedure is derived from the fundamental equations of nature combined with the pertinent phenomenological relations. The basic differential equations (Bird, 27) to be considered for a Newtonian fluid are as follows:

Momentum x:

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} = - \frac{1}{\rho} \frac{\partial p}{\partial x} + f_v + \frac{1}{\rho} \left(\frac{\partial \tau}{\partial x} \right)_{xx} + \frac{\partial \tau}{\partial y} \tau_{xy} + \frac{\partial \tau}{\partial z} \tau_{xz} \quad (2.1)$$

Momentum y:

$$\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} + w \frac{\partial v}{\partial z} = - \frac{1}{\rho} \frac{\partial p}{\partial y} - f_u + \frac{1}{\rho} \left(\frac{\partial \tau}{\partial x} \right)_{yx} + \frac{\partial \tau}{\partial y} \tau_{yy} + \frac{\partial \tau}{\partial x} \tau_{yz} \quad (2.2)$$

Momentum z:

$$\frac{\partial w}{\partial t} + u \frac{\partial w}{\partial x} + v \frac{\partial w}{\partial y} + w \frac{\partial w}{\partial z} = - \frac{1}{\rho} \frac{\partial p}{\partial z} - g + \frac{1}{\rho} \left(\frac{\partial \tau}{\partial x} \right)_{zx} + \frac{\partial \tau}{\partial y} \tau_{zy} + \frac{\partial \tau}{\partial z} \tau_{zz} \quad (2.3)$$

where

f - Coriolis parameter, $2\Omega \sin \phi$

τ_{ij} - shear stress tensor,

g - gravitational acceleration, ft^2/sec

ρ - density of fluid, lb_m/ft^3

Conservation of mass ($\rho = \text{constant}$) :

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \quad (2.4)$$

where

$u(x, y, z, t)$ = velocity in the x direction

$v(x, y, z, t)$ = velocity in the y direction

$w(x, y, z, t)$ = velocity in the z direction

$p(x, y, z, t)$ = pressure

Concentration or energy equation:

$$\begin{aligned} \rho c_p \left(\frac{\partial c}{\partial t} + u \frac{\partial c}{\partial x} + v \frac{\partial c}{\partial y} + w \frac{\partial c}{\partial z} \right) - \frac{\partial}{\partial x} \left(e_x \frac{\partial c}{\partial x} \right) \\ - \frac{\partial}{\partial y} \left(e_y \frac{\partial c}{\partial y} \right) - \frac{\partial}{\partial z} \left(e_z \frac{\partial c}{\partial z} \right) = S(x, y, z, t) + \text{Dissipation} \end{aligned}$$

Terms (2.5)

where

c_p - specific heat of water in $\text{Btu/lb}_m \cdot ^\circ\text{F}$

e_i - the diffusion tensor - molecular and viscous

$S(x, y, z, t)$ - source term in $\text{Btu/ft}^3\text{-sec}$

c - non-reacting substance

In this thesis, the dissipation terms are neglected.

At present (2) computational techniques are inadequate to deal with three dimensional fluid flow problems. The approach here is to reduce the equations to a two dimensional system by vertically averaging the u , v , and c

components of the fundamental equations. This is shown in Equation 2.6, in symbolic form

$$\begin{array}{|c|} \hline U \\ \hline V \\ \hline C \\ \hline \end{array} = \frac{1}{h + \eta} \int_{-h}^{\eta} \begin{array}{|c|} \hline u' \\ \hline v \\ \hline c \\ \hline \end{array} dz \quad (2.6)$$

where η , surface elevation, and h , bottom depth, are shown in Figure 2.1. In general, these variables have a distinct vertical distribution. For example,

$$u = U [1 + E_u(z)] \quad (2.7a)$$

$$v = V [1 + E_v(z)] \quad (2.7b)$$

where E_u and E_v are distribution coefficients.

In order to simplify equations 2.1 to 2.3, we make two general assumptions. First, that the magnitude of the vertical velocity is much less than the magnitude of horizontal velocity components. Secondly, that the partial derivatives, $\partial/\partial x$ and $\partial/\partial y$ are much less than the vertical term, $\partial/\partial z$. These assumptions reduce equations 2.1 to 2.3 as follows:

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = - \frac{1}{\rho} \frac{\partial p}{\partial x} + fv + \frac{1}{\rho} \frac{\partial \tau_{xz}}{\partial z} \quad (2.8)$$

$$\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} = - \frac{1}{\rho} \frac{\partial p}{\partial y} - fu + \frac{1}{\rho} \frac{\partial \tau_{yz}}{\partial z} \quad (2.9)$$

$h(x, y)$ - Average grid depth

$\eta(x, y, t)$ - Tidal variation in grid (plus or minus)

FIGURE 2.1. COORDINATE AND VARIABLE SCHEME FOR THE MODEL

$$\frac{\partial p}{\partial z} + \rho g = 0 \quad (2.10)$$

Assuming uniform density and integrating from bottom,

$z = -h$, to water surface, $z = n$, Equation 2.9 becomes

$$p(x, y, t) = \rho g[n(x, y, t) - z] + p_0 \quad (2.11)$$

where p_0 is surface pressure. Taking partial derivatives

of Equation 2.10 for substitution into Equation 2.7 and

Equation 2.8 we have

$$\frac{\partial p}{\partial x} = \rho g \frac{\partial n}{\partial x} \quad (2.12)$$

$$\frac{\partial p}{\partial y} = \rho g \frac{\partial n}{\partial y} \quad (2.13)$$

because

$$dp_0 = 0 \quad (2.14)$$

Making use of Leibnitz' rule the resulting simplification shown by Grimsrud (6) gives us the hydraulic equations in the following form

$$\frac{\partial U}{\partial t} + U \frac{\partial U}{\partial x} + V \frac{\partial U}{\partial y} = -g \frac{\partial n}{\partial x} + fV + \frac{1}{\rho(h+n)} (\tau_{sx} - \tau_{bx}) \quad (2.15)$$

$$\frac{\partial V}{\partial t} + U \frac{\partial V}{\partial x} + V \frac{\partial V}{\partial y} = -g \frac{\partial n}{\partial y} - fU + \frac{1}{\rho(h+n)} (\tau_{sy} - \tau_{by}) \quad (2.16)$$

$$\frac{\partial \eta}{\partial t} + \frac{\partial (HU)}{\partial x} + \frac{\partial (HV)}{\partial x} = 0 \quad (2.17)$$

where

τ_{bi} - bottom shear stress

τ_{si} - surface shear stress

$$H = h + \eta$$

with boundary condition

$$w(\eta) = u(\eta) \frac{\partial \eta}{\partial x} + v(\eta) \frac{\partial \eta}{\partial y} + \frac{\partial \eta}{\partial t} = \frac{D\eta}{Dt}$$

The bottom stresses in the x and y directions are approximated by the Chezy relationship of the form

$$\tau_{bx} = \rho g U \frac{(U^2 + V^2)^{1/2}}{C_z^2} \quad (2.18)$$

$$\tau_{by} = \rho g V \frac{(U^2 + V^2)^{1/2}}{C_z^2} \quad (2.19)$$

where C_z = Chezy coefficient $[(8g/\text{friction factor})^{1/2}]$ and is a function of bottom roughness and depth and calculated from

$$C_z = \frac{1.49}{N} (h + \eta)^{1/6} \quad (2.20)$$

with N - Manning's formula, $(1/\text{len})^{1/6}$

The basic model equations now contain all the phenomenological relationships necessary for conversion to a finite difference scheme. Equation 2.5, as yet unmodified, is now time averaged to eliminate the turbulent fluctuations associated with the flow. We introduce, for a vertically averaged substance

$$C = \frac{1}{h} \int_{-h}^h c_a dz \quad (2.21)$$

where

$$c_a(z) = C [1 + E_a(z)] \quad (2.22)$$

and E_a is the density distribution function.

Bearing definitions 2.21 and 2.22 in mind we have

$$\int_{-h}^h E_a(z) dz = 0 \quad (2.23)$$

which actually defines the density distribution function.

Vertical integration of Equation 2.5 and use of Leibnitz' rule in conjunction with Equations 2.21 and 2.22 we have:

$$\begin{aligned} \frac{\partial HC}{\partial t} + \frac{\partial [\langle 1 + E_u(z) E_a(z) \rangle UC]}{\partial x} + \frac{\partial [\langle 1 + E_v(z) E_a(z) \rangle VC]}{\partial y} \\ = \frac{\partial \left\langle e_x \frac{\partial c_a}{\partial x} \right\rangle}{\partial x} + \frac{\partial \left\langle e_y \frac{\partial c_a}{\partial y} \right\rangle}{\partial y} + \frac{\partial \left\langle e_z \frac{\partial c_a}{\partial z} \right\rangle}{\partial z} + HS \end{aligned} \quad (2.24)$$

Assuming that Narragansett Bay is well mixed imposes the condition that no differences in mass concentrations exist over vertical structure.

$$E_a \cong 0 \quad (2.25)$$

Applying the above considerations to the model, Equation 2.24 reduces to

$$\frac{\partial HC}{\partial t} + \frac{\partial (HUC)}{\partial x} + \frac{\partial (HVC)}{\partial y} = \frac{\partial}{\partial x} (HD_x \frac{\partial C}{\partial x}) + \frac{\partial}{\partial y} (HD_y \frac{\partial C}{\partial y}) + HS \quad (2.26)$$

where D_x and D_y are dispersion coefficients.

In order to develop relations to express adequately these dispersive terms a brief attempt will be made to investigate the mechanisms of dispersion.

B. DISPERSION

Dispersion of substances is caused by the mean flow velocity differences that occur in all directions. These variations of velocity, greater in the deeper portions and smaller in the shallow areas, cause stretching and spreading of substances in a non-homogenous fluid. Turbulent diffusion is primarily responsible for the cross-sectional spreading that tends to transfer constituents

from the areas of higher concentration to those of lower concentration.

Considering one-dimensional steady flow the longitudinal dispersion coefficient found by Elder (28) is

$$D_1 = 5.93 Hu^* \quad (2.27)$$

where u^* - friction velocity (shear stress velocity)

The friction velocity is related to the mean velocity by the relation:

$$u^* = \left(\frac{\tau_{bx}}{\rho} \right)^{1/2} = u_g^{1/2} C_z^{-1} \quad (2.28)$$

where τ_{bx} - bed shear due to u , the uniform flow velocity

Now combining Equations 2.27 and 2.28 results in

$$D_1 = 5.93 Hu_g^{1/2} C_z^{-1} \quad (2.29)$$

For the lateral turbulent dispersion, perpendicular to the mean flow, Elder (28) obtained:

$$D_y = 0.23 Hu^* \quad (2.30)$$

Oddly enough, this formulation, designed specifically for river flow, underestimated the longitudinal dispersion for river flow. For the slowly time varying flow conditions such as Narragansett Bay it is considered in better agreement. In addition, the longitudinal dispersion is influenced by wind generated local circulation and wave

action (Wilson & Masch, 29). Rather naturally, the lateral turbulent diffusion is affected by the same wind and wave processes.

Since the longitudinal dispersion coefficient is generally larger, except around a source term than the lateral coefficient, the dispersion is anisotropic. To make the model suitable for arbitrary direction and the influence of large scale substance variations from grid to grid, the general expression for dispersive transport becomes

$$\frac{\partial [(E_{xx} \frac{\partial c}{\partial x} + E_{xy} \frac{\partial c}{\partial y}) H]}{\partial x} + \frac{\partial [(E_{yx} \frac{\partial c}{\partial y} + E_{yy} \frac{\partial c}{\partial x}) H]}{\partial y} \quad (2.31)$$

where the dispersion coefficients E_{xx} , E_{xy} , E_{yx} and E_{yy} are dependent on the current magnitude and direction. The relationship 2.31 more closely models the physical bay situation but requires four dispersion coefficients which are at least as difficult to determine as the two included in Equation 2.26. In addition the coupling of the longitudinal and lateral diffusion coefficient makes the computation cumbersome because it would couple the x and y conservation equations requiring at least twice the effort to solve substance distribution. Realizing the computational limitations of available computer this approach was deemed unacceptable.

A possible alternate approach by Holley (30) is to compare magnitudes of mass transport by longitudinal dispersion versus advective transport. Since the ratio of dispersion over advection is generally very small, except around outfall areas where steep gradients do exist, the general procedure is to assume that variations in the longitudinal dispersion will not affect the solution. The net result of the above discussion is to assume that the process is isentropic in the sense that there is uncoupled lateral and longitudinal dispersion which are independent functions of velocity, Chezy coefficient and depth in one coordinate direction.

Finally, after all various alternatives were evaluated, the formulation in Equation 2.29 was considered the best choice and is currently being used in the model.

This concludes the introduction of basic differential equations with phenomenological relations as shown below, as the basic equation set for the forthcoming finite difference formulation.

$$\frac{\partial U}{\partial t} + u \frac{\partial U}{\partial x} + v \frac{\partial U}{\partial y} - fV + g \frac{\partial \eta}{\partial x} + g \frac{U(U^2 + V^2)^{1/2}}{C_z^2 H} = 0 \quad (2.32)$$

$$\frac{\partial v}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial v}{\partial y} + fU + g \frac{\partial \eta}{\partial x} + g \frac{v(u^2 + v^2)^{1/2}}{C_z^2 H} = 0 \quad (2.33)$$

$$\frac{\partial \eta}{\partial t} + \frac{\partial HU}{\partial x} + \frac{\partial (HV)}{\partial y} = 0 \quad (2.34)$$

$$\begin{aligned} \frac{\partial (HC)}{\partial t} + \frac{\partial (HUC)}{\partial x} + \frac{\partial (HVC)}{\partial y} &= \frac{\partial}{\partial x} (5.93 HUg^{1/2} C_z^{-1}) \\ &+ \frac{\partial}{\partial y} (5.93 HUg^{1/2} C_z^{-1}) + S \end{aligned} \quad (2.35)$$

C. FINITE DIFFERENCE APPROXIMATIONS

For the solution of the Equations 2.32 to 2.35 the approach of Leendertse (1) will be followed. In this scheme, the variables η , c , v , u , h are arranged, with general coordinate system explanation, as shown in Figure 2.2.

This scheme has the advantage that for the variable operated upon in time there is a centrally located spatial derivative for the linear term. In the x-momentum Equation 2.32, the time-derivative of water level ($g \frac{\partial \eta}{\partial x}$) is an example of this.

In accordance with the semi-implicit method the time-step is split into two halves, and the time-derivative taken over the half time-step. Semi-implicit means solving

$$x_c = (m - \frac{1}{2}) L/2$$

$$y_c = (n - \frac{1}{2}) L/2$$

$$\eta_{m,n} = \eta(x_c, y_c)$$

$$U_{m,n} = u(x_c + L/2, y_c)$$

$$V_{m,n} = v(x_c, y_c + L/2)$$

$$h_{m,n} = h(x_c + L/2, y_c + L/2)$$

$$c_{m,n} = c(x_c, y_c)$$

FIGURE 2.2. SPACE STAGGERED GRID SYSTEM

first explicitly (individual values are calculated at next time step) and then implicitly (solve whole row simultaneously). Thus, for the function F , continuous in space and time, the notation is:

$$F(mDL, nDL, tDT) = F^t \quad (2.36)$$

where DL is the grid spacing. The first forward time derivative is:

$$\frac{\partial F}{\partial t} = \frac{2}{DT} \delta_t F_{m,n}^t = \frac{2}{DT} (F_{m,n}^{t+1/2} - F_{m,n}^t) \quad (2.37)$$

where DT is time interval. We adopt the following notation for various convenient functions of space and time:

$$\overline{F}_{m,n}^x = \frac{1}{2} (F_{m+1/2,n} + F_{m-1/2,n}) \quad (2.38)$$

$$\overline{F}_{m,n}^y = \frac{1}{2} (F_{m,n+1/2} + F_{m,n-1/2}) \quad (2.39)$$

$$\delta_x F_{m,n} = (F_{m+1/2,n} - F_{m-1/2,n}) \quad (2.40)$$

$$\delta_y F_{m,n} = (F_{m,n+1/2} - F_{m,n-1/2}) \quad (2.41)$$

$$\delta_x^* F_{m,n} = \frac{1}{2} (F_{m+1,n} - F_{m,n-1}) \quad (2.42)$$

$$\delta_y^* F_{m,n} = \frac{1}{2} (F_{m,n+1} - F_{m,n-1}) \quad (2.43)$$

$$\begin{aligned} \overline{\overline{F}}_{m,n} &= \frac{1}{4} (F_{m+1/2,n+1/2} + F_{m-1/2,n+1/2} + F_{m+1/2,n-1/2} \\ &\quad + F_{m-1/2,n-1/2}) \end{aligned} \quad (2.44)$$

The momentum and conservation of mass equations may then be transformed into finite-difference equations and solved for the new value in time for a total of eight equations, four for each time step. The equations are given in Appendix B and D.

The solution of Equations B.1 to B.6 (Appendix B and D) is called by Leendertse a "multi-operation" method, which is a modification of the "leap-frog" method. In the first half time-step, values of U and η are computed implicitly along a grid row in the x -direction at the time $(t+1/2) \Delta T$. Then V is computed at the same time level explicitly. In the second half time-step, V and n are computed implicitly at $(t+1) \Delta T$ along grid rows in the y -direction, after which U is calculated explicitly at $(t+1) \Delta T$.

In the first half of the time-step, the time derivative of U in the x -momentum equation is approximated by a backward difference:

$$\frac{\partial}{\partial t}(U^{t+1/2}) = \frac{2}{\Delta T}(U^{t+1/2} - U^t) = \text{fcn}(\eta^{t+1/2}) \quad (2.45)$$

In the second half time-step, a forward difference is used:

$$\frac{\partial}{\partial t}(U^{t+1}) = \frac{2}{\Delta T}(U^{t+1} - U^{t+1/2}) = \text{fcn}(\eta^{t+1/2}) \quad (2.46)$$

Thus, over a full time-step, the time derivative is a central difference with respect to the water level:

$$\frac{\partial U}{\partial t} = \frac{U^{t+1} - U^t}{\Delta T} = \text{fcn}(\eta^{t+1/2}) \quad (2.47)$$

This composite relation defines the leap-frog method.

The set of difference equations for the implicit time-step on U and η may be written as

$$[A] (U^{t+1/2} \text{ or } \eta^{t+1/2}) = (b) \quad (2.48)$$

where $[A]$ is a tridiagonal matrix and (b) is a column vector of known terms. Equation 2.48 may then be solved by Gaussian elimination (see Mitchell (24) for example) for the new values of U and η at $(t+1/2)$. A similar procedure is used for the second implicit operation involving V and η at time $(t+1)$. The details are given in (Hess (4), Appendix B and C).

D. DIFFERENCING COMMENTS

D.1. Stability

An extensive analytical treatment of stability has been given by Leendertse (1, 2) with further comments by Grimsrud (6), Hess (4), and Spaulding (16). Whenever a problem in the physical values produced by a computational scheme occurs by a model user the word 'stability' is gen-

erally used. Instability may be defined as the unlimited amplifications of errors. This can occur because of the dissimilar nature of upstream or central differencing or the simplified unidimensional dispersion coefficient used with a source with significant temperature gradients.

D.2. Boundary Conditions

In Figure 2.3, the general boundary conditions format is outlined for the model. Hess (4) summarized the difficulty encountered by Leendertse (1) when handling the spatial derivatives, Equations 2.41 and 2.42. Briefly stated, the convective terms encountered at land boundaries are dropped in the solution of the momentum equation. This effect causes an inaccuracy in the hydraulic model and will create computational problems for a source term with a low dispersion coefficient if the substance varies significantly from grid to grid. Some model users adhere to the policy that the upstream differencing technique (Appendix E), which enhances the dispersion coefficient a thousand fold in the model, should be used. In essence, the model creates far field conditions for a dispersed substance in what is considered the intermediate zone.

A technique that might be used (Spaulding, 16) is an upstream differencing technique around a source and conver-

<u>LOCATION</u>	<u>VARIABLE</u>	<u>MODEL INPUT</u>
Source (Power plant)	Flow Rate (Fixed) * Temperature Difference Through Plant YDS ³ /SEC	Velocity*Concentration (YDS/SEC) - °C
Rivers	Flow Rate (Fixed) YDS ³ /SEC	Velocity*Concentration at Boundary (YDS/SEC) - °C
Mt. Hope Bay	Tidal Flow Rate (Variable) YDS ³ /SEC	Velocity*Concentration at Boundary (YDS/SEC) - °C
Rhode Island Sound	Tidal Height (Variable) YDS	Velocity*Concentration at Boundary (YDS/SEC) - °C

FIGURE 2.3. BOUNDARY CONDITIONS

sion to a central differencing scheme (see Appendix E) at some specified distance from source discontinuity. This author prefers, if necessary, to use a formulation suggested by Kurt Hess that would naturally enhance dispersion coefficient for large discontinuities of concentration in the model near a source. This is then an alternative to arbitrarily increasing the dispersion coefficient in the upstream differencing technique, for the entire bay, as shown below.

$$D_{m+1/2} = D \left[1 + \frac{(C_{m+1} - C_m)^2}{(C_{m+1} + C_m)^2} E \right] \quad (2.49)$$

$$D_{m-1/2} = D \left[1 + \frac{(C_m - C_{m-1})^2}{(C_m + C_{m-1})^2} E \right] \quad (2.50)$$

where

D - is the normal model dispersion coefficient

E - arbitrary constant of order one.

This means that the centered spacial derivative can be used when the adjacent concentrations are different without having computational problems for suitable values of E. This technique was not used here.

D.3. Computational Differences for Central and Upstream Differencing

An explanation of the computational problems with regard to upstream and central differencing is now necessary. According to Leendertse (2), certain difficulties are encountered upstream from sources with respect to the convective term. Consider Figure 2.4, and the case of a centered spatial derivative ($A = B = 1/2$). Suppose the concentration at $m+1$ is unity, and zero elsewhere. Applying the finite-difference equation at M leads to a decrease

FIGURE 2.4. ONE DIMENSIONAL CONCENTRATION SCHEME

in concentration C_m . The remedy is to use upstream dif-

ferencing ($B = 0$, $A = 1$) at grid m (or $B = 1$, $A = 0$ if $u < 0$) so that concentration at m will then remain zero.

A few calculations will show that if upstream differencing is used only at m , mass will not be conserved elsewhere. Therefore, for consistency, upstream differencing would have to be used everywhere. However, as shown by Leendertse (1, p. 34), this approximation results in an effective increase in the dispersion coefficient.

One possible alternative is to use the centered spatial derivative, and increase the dispersion coefficient artificially as shown before in Equation 2.49, which allows a higher dispersion when the adjacent concentrations are different, but no increase when they are the same.

The primary purpose of this thesis is to verify the techniques and applicability of thermal model to Narragansett Bay. With this in mind, the model now uses the formulation conceived by Leendertse (3) with a central differencing scheme. The final decision on whether adjustment in the present dispersion coefficient, using for instance Equation 2.49, will occur after an evaluation of the results.

III. TEMPERATURE AND AIR WATER INTERFACE BOUNDARY

CONDITIONS AND VERIFICATION DATA RELATIONSHIPS

A. AIR WATER INTERFACE-SURFACE HEAT TRANSFER PROCESSES

The literature, (5, 9, 11, 12, 15, 17, 25), has treated the heat transfer rate at air-water interface as a formulation of a net heat flux equation which is composed of specific transfer terms by distinguishing air, water and air-water terms.

Figure 3.1 shows the term by term formulation of the heat transfer processes which control the water temperature at the air-water interface. Figure 3.2 shows general temperature, pressure and velocity profiles expected at the interface.

The general continuity equation for the interface is:

$$\frac{\partial}{\partial t} (m_{cv}) = \int dw_{in} - \int dw_{out} \quad (3.1)$$

where

t - time

cv - refers to the control volume in Figure 3.1

Since the volume of the control volume is assumed small

$$m_{cv} \cong 0 \quad (3.2)$$

Equation (3.1) becomes) (see Figure 3.1)

$$0 = w_w - w_a \quad (3.3)$$

$HS1$ - incident solar radiation heat transfer rate (HTR)

$HS1_{SR}$ - reflected solar radiation HTR

$$HS1_{NET} = HS1 - HS1_{SR}$$

HA - incident atmospheric radiation HTR

HA_{SR} - reflected atmospheric radiation HTR

$$HA_{NET} = HA - HA_{SR}$$

BH - back radiation HTR from surface

HC - conduction heat transfer rate from atmosphere side of interface conversion

w_a - evaporation mass flow rate, atmosphere side of interface

w_w - evaporation mass flow rate, water side of interface

h_f - enthalpy, saturated liquid state

h_g - enthalpy, saturated vapor state

FIGURE 3.1. SCHEMATIC, SURFACE HEAT TRANSFER PROCESS

PER UNIT AREA

TA - temperature of air

TS - temperature surface water

TW = TS - water temperature, constant for depth of grid

EA - air vapor pressure, function relative humidity, TA

ES - saturated vapor pressure, function of TW

PA-atmospheric pressure

WA - wind velocity in MPH

V - water velocity constant for depth of grid, assumed

independent of wind velocity

FIGURE 3.2. TEMPERATURE, PRESSURE AND VELOCITY

PROFILES NEAR INTERFACE

or

$$w_w = w_a = w_e \quad (3.4)$$

where w_e is the evaporation rate.

The general steady flow energy equation for the control volume is:

$$q - P_x = \left(\frac{\partial E_{cv}}{\partial t} \right) + \int (A)_{out} dw_{out} - \int (A)_{in} dw_{in} \quad (3.5)$$

where

q - net heat transfer rate to control volume (positive into cv)

P_x - net shaft power to control volume (power to external elements from cv positive)

E - energy inside control volume

$$A = \left(h + \frac{V^2}{g} + gz \right)$$

h - enthalpy

V - velocity

g - acceleration of gravity

z - height in gravitational field above arbitrary level

Since mass is conserved, as shown in Equation 3.2,

$$E_{cv} \cong 0 \quad (3.6)$$

Also for conditions in Figure 3.1

$$P_x = 0 \quad (3.7a)$$

$$v = 0 \quad (3.7b)$$

$$z = 0 \quad (3.7c)$$

Equation 3.5 with substitution of 3.6, 3.7a, 3.7b, and 3.7c reduces to

$$q = w_e (h_g - h_f) \quad (3.8)$$

or

$$q = w_e h_{fg} \quad (3.9)$$

where h_{fg} is the latent heat of vaporization evaluated at the surface temperature, T_s . Summing heat transfer rates for control volume in Figure 3.1, Equation 3.9 becomes:

$$HS1_{NET} + HA_{NET} - BH + HC + HTOT = w_e h_{fg} \quad (3.10)$$

where, by definition

$$HE = w_e h_{fg} \quad (3.11)$$

Equation 3.10 becomes

$$HS1_{NET} + HA_{NET} - BH + HC + HTOT - HE = 0 \quad (3.13)$$

or

$$-HTOT = HS1_{NET} + HA_{NET} - BH + HC - HE \quad (3.13)$$

Note that HE is considered an enthalpy flux and not a heat transfer rate. Reviewing sign convention, we see that if the right hand side (RHS) of Equation 3.13 is positive, HTOT is negative and the heat transfer across the interface is to the water below the interface. If the RHS of

Equation 3.13 is negative, HTOT is positive and the heat transfer across the interface is from the water below the interface.

A common formulation found in the literature (Edinger and Geyer, 12) is the grouping of water independent heat exchange rates for solar and atmospheric radiation as shown

$$HR = HS_{NET} + HA_{NET} \quad (3.14)$$

In order to be consistent with current usage of HC and HE having the same signs in the heat balance, the following change is made:

$$HC = -(-HC) \quad (3.15)$$

Finally, the equation used in the model is:

$$HTOT = HR - (BH + HC + HE) \quad (3.16)$$

In summary, the specific formulation of some of these quantified heat exchange rates into functions of model variables that are both physically complex and interrelated poses a challenge. Each net heat transfer rate, as described in the model, will be discussed with regard to literature formulations and current thinking.

B. INCIDENT SOLAR RADIATION HEAT TRANSFER RATE

When no solar radiation data is available, a common approach (Harleman, 15, 24) is to formulate the solar radi-

ation heat transfer rate as a function of a solar constant, solar altitude, normalized radius of earth's orbit, atmospheric transmission coefficient, optical air mass and cloudiness. In Wonderlich (19) and List (20) equations for calculating these values can be found.

Fortunately for the Narragansett Bay area, Eppley Laboratory in Newport, Rhode Island have been taking continuous readings of net solar energy since the early 1950's. If no data is read in on an hourly basis the model requires the total solar input for that day or HS1. One can determine what hourly variations, HS2, there would be for clear sky conditions by using the following empirical equations derived from actual solar radiation plots throughout the year:

$$D = HS1(IDY) / (1.7 + (HS1(IDY) - 100.) / 350.) \quad (3.17a)$$

$$G = 2. \text{ PI } (TIMEX - 6. (1. + .2 \text{ EXP}(-3. (182. - \text{ABS}(\text{DAY} - 182.))) / 182.))) \quad (3.17b)$$

$$T = 24. (1. - .2 \text{ COS}(2. \text{ PI } \text{DAY} / 365)) \quad (3.17c)$$

$$HS2(IDY) = D \text{ SIN}(G/T) \quad (3.17d)$$

$$HS1(IDY) = 17.85 \text{ HS2}(IDY) \quad (3.17e)$$

where

HS1(IDY) - total solar input for day IDY

TIMEX = initial starting time = 0 at 7 a.m.

DAY = IDY = Day of year, e.g., 14 July is DAY 195

PI = 3.1416

$$17.85 = 0.2 * 24 \frac{\text{hours}}{\text{day}} / 0.27$$

0.2 = Eppley Laboratory scale factor (can also be .1)

0.27 = conversion factor from Grm-Cal/cm² to Btu/ft²

Since hourly solar data is read in, the final step of determining the affects of cloudiness on above formulation was not pursued. A simple procedure of taking total solar radiation for input day and determining hourly values on this basis and adding or subtracting a certain amount depending on the cloudiness factor for an hour versus average cloudiness factor for a day should bring results within 10-20% of the true value.

C. REFLECTED SOLAR RADIATION HEAT-TRANSFER RATE

The reflected solar radiation heat-transfer rate is usually calculated from the incident solar rate and a solar reflectivity, R_{sr} , defined as:

$$R_{sr} = \frac{HSI_{sr}}{HSI} \quad (3.18)$$

Typical data can be found in Anderson (21). R_{sr} can be estimated from the following empirical formula:

$$R_{sr} = a_1 \alpha^{b_1} \quad (3.19)$$

FIGURE 3.3. TYPICAL NET SOLAR RADIATION DATA FOR NARRAGANSETT BAY

where α is the solar (sun) altitude in degrees and a_1 and b_1 are functions of cloudiness, CL, and given in Table 3.1.

<u>cloudiness, CL</u>	<u>Sky</u>	<u>a_1</u>	<u>b_1</u>
0	Clear	1.18	-0.77
0.1-0.5	Scattered	2.20	-0.97
0.6-0.9	Broken	0.95	-0.75
1.0	Overcast	0.35	-1.45

TABLE 3.1. REFLECTED SOLAR RADIATION CONSTANTS

As previously mentioned, Eppley Laboratory measures continuous net input solar heat transfer rate, (HS2), so that the use of the previously outlined procedure on reflected solar radiation is not required.

D. INCIDENT ATMOSPHERIC RADIATION HEAT-TRANSFER RATE

The incident atmospheric radiation heat-transfer rate may be calculated from a relationship formulated by Brunt (Anderson (21))

$$HA = SB(TA + 460)^4 (CB + 0.031(EA) \cdot ^5) \quad (3.20)$$

where

HA - Btu/ft² - day

SB - Stefan-Boltzman constant, $4.15 * 10^{-8} \frac{\text{Btu}}{\text{ft}^2 \text{ day } ^\circ \text{R}^4}$

TA - air temperature, ^oF, (measured six feet above surface)

EA - atmospheric vapor pressure, mmHg (measured six feet above surface)

CB - coefficient determined by air temperature and C' the ratio of the measured solar radiation to the clear sky solar radiation

CL is determined from the total daily solar radiation by integrating the solar radiation curve for a particular day from the pyreheliometer reading and dividing this value by the clear sky solar radiation. The values of TA and CL then determine CB as shown in Reference 12, Figure 2.5, page 26. The effect on HA can be seen in Reference 12, Figure 2.4, page 25.

The Brunt coefficient may be estimated from the following equation:

$$CB = .74 - \frac{3.5(96 - TA)^{1.67}}{10(4 + 3CL)} \quad (3.21)$$

where

TA - temperature of air in ^oF

CL - cloudiness ratio

An alternate method, not used in the model for determining HA, from Swinbank (22) is:

$$HA = 1.2 * 10^{-13} (TA + 460)^6 (1 + 0.17CL^2) \quad (3.22)$$

If less accuracy is desired assume black body radiation in Equation 3.20 and let the second bracket equal 0.87 or emissivity constant.

E. REFLECTED ATMOSPHERIC RADIATION HEAT-TRANSFER RATE

The reflected atmospheric radiation heat-transfer rate is usually calculated from the incident atmospheric rate and an atmospheric reflectivity, R_{ar} , defined as:

$$R_{ar} = \frac{HA_{ar}}{HA} \quad (3.23)$$

The value of R_{ar} is usually taken as 0.03 (Edinger and Geyer (12)). The result is:

$$HA_{NET} = HA - HA_{ar} = 0.97HA \quad (3.24)$$

F. BACK RADIATION HEAT-TRANSFER RATE FROM WATER SURFACE

The back radiation heat-transfer from the water surface is calculated from black-body radiation with an emissivity of 0.97:

$$BH = EW \times SB(TW + 460)^4 \quad (3.25)$$

where

BH - Btu/ft² - day

EW - emissivity of water surface = 0.97

SB - Stefan-Boltzmann constant = $4.2 * 10^{-8} \frac{\text{Btu}}{\text{ft}^2 \text{day}^\circ \text{R}^4}$

TW - °F water temperature

G. AIR VAPOR PRESSURE, EA

EA is empirically determined by first finding partial pressure, PMM as follows:

$$\text{PMM} = A - B \cos \left(\text{PI} \left(\frac{((\text{TA}-30.)/70.)C+D}{180.} \right) \right) \quad (3.26)$$

and A, B, C, and D in mmHg are found in Table 3.2

TA (°F)	A	B	C	D
30.00-59.99	94.5	90.	54.5	2.5
60.00-79.99	94.5	90.	51.	14.
80.00-89.99	94.5	90.	61.	-3.0
90.00-100.00	99.5	100.	59.5	0.

TABLE 3.2. AIR VAPOR PRESSURE CONSTANTS

$$\text{EA} = \left(\text{PMM} - \left(\frac{((\text{TA}-30)/70.)3.5 + 1.}{(\text{RH}-10.)/90. + ((\text{TA}-30.)/70.)3.5+1.} \right) \right) \quad (3.27)$$

where RH is relative humidity in percent.

H. SATURATED VAPOR PRESSURE (DUE POINT TEMPERATURE)

The vapor pressure, ES, is found from the simple empirical formula

$$ES = 99.0 - 96.0 \cos(3.14(((TW - 30.)/50.)^{33.7})/180.) \quad (3.28)$$

I. EVAPORATION HEAT-TRANSFER RATE

The evaporation heat-transfer rate is calculated from:

$$HE = f(V) (ES - EA) \quad (3.29)$$

where

$$HE = \text{Btu/ft}^2 - \text{DAY}$$

V - wind velocity measured at specific elevation

above the water surface, MPH

f(V) - wind velocity function, energy/time-area-pressure

ES - vapor pressure at water surface temperature, TW

EA - vapor pressure measured at specific elevation above the water surface at air temperature TA

The wind velocity function f(V) is usually expressed as

$$f(V) = a_2 + b_2 V \quad (3.30)$$

Table 3.3 presents typical values of a_2 and b_2 .

source	a_2 (Btu/day-ft ² -mmHg)	b_2 (Btu/day-ft ² -mmHg-mph)
Lake Hefner	0	11.4
Lake Colorado City	0	16.8
Meyer	73	7.3

TABLE 3.3. WIND VELOCITY FUNCTION PARAMETERS

Note that Table 3.3 implies the following set of units on Equations 3.29 and 3.30.

HE - Btu/ft² - day

V - mph

[EA, ES - mmHg]

It should also be noted that certain quantities in Equations 3.29 and 3.30 are time averages and are measured at specified elevations above the water surface. Table 3.4 summarizes these details.

Source	V		EA, ES	
	Averaging Period	Elevation (Ft.)	Averaging Period	Elevation (Ft.)
Lake Hefner	3 hours	24	3 hours	24
Lake Colorado City	24 hours	24	24 hours	24
Meyer	Monthly	?	?	?

TABLE 3.4. EVAPORATION FORMULA MEASUREMENT PARAMETERS

The Lake Hefner values are more widely used because of the extensive investigative work that went into their formulation but the equation, at best, is a rough approximation of a physical process that is not well defined. When a calculation of the net heat transfer rate is performed the result is of the order of the evaporation rate. Thus, long computer runs and a massive data gathering effort to precisely measure air and water temperature at several elevations in conjunction with wind speed, humidity and wave height measurements are necessary to justify the application of the Lake Hefner values on Narragansett Bay. In summary, improvement on the present formula is very necessary and a plausible research area.

J. EVAPORATION MASS FLOW RATE

The evaporation mass flow rate can be estimated from the evaporation heat-transfer rate by:

$$\frac{w_e}{A} = HE/h_{fg} \quad (3.31)$$

where

w_e/A - evaporation mass flow rate, mass/time-area

HE - energy/time-area

h_{fg} - latent heat of vaporization at TW, energy/mass

with h_{fg} estimated from

$$h_{fg} = 1087 - 0.54 \text{ TW} \quad (3.32)$$

for TW - °F and h_{fg} in Btu/lb_m. Use of Equations 3.29 through 3.32 with values from Table 3.3 will yield evaporation mass flow rates in lb_m/ft² - day.

K. CONDUCTION HEAT-TRANSFER RATE

The conduction heat-transfer rate is approximated as a fraction of the evaporation heat-transfer rate through the Bowen ratio, B:

$$-HC = HE * B \quad (3.33)$$

and

$$B = C_3 \frac{(TS - TA)}{(ES - EA)} * \frac{P}{760} \quad (3.34)$$

where

TS - surface temperature ($^{\circ}\text{F}$) = TW

TA - air temperature, $^{\circ}\text{F}$

ES - saturated vapor pressure at water surface temperature, TS

EA - air vapor pressure calculated from air temperature, TA, and relative humidity, RH

P - barometric pressure, mmHG

C_3 - an experimental constant usually taken as 0.26 (0.24 for smooth water surfaces and 0.28 for rough water surfaces).

Note that a minus sign has been introduced into Equation 3.33 due to the sign convention in Figure 3.1. If TS is less than TA then from Equations 3.33 and 3.34, $HTOT$ will be positive and the heat transfer will be from the air to the water surface in agreement with the sign convention of Figure 3.1.

Combining Equations 3.29, 3.30, 3.33, and 3.34 yields

$$HC = -C_3 f(V) (TS - TA) \frac{P}{760} \quad (3.35)$$

or for $P = 760$ mmHg we have

$$HC = -C_3 (a_2 + b_2 V) (TS - TA) \quad (3.36)$$

Again, emphasis must be placed on the empirical

nature of conduction heat rate formulation with regard to the Bowen ratio and the wind factor.

L. MODEL FORMULATION

Substitution of Equations 3.20, 3.25, 3.29, and 3.36 into 3.14 and 3.16 results in the model formula 3.37, shown below.

$$\begin{aligned} \text{HTOT} = & \text{HS2} + \text{SB} (\text{TA} + 460)^4 (\text{CB} + .031(\text{EA})^{0.5}) \\ & - \text{EW} * \text{SB} * (\text{TW} + 460)^4 - (\text{a}_2 + \text{b}_2 \text{ V}) (\text{ES} - \text{EA}) \\ & - \text{C}_3 (\text{a}_2 + \text{b}_2 \text{ V}) (\text{TW} - \text{TA}) \end{aligned} \quad (3.37)$$

Since ES is a function of water temperature only, we assume that for the time increment used in the model there is no significant error introduced by using the calculated water temperature value from the previous time step. In addition, the previous water temperature values are used to predict current heat exchange rates as shown in Equation 3.37. The other variables, air temperature, wind speed, relative humidity, solar radiation, and cloudiness are given, so one can now determine HTOT directly from Equation 3.37.

The model vertically averages (no buoyant effects) temperature structure so the energy equation is considered

linear if the net heat exchange is linear for the temperature range considered. The net heat exchange rate for man made conditions requires only the water temperature excess, assuming that the air and natural water temperature remain unchanged as formulated in the following way:

$$\begin{aligned} \text{Forced Water} \\ \text{Temperature Rise} &= \text{Man Made Rise} - \text{Natural Condition} \end{aligned} \quad (3.38)$$

or

$$\begin{aligned} \text{FTR} = \text{HS2}_{\text{MM}} + \text{HA}_{\text{MM}} - \text{BH}_{\text{MM}} - \text{HE}_{\text{MM}} - \text{HC}_{\text{MM}} - \text{HS2}_{\text{N}} + \text{HA}_{\text{N}} \\ - \text{BH}_{\text{N}} - \text{HE}_{\text{N}} - \text{HC}_{\text{N}} \end{aligned} \quad (3.39)$$

where MM index means man made condition, N is natural condition, and FTR equals forced water temperature rise (DELTA T in model). The following assumptions are made with regard to Equation 3.39:

- 1) $\text{HS2}_{\text{MM}} = \text{HS2}_{\text{N}}$ (net solar input)
- 2) $\text{HA}_{\text{MM}} = f(\text{TA, cloudiness}) = \text{HA}_{\text{N}}$ (incoming radiation)
- 3) $\text{BH}_{\text{MM}} = \text{BH}_{\text{N}} + \text{BH}_{\text{FTR}}$ (back radiation)
- 4) $\text{HE}_{\text{MM}} = \text{HE}_{\text{N}} + \text{HE}_{\text{FTR}}$ (evaporation)
- 5) $\text{HC}_{\text{MM}} = \text{HC}_{\text{N}} + \text{HC}_{\text{FTR}}$ (conduction)

Noting that we must know approximate temperature range of water for linearized saturated vapor pressure, ES, we now rewrite 3.39 into the following form:

$$(\text{Net Heat Exchange})_{\text{FTR}} = \text{BH}_{\text{FTR}} + \text{HE}_{\text{FTR}} + \text{HC}_{\text{FTR}} \quad (3.40)$$

where

$$\text{BH}_{\text{FTR}} = \text{EW} * \text{SB} * (\text{TW}_{\text{FTR}} + 460)^4$$

$$\text{HE}_{\text{FTR}} = (a_2 + b_2 V) \text{ES} * \text{TW}_{\text{FTR}}$$

$a_2 + b_2 V$ - wind evaporation function

ES - saturated vapor pressure for water temperature
(mmHg)

TW_{FTR} - calculated forced water temperature rise from
model ($^{\circ}\text{C}$)

$$\text{HC} = 0.26 (a_2 + b_2 V) \text{TW}_{\text{FTR}}$$

Linearization of BH_{FTR} is done by using the following
binomial expansion:

$$\begin{aligned} (Y + G)^m &= G^m + mG^{m-1}Y + \frac{m(m-1)}{2!} G^{m-2}Y^2 \\ &\quad + \frac{m(m-1)(m-2)}{3!} G^{m-3}Y^3 \end{aligned} \quad (3.41)$$

for

$$Y = \text{TW}$$

$$G = 460^{\circ}\text{F}$$

$$m = 4$$

Equation 3.41 becomes

$$(TW + 460)^4 = (460)^4 (1 + 4 * TW/460 + 6 * (TW/460)^2 + 4 * (TW/460)^3 + (TW/460)^4) \quad (3.42)$$

and neglecting the last three terms as small we have

$$BH_{FTR} = EW(460)^3 4TW_{FTR} \quad (3.43)$$

The use of the forced temperature rise for a heated effluent is ideal because it allows predictions that are much less sensitive to inaccuracies in the meteorological data being used. This method improves predictive confidence for intelligent "worst case" analysis by separately considering maximum temperature rise during tidal cycle coupled and the maximum natural rise, say, during a hot summer day. As an add to understanding the tidal excursions of isotherms and the maximum value and location they attain, the forced temperature rise calculations are very valuable especially if one is concerned with small temperature differences of the order of 0.1°C in the far field.

M. EQUILIBRIUM TEMPERATURE

If the net heat transfer rate, $HTOT$, to the water, as given in Equation 3.37 is zero the grid point water temperature is then said to be at its equilibrium temperature, TE . Therefore, Equation 3.37 becomes:

$$\begin{aligned}
0 = & HS2 + SB(TA + 460)^4 (CB + .031 (EA)^{1/2}) \\
& - EW*SB(TE + 460)^4 - (a_2 + b_2V) (ES - EA) \\
& - C_3 (a_2 + b_2V) (TE - TA)
\end{aligned} \tag{3.44}$$

S Solving Equation 3.44 in terms of TE requires at worst an iterative procedure because the saturated vapor pressure function, ES is calculated from the equilibrium temperature. In actuality, the solution of Equation 3.43 requires about six iterations in the computer model for five place accuracy. In the next section, the heat exchange coefficient approach will be used to actually calculate the equilibrium coefficient.

N. EXCHANGE COEFFICIENT

The use of Newton's law of cooling, Equation 3.45, is essential for making an engineering estimate of the equilibrium temperature.

$$Q = K * DT \tag{3.45}$$

where

Q - heat transfer rate (HTOT in model) normal to grid surface area (Btu/ft²- day)

K - idealized heat transfer coefficient (Btu/ft²-day-°F)

DT - temperature difference (TE - TW) ($^{\circ}\text{F}$)

By subtracting Equation 3.44 from 3.37 it follows that

$$\begin{aligned} \text{HTOT} = & -[\text{EW} * \text{SB}[(\text{TW} + 460)^4 - (\text{TE} + 460)^4] \\ & + (a_2 + b_2 V)(\text{ES} - \text{EE}) + C_3 (a_2 + b_2 V)(\text{TW} - \text{TE})] \end{aligned} \quad (3.46)$$

where EE is saturated vapor pressure evaluated at TE. Now by combining 3.45 and 3.46 and solving for K we have the relationship

$$\begin{aligned} K = & \text{EW} * \text{SB}[(\text{TW} + 460)^4 - (\text{TE} + 460)^4] \\ & + (a_2 + b_2 V)(\text{ES} - \text{EE}) + C_3 (a_2 + b_2 V)(\text{TW} - \text{TE}) / (\text{TW} - \text{TE}) \end{aligned} \quad (3.47)$$

By using the binomial expansion and neglecting second and higher order terms in Equation 3.41 and Equation 3.48 the linear vapor pressure approximation, BETA, shown below

$$\text{ES} - \text{EE} = \text{BETA}(\text{TW} - \text{TE}) \quad (3.48)$$

where BETA is found in Table 3.5, we have, from Equations 3.46 to 3.48,

$$K = 4\text{EW} * \text{SB} 460^3 + (a_2 + b_2 V)(C_3 + \text{BETA}) \quad (3.49)$$

After substitution of

$$\text{EW} = 0.97 \text{ and } \text{SB} = 4.2 \times 10^{-8} \frac{\text{Btu}}{\text{ft}^2 \text{-day } ^{\circ}\text{R}}$$

Temperature Range °F	BETA (mmHg °F ⁻¹)
40-50	0.291
50-60	0.405
60-70	0.553
70-80	0.774
80-90	0.990
90-100	1.289

TABLE 3.5. LINEARIZED VAPOR PRESSURE CONSTANT, BETA
(REFERENCE 12)

The final result is:

$$K = 15.7 + (a_2 + b_2 V) (C_3 + \text{BETA}) \quad (3.50)$$

where K has units of Btu/ft² - day °F and a_2 , b_2 , V, C_3 , BETA are all constants. Finally, we substitute 3.37 and 3.50 into Fourier's law, Equation 3.45, and the result is:

$$T_E = \frac{HTOT}{K} + TW \quad (3.51)$$

Equation 3.51 now is used to calculate the equilibrium temperature in the model.

IV. COMPUTER MODEL SUMMARY

A. PRELIMINARY MODEL DETAILS

A.1. General

The computational scheme is controlled from the main section of the computer program by calling subprograms in order with suitable comments inserted to guide user through model operation. Pertinent hydrodynamic information for Narragansett Bay can be found in Kurt Hess's, Numerical Tidal Model of Narragansett Bay (4). Following the general computational procedure in the main section of the thermal model we encounter the following input control parameters:

IPRIND - Number of 4-minute intervals after which temperature displays are read into storage.

If IPRIND equals 15, it does this once an hour.

HS1(IDY) - Total daily solar radiation for day-IDY
(not used if hourly values are available)

RDCNP - Logical variable, if true, one should specify temperature field. If false program defaults to a constant bay temperature field of arbitrary specification, TBNB.

A.2. Computation Parameters

DELTAT - Logical variable, if true, model will calculate temperature above ambient (forced temperature rise, FTR) where we now define boundary temperature to be nearly zero:

TMHOPE = .00001°C

TRIVER = .00001°C

TSOUND = .00001°C

- If false, the model calculates ambient plus forced temperature rise

TBNB - Arbitrary temperature field specification

UPCON - Variable that increases dispersion coefficient, same for x and y direction with a range of values from 2 to 500 yd^2/sec . (Dived by 5.93 from Equation 2.27)

TIN - Temperature increase in condenser (°C)

QIN - Condenser flow rate (cfs)

SITE - Various location choices for surface or submerged discharge from heat source

NPRINT(I) - Print out of velocity and temperature field, first index must be 1 and all numbers thereafter must be

in increments of 15 or 30, e.g., 1

15, 30, 60, 75, 105 . . .

A.3. Main Body of Program

Subroutine HEATIN - Specifies source term and
indices for power plant
siting

Subroutine INVAL - Reads and writes all initial
values for program

Subroutine OPENED - Specifies all hydrodynamic
and thermal boundary conditions

Subroutine UPNFHT - Calculates VP and SEP on column n
(north-south) for first
half timestep

where

$$UP = u^{t+1/2} \quad U = u^t$$

$$SEP = n^{t+1/2} \quad SE = n^t$$

$$VP = v^{t+1/2} \quad V = v^t$$

so "P" means higher time level in notation seen
above

Subroutine VPMFHT - Calculates VP on row m
(east-west) for first
half timestep

Contained within subroutine VPMFHT are the following:

- a. Subroutine WATDEP - Heat exchange values that
are a function of water
temperature
- b. Subroutine WATIND - Heat exchange values that
are independent of water
temperature
- c. Subroutine AZ - Calculates the average bay
temperature from a total of
six arbitrary subdivisions
- d. Subroutine PRINT - Controls all print punch
operations as well as time-
step reallocation for
variables

Subroutine VPMSHT - Computes VP and SEP on column
m second half timestep

Subroutine UPNSHT - Computes SEP on row n second
half timestep

Subroutine DISPLY - Graphical output of thermal
model at end of the computa-
tional run. Calls IBM sub-
routine PLOT at the end of the
computer run

Subroutine ANALYZE - Tidal pattern real vs. actual

A.4. Data

YR - Year, e.g., 57 for 1957

DAY - Day of Year, e.g., 194 for July 17

THR - Hour in Day, e.g., 17

TMIN - Minute, e.g., 48

TMHOPE - Mt. Hope temperature condition

TRIVER - River temperature conditions around bay

TSOUND - Rhode Island Sound temperature condition.

A.5. Execution Parameters

IMODES = 2, for central and, 1 for upstream
differencing

IPUNCH - timestep at which model will punch out
data

AT - half timestep = 120 sec

MAXST - computational length, MAXST/15 = number
of hours real time

B. MODEL APPLICATION FOR NARRAGANSETT BAY, HYDRODYNAMICS SECTION

B.1. Introduction

Now that the fundamentals of the computer scheme have been discussed, the model may be applied to the

specific case of Narragansett Bay. This requires the selection of the grid net which describes the Bay geography, with physical data on grid depths and bottom friction read in. The hydrodynamic boundary conditions are given as time varying functions at Mt. Hope Bay and Rhode Island Sound. The following sections outline the application procedure.

B.2. Grid Net Selection

Few, if any, guidelines exist for the selection of an optimum grid system for a water body, especially one like Narragansett Bay with its complicated geography. The first step taken, however, was the choice of the water boundaries. The area of the Bay to be modeled is bounded on the south by Rhode Island Sound, on the east by the entrance of Mt. Hope Bay, and the north at the narrowing of the Seekonk River. This area represents about two-thirds of the entire Bay. The portion excluded, Mt. Hope Bay and the Sakonnet River, comprises another estuarine system, and is connected to the main part of the Bay by a narrow passage.

Secondly, the computation scheme imposes a minimum of two grids per row or columns in the field. Thus, the narrowest channel must be at least two grids wide. These critical areas occur in the lower Bay, in the East and West

passages, and in the upper Bay in the Providence River (Figure 4.1). Therefore, a grid length of one-half nautical mile (1012.7 yds.) was chosen. The resulting grid net consists of 314 water and 11 water-boundary grids within the rectangular (19 by 48) field for a total of 325 grids. The model axis has been rotated 10.1 degrees clockwise from the true north-south direction for more accurate representation of the shore geometry.

B.3. Model Time Step Selection

One important property of the implicit solution method is its unconditional numerical stability, (values need only be bounded) regardless of time step. However, the size of the time step has an effect on the accuracy of the solution.

Leendertse (1) has shown that the solution is accurate when Equation 4.1, shown below, is less than 5.

$$\frac{AT}{L} (gh_{\max})^{1/2} \leq 5 \quad (4.1)$$

where

AT - time step

L - grid length

g - acceleration of gravity

$h_{\max}$ = maximum bay depth

RHODE ISLAND SOUND

□ BOUNDARY CONDITION
GRID ELEMENTS

FIGURE 4.1. GRID SYSTEM FOR NARRAGANSETT BAY

Note that the factor $\sqrt{gh}$ is the maximum long-wave celerity. For a maximum depth of 152 feet in the bay a grid length of 3038 feet, and a time step of 220 seconds Equation 4.1 has a value of 4.91. Therefore, a time step, ΔT , of this size or less insures good accuracy, especially since the average depth of the Bay is only 30 feet.

B.4. Bay Depths

Bathymetric variations are accounted for in the depth specification at each grid square. In accordance with the placement of variables within the grid, Figure 4.2, the depth in the corner of the grid at $(x_c + 1/2, y_c + 1/2)$ is entered as data for all grids in the computation field.

FIGURE 4.2. DEPTH SPECIFICATION

The number entered is the actual depth at mean sea level at that point on the grid, and not the average depth over the grid square as shown in Figure 4.2. Depths may also be entered without harm at grid squares outside the computation field, such as those adjacent to water grids.

General information on the bathymetry was obtained from the U.S. Coast and Geodetic Survey chart No. 353, which gives depths at mean low water. It should be noted that while such charts are useful, certain small-scale features may not be evident from them. For certain critical locations, therefore, depth surveys would be quite useful. These were carried out in the West Passage at the Jamestown Bridge, and at the Mt. Hope Bridge.

B.5. Chezy Coefficient

The effects of bottom friction are introduced through the Chezy coefficient

$$C_z = \frac{1.49}{N} (h + \eta)^{1/6} \quad (2.20)$$

The dependence of Equation 2.20 on η makes C_z a time-varying function. However, since the water level, η , is usually much smaller than the depth, h , at mean sea level, its influence is small (Hess, 4). Thus, values of C_z are computed at the start of each run (for $\eta = 0$), and are

not changed afterward.

The selection of the Manning factor (N in $\text{ft}^{1/6}$) poses a somewhat more difficult problem, due to the lack of extensive studies for rivers and bays. Masch and Brandes (49), for example, use values between 0.018 and 0.054, which corresponds to "rubble set in cement" and "natural river channels: winding, with pools and shoals", respectively, in a table given by Henderson (50). The essential concept is bottom roughness, which varies considerably in an area as large as Narragansett Bay. For approximation, then, the Manning factor was taken as a linear function of m , the north-south section number:

$$N(m) = N_{\text{avg}} (1.3 - 0.6m/\text{max}) \quad (4.2)$$

which varies from $1.3 N_{\text{avg}}$ in the Providence River to $0.7 N_{\text{avg}}$ at the mouth of the Bay. The average value, N_{avg} , was determined from comparisons of predicted and observed velocities, and was taken as 0.020.

B.6. Rhode Island Sound Boundary

The primary driving force at the mouth of Narragansett Bay is the astronomical tide, and thus is entered as a water level boundary condition at that location, grids $m = 48$, $n = 8, 9, 11, 12, 13$. The coast and Geodetic Survey regularly collects and analyzes tidal elevations at

several locations around the Bay. The primary stations are at Newport, Bristol, and Providence, and the data obtained is used to calculate the amplitude and phase angle of the twenty or so largest tidal constituents (51). A number of secondary stations have been occupied, and the times of high and low water relative to Newport are given for them in reference 51.

The tidal forcing function may be represented by the sum of several sinusoidally varying terms, each with a specified amplitude, angular speed, and phase angle (52). The phase angle is taken relative to Greenwich, England; the amplitude is modified by a function of lunar position, f_n . The equation for the water level, η , is

$$\eta(t) = H_0 + \sum_n f_n(t) H_n \cos [w_n t + (V_0 + u)_n - k_n] \quad (4.3)$$

where

H_0 - the height of the mean sea level above the datum
(mean low water)

and for each constituent, n ,

$f_n(t)$ - amplitude factor depending on the position
of the moon's line of nodes

H_n - amplitude of the constituent

w_n - angular speed (degrees per hour) of the constituent

$(V_0 + u)_n$ - value of the equilibrium argument when
 $t = 0$

k_n - epoch (angular phase difference from Greenwich)

t - time (hours) from reference time

The values of H_0 , H_n , and k_n are calculated for each tide station. The angular speed (w), lunar node function f_n and equilibrium argument $(V_0 + u)_n$ can be calculated from knowledge of astronomical motions, and are tabulated in reference 52. (See Hess (4), Subroutine KURIH).

The tide at the lower boundary is calculated at each of the end grids ($m = 48$, $n = 8, 9, 11-13$) by an equation of the form 4.3. The tide at the intermediate grids is obtained by linear interpolation. The amplitude and epoch of each constituent used at the boundary is derived from the analysis of tidal data taken at three previously mentioned stations. The tidal values will be improved by data obtained from the Ocean Engineering Department's, Whale Rock tide gauge.

Several other types of boundary conditions are included in the model, and can be used in various hydrodynamic experiments. (See Hess (4), Chapter II).

B.7. Providence River Boundaries

The boundaries located in the northern part of

the Bay represents river flows and are velocity boundary conditions in the model. The Providence Harbor is the sum of several rivers, while the Pawtuxet River joins the Providence River further down the Bay. Several smaller river flows into the Bay are neglected because their discharge flow rates would have no noticeable affect on local fluid motions.

The total volumetric flow rate from the Blackstone-Seekonk, Moshassuck, and Woonasquatucket Rivers is entered at boundary grid $m = 1$, $n = 3$ and 4 to simplify the model grid system in that region. The mean annual flow rate, about 890 cfs including discharge from the City of Providence, is fairly small compared to tidal flowrate so that local velocities do not differ significantly in the area as a result. The daily average flowrate may either be obtained from surface water records (53) or estimated from the ratio of monthly to yearly mean discharges.

The Pawtuxet River boundary ($m = 10$ and 11, $n = 4$) is handled in the same manner as the Providence Harbor boundary.

B.8. The Mt. Hope Boundary

The boundary at the entrance to Mt. Hope Bay probably is the most difficult to model accurately. The

local geography does not permit the use of the Bristol Harbor tide as a water level boundary condition, so a tidal velocity, based upon the volumetric flowrate, is used.

The total flow under the Mt. Hope Bridge is determined by tidal differences, river discharges, and wind effects. The tidal flow results from water level variations between the Narragansett and Mt. Hope Bays where the Mt. Hope Bay is also connected to the Rhode Island Sound by the Sakonnet River. Also, a certain fraction of the fresh water discharge into the Mt. Hope Bay, primarily from the Taunton River (mean annual flowrate of 660 cfs), passes under the bridge. Local winds may contribute to daily variations in the flow, but they are neglected since no data on wind currents is available.

The earliest available measurement of the flow under the bridge were reported by Haight (54), who used a 7 foot pole and three current meters on August 7 and 8, 1930. Recent measurements, Binkerd (55), (August 5 and 18, 1971) were taken by using several poles spaced across the section under the bridge. The general approach of analyzing the data used by Haight was applied to the newer observations.

Due to the nature of the bay geometry, Haight (54)

showed that the currents due to the lunar (M_2 , M_4 , and M_6) constituents of the tide accounted for most of the obtained current. The flowrate can then be approximated by

$$q = \sum_{k=1}^3 q_k \cos \left[\frac{2\pi k}{12.42} (t - \tau_k) \right] \quad (4.4)$$

where q is the flowrate, and τ the time to first flood after high water. The flowrate was deduced from the 1930 data by integrating the velocity over the depth, and multiplying by a weighted area under the bridge ($90,600 \text{ ft}^2$).

The flowrates for the other observations were calculated by summing the products of the pole velocity and the incremental area; the resultant values were adjusted for the tidal range and smoothed. A weighted average was then analyzed, by a least squares technique, using an equation similar to 4.4. The results are shown in Table 4.1.

k	Lunar Constituent	Period (hr.) T	Time to First Flood (hrs)	Current (kts)	q_k (10^3 cfs)
1	M_2	12.42	9.87	1.12	150.5
2	M_4	6.21	6.29	0.29	33.2
3	M_6	4.14	3.32	0.15	35.4

TABLE 4.1. LUNAR CONSTITUENT ANALYSIS OF FLOW
UNDER MT. HOPE BRIDGE

The tidal velocity is obtained by dividing the flowrate, q , by the area at the boundary.

The portion of the Taunton River discharge passing under the bridge is obtained from Hicks, (57), who estimated the river outflow from the ebb flowrates through each Bay passage. The value used here is 72% of the annual mean flow or 475 cfs.

C. MODEL APPLICATIONS FOR NARRAGANSETT BAY - THERMAL SECTION

C.1. Boundary Conditions

As previously mentioned in the hydrodynamic section, the river flow rates are small compared to tidal flow and as a consequence the river temperature boundary conditions around the bay have no noticeable affect on spatial heat variations. Nevertheless, a constant value of 22.20°C was chosen to represent mid-summer conditions at all river outfall areas. The Mt. Hope boundary condition is important because the flow under the bridge is of the order of 10-20% of the tidal flow. From data available at this time (37) a constant value of 21.75°C was chosen. Finally, at the Rhode Island Sound boundary condition, a constant value of 18.5°C is used (31). It is quite obvious that the fixed Rhode Island Sound boundary condition will represent

the greatest source of inaccuracy in the model. A proposed improvement would be to vary the boundary condition as a function of tidal velocity across lower east and west passage as shown in Equation 4.5

$$\begin{array}{l} \text{Rhode Island temperature} \\ \text{boundary condition} \end{array} = 18.65 + \frac{\text{Ampl} * \text{Vel}}{\text{Vel}_{\text{max}}} \quad (4.5)$$

where

18.65 is now the average value of the boundary condition

Ampl = .15°C - half temperature tidal excursion

Vel - tidal velocity (yds/sec)

Vel_{max} - maximum tidal velocity - taken as .125 yds/sec

Temperature excursion was determined by plotting at a typical North-South temperature profile shown in Figure 4.3.

The use of Equation 4.5 would help model boundary condition by taking into account, in an approximate way, the flow of warm water back into the bay.

C.2. Thermal Model Modes

The model can operate under various schemes that are shown in Table 4.2. These were formulated to help isolate the various heat transfer processes involved in simulating both natural and man-made conditions. Mode I is most commonly used.

FIGURE 4.3. NORTH-SOUTH TEMPERATURE PROFILE

DELTAT	CONDITIONS	RDCNP	TBNB	BOUNDARY CONDITIONS	NET HEAT EXCHANGE	POWER PLANT	MODE
False	Ambient	False	21°C All Bay	AA TMHOPE=21.75°C TRIVER=22.2°C TSOUND=18.5°C	HTOT	No	A
					HTOT = 0*	No	B
		True	Not Used in Model	Same as AA Above	HTOT	No	C
					HTOT = 0	No	D
	Ambient Plus Forced Temperature Rise	False	21°C All Bay	Same as AA Above	HTOT	Yes	E
					HTOT = 0	Yes	F
		True	Not Used in Model	Same as AA Above	HTOT	Yes	G
					HTOT = 0	Yes	H
True	Forced Temperature Rise	False	.00001°C All Bay	BB TMHOPE=.00001°C TRIVER=.00001°C TSOUND=.00001°C	HTOT	Yes	I
					HTOT = 0	Yes	J
		True	Not Used in Model	Same as BB Above	HTOT	Yes	K
					HTOT = 0	Yes	L

* Adiabatic Surface Condition

TABLE 4.2. THERMAL MODEL MODES

C.3. Net Heat Exchange

The value of HTOT, the net heat exchange transfer rate, is obtained from Equation 3.37. This is read into the model by the following formulation:

$$HTOT \times AREA = \frac{Btu}{ft^2 \cdot day} \times GSA \times \frac{yd^2 \times 9 \text{ ft}^2 / yd^2}{(24 \text{ hr/day}) (3600 \text{ sec/hr})} \quad (4.6)$$

$$\text{Heat into box} = \frac{9 \times GSA}{24 \times 3600} \quad \frac{Btu}{sec} = Q \quad (4.7)$$

where GSA - grid surface area

$$\text{but } Q = mc_p DT \quad (4.8)$$

and

Q - heat transfer rate per unit time

c_p - specific heat of water at constant pressure

DT = temperature change in box per unit time

Combining 4.7 and 4.8 and solving for DT we have:

$$DT = \frac{Q}{mc_p} = \frac{9 \times GSA}{24 \times 3600} \times 64 \frac{lb}{ft^3} [GSA \text{ yd}^2 \times \frac{9 \text{ ft}^2}{yd^2}] \times \text{Depth (yd)} \times \frac{3 \text{ ft}}{yd} \quad (4.9)$$

Consolidating, the result is

$$DT = \frac{HTOT}{24 \times 3600 \times 64 \times 3 \times \text{Depth}} = \text{°F/sec} \quad (4.10)$$

for a depth of 30 feet the final result is

$$T = \frac{HTOT}{1.66 * 10^7} \text{ } ^\circ\text{F/sec} \quad (4.11)$$

For a value of $HTOT = 10 \text{ Btu/ft}^2\text{-day}$, the net heat flux, we have

$$DT = \frac{10 * 86,400}{1.66 * 10^7} \quad (4.12)$$

$$= \frac{8.6 * 10^5}{1.66 * 10^7} = .052 \text{ } ^\circ\text{F/day} \quad (4.13)$$

For one year we would have

$$T = .052 * 365 = 19^\circ\text{F} \quad (4.14)$$

which is of the order of the annual variation in the Narragansett Bay area.

The read in variables required for computing Equation 3.37 are the following:

TA - temperature of the air, $^\circ\text{F}$ (T.F. Green Airport,
(56))

RH - Relative humidity, percent (T.F. Green Airport,
(56))

HS2(1) - Hourly solar radiation parameter (grm-cal/cm^2)
(scale factor of .2 from Eppley Laboratory,
Unpublished)

WA - Wind speed, miles per hour (T.F. Green Airport,
(56))

ANG - Direction that wind blows from, degrees (T.F.

Green Airport, (56))

CLDCVR - Percent of sky covered with clouds (T.F.

Green Airport, (56))

C.4. Power Plant

To determine power plant requirements, the cooling water rate per unit power must be known (see Figure 4.4).

FIGURE 4.4. POWER PLANT SCHEMATIC

A straightforward calculation is presented using the steady flow energy equation

$$q - P_x = W_{cw} \left[\left(h_6 + \frac{v_6^2}{2} + z_6 \right) - \left(h_5 + \frac{v_5^2}{2} + z_5 \right) \right] \quad (4.15)$$

$$q_{out} - 0 = W_{cw} [h_6 + 0 + 0] - (h_5 + 0 + 0) \quad (4.16)$$

$$q_{out} = W_{cw} (h_6 - h_5) \quad (4.17)$$

where

q_{out} - heat removed from working fluid after it has passed through turbine

W_{cw} - cooling water flow rate

h - enthalpy of fluid

Transforming Equation 4.17 we have

$$\frac{P \cdot q_{out}}{P} = P \cdot \frac{q_{in} - P}{P} * \frac{1/q_{in}}{1/q_{in}} = W_{cw} (h_6 - h_5) \quad (4.18)$$

$$\frac{P(1-E)}{E} = W_{cw} (h_6 - h_5) \quad (4.19)$$

where $E = \frac{P}{q_{in}}$ - efficiency

for $h = c_p DT_{cw}$

and DT_{cw} - temperature increase, $^{\circ}F$, in cooling water through heat exchanger

Equation 4.19 becomes, after a little rearranging

$$\frac{W_{CW}}{P} = \frac{1-E}{E} \frac{1}{c_p DT_{CW}} \quad (4.20)$$

Assuming

$$E = \text{plant efficiency} = 40\%$$

$$c_p = 1 \text{ Btu/lb}_m^{\circ}\text{F}$$

$$DT_{CW} = 20^{\circ}\text{F}$$

Equation 4.20 is now

$$\frac{W_{CW}}{P} = \frac{1-.4/.4}{\text{Btu/hr}} * \frac{\text{lb}_m^{\circ}\text{F}}{1 \text{ Btu} \times 20^{\circ}\text{F}} * \frac{3413 \text{ Btu/hr}}{\text{Kw}} * \frac{10^3 \text{ kw}}{\text{Mw}} \quad (4.21)$$

which results in

$$\frac{W_{CW}}{P} = 255.97 * 10^3 \frac{\text{lb}_m}{\text{hr Mw}} * \frac{\text{ft}^3}{64 \text{ lb}_m} + \frac{\text{hr}}{3600 \text{ sec}} \quad (4.22)$$

$$= 1.1 \frac{\text{cfs}}{\text{Mw}} \quad (4.23)$$

For a plant with an 1800 megawatt capacity we would need approximately 2000 cfs for a rated efficiency of 40%.

The data used in the model is summarized as follows:

$$W_{CW} = 2000 \text{ cfs} = Q_{IN} \quad (4.24)$$

$$DT_{CW} = 12^{\circ}\text{C} = T_{IN}$$

These two values represent reasonable values but certain engineers might prefer to use a cooling water rate

based on 1500 cfs/1,000 megawatts or a $DT_{cw} = 25^{\circ}F$. There are so many possible choices of flow rates, temperature increases and site locations that the model is structured to handle these many personal preferences in user production runs.

Also, it should be kept in mind, that a power plant generally has an average power production rate below the 95% maximum output rate under peak load conditions to further complicate environmental studies.

C.5. Bay Zonal Divisions

The bay was divided into six major geographically similar sections each with various subsections that comprise the main hydrodynamic elements of the model. This is seen in Figure 4.5. The Rome Point area will affect primarily zone 1.

C.6. Rome Point Area

An enlarged section of Narragansett Bay map Figure 4.10 for the Rome Point area is seen in Figure 4.6. In the prediction portion of this report, isotherms will be drawn in, with average temperature values included in each box.

FIGURE 4.5. NARRAGANSETT BAY ZONAL DIVISIONS

FIGURE 4.6 . ROME POINT AREA

V. GENERAL STUDIES OF TEMPERATURE MODEL BEHAVIOR

A. EFFECT OF THE DIFFERENCES

As mentioned in Chapter II and Appendix D the differencing schemes will affect the computed values. The central differencing scheme is preferred because it does not alter the natural dispersion coefficient in the model and is insensitive to the divergent flow patterns. It should be kept in mind that for the dispersion coefficient value of $5.0 \text{ yd}^2/\text{sec}$ used by Sapulding (16) and considered realistic there is a transient response in the model of several days and with a heat source causes wild computational behavior that propagates near discharge.

B. VERIFICATION PROCEDURE

The most logical first step is to have a uniform temperature for the Bay and its exits and entrances with no heat exchange across the air-water interface. This was done and the results of this are shown graphically in Figure 5.1. A value of the dispersion constant, UPCON, was chosen as 500 for rapid mixing and convergence to the steady state bay temperature. This procedure required two hours of computer time.

The energy loss is only $0.03/21.00$ or 0.14 percent drop

FIGURE 5.1. ENERGY BALANCE FOR BAY, UNIFORM TEMPERATURE CASE

in almost four days but the maximum rate of decrease is of the order of 0.05 percent for the four day period. This is quite acceptable when compared to the findings of Leendertse (2) and establishes the primary verification of the model.

C. STARTING TRANSIENT

When the computations during first few hours of simulation are made, it is assumed that the model will tend toward equilibrium from some arbitrary initial temperature field. The transient response for the forced temperature rise apparently follows two and possibly three phases for the shallow water region selected for a possible power plant site. These phases are shown in Figure 5.2.

FIGURE 5.2. PHASES OF TRANSIENT RESPONSE FOR FORCED TEMPERATURE RISE AND TIDAL AVERAGES

phase I is primarily the rapid increase in the temperature to within 80-90 percent of the steady state value. Steady state means that the apparent temperature average from tidal cycle to tidal cycle is at most a gradual but regular change. Phase II will consist of the alignment of the temperature peaks and dips with some sort of tidal regularity. Finally, Phase III, not always distinct from II, will represent the level at which we have established some steady state value for the forced temperature rise. Further investigation is necessary to determine how steady state values vary over an average monthly variation of tidal cycles. The steady state is emphasized as the apparent average of the temperature oscillation that may itself have a much larger period of oscillation. Each grid has its own transient response characteristics so reference here is made only to grid $m = 35$, $n = 5$. Figure 5.3 gives general guidelines for reaching steady state forced temperature rise as a function of dispersion coefficient.

Once a general understanding of the temperature transient response is obtained it is a simple matter of adding it onto the ambient condition provided one stays within the bounds of the linearization assumptions explained in Chapter III, Section L.

FIGURE 5.3. THE ESTABLISHMENT OF THE STEADY STATE TIDALY
 AVERAGED VALUES OF FORCED TEMPERATURE RISE AS A
 FUNCTION OF DIFFUSION COEFFICIENT FOR GRID $m = 35$, $n = 5$

In summary, the transient response is of the order of 5-10 tidal cycles for the lower range of dispersion coefficient; requiring careful preliminary investigation before making any evaluations of forced temperature rise.

D. DISPERSION COEFFICIENT

In the following discussion, the Rome Point location $m = 36$, $n = 5$ was chosen because its shallow depth and local interest make it a good example. As is seen from Figure 5.3, a diffusion coefficient of the order of 5-20 yd^2/sec in the vicinity of grid $m = 36$, $n = 5$, will force the model into computational difficulty, that is, a forced temperature rise greater than DT_{cw} of condenser. Figure 5.3 shows the general temperature increases for the various dispersion coefficients that may be used as a guide for determining the average tidal temperature increases in the outfall area.

The dispersion coefficient enhancing technique, elaborated in Chapter II, Section D, and Appendix D, would enable one to use a value of 5-20 yd^2/sec in the model and would be as close to the real conditions as possible. At this stage in the development of the model, it was decided to use the value of 50 yd^2/sec throughout the bay as a

FIGURE 5.4. GRAPHICAL REPRESENTATION OF MINIMUM
VALUE OF DISPERSION COEFFICIENT FOR ROME POINT,

$$m = 36, n = 5$$

first estimate in determining the general isotherm pattern around the discharge. With a grid size of about 1000 yards and the model interest in the far field it is felt that the results for a dispersion coefficient of the order of 50

VI. COMPARISON OF CALCULATED RESULTS AND HISTORICAL DATA

A. BACKGROUND

Given the necessary meteorological data, solar inputs, and boundary conditions it is feasible to predict the bay temperature field through thermal model calculations. In any model verification procedure, the comparison between measured and computed values is difficult because of the small area encompassed by measurements versus the larger $1/2$ by $1/2$ nautical mile area of the model grids. Since model averages vertical water temperature column, surface to bottom temperature measurements continuously taken on area wide basis, are required to achieve more realistic verification criterion. Being realistic, the reference period July, 1957 was chosen to give insight on where the model and measurements are most divergent because of the dissimilar nature of the model and the historical measurements.

This does not mean that the model has little value, which it does have for large scale simulation, but rather that measurements should be taken on a length and time scale comparable to the model. The summer of 1957 was chosen for comparison because it contains the heaviest concentration of temperature data taken in Narragansett Bay.

B. MODEL SIMULATION CONDITIONS

The following conditions were adopted for comparison procedure (see next page).

C. NARRAGANSETT BAY DATA

C.1. Narragansett Marine Lab Pier

The data obtained from Hicks (37) and Day (38) is plotted in Figure 6.1 along with the computer results. In addition, the lower boundary condition derived from the average of July measurements at Brenton's Reef (31) was changed arbitrarily from 18.5 to 19.5°C and this result is also shown in Figure 6.1.

It is quite clear that the model grid predictions are between 1.0°C and 2°C too low.

C.2. Newport, Rhode Island

The Newport Data (41) as presented in Table 6.1 shows reasonable agreement with data.

<u>DATE</u>	<u>TIME</u>	<u>MEASURED</u>	<u>MODEL</u>
July 16	11:30	20.0°C	19.85°C
July 17	11:30	20.0°C	19.90°C
July 18	14:10	21.67°C	20.20°C

(Table Continued)

<u>DATE</u>	<u>TIME</u>	<u>MEASURED</u>	<u>MODEL</u>
Monthly Average	Morning	20.1°C	20.0°C

TABLE 6.1. NEWPORT TEMPERATURE DATA, (41) GRID

LOCATION n = 15, m = 40

C.3. Bay Data

Hicks (37) undertook Cruise III between July 15 to July 19, 1957 with a total of 19 stations around the bay. In most cases at least four depth measurements were taken at each station and the average of these was used as a comparison with the model as shown in Table 6.2.

The agreement is good for stations where the temperature in the water column is rather uniform. For the Rhode Island Sound station, where the bottom temperatures go as low as 15.3°C, 3.2°C cooler than any temperature in the bay thermal field, the average of measured values are about 0.5°C too low.

C.4. Meteorological Data

The air temperature measurements taken at T.F. Green Airport (56) can be seen in Figure'6.2 and they show no extreme activity for this period. Although the monthly

VARIABLE NUMBER	CONDITIONS	VALUE
1	YEAR (YR)	57.
2	DAY	195.
3	THR (HOUR)	17.
4	TMIN (MINUTE)	48.
5	TMHOPE (Temperature Mt. Hope Bay)	21.75°C
6	TRIVER (Temperature of Rivers)	22.2°C
7	TSOUND (Temperature of R.I. Sound)	18.50°C
8	TBNB (Temperature Field)	21.0°C
9	IMODES (1-Upstream; 2-Central Differencing)	2
10	RDCNP (Temperature Read In, °C)	False
11	UPCON (Dispersion Coefficient Constant)	500 x Elder's Value/5.93
12	QIN (Source Flow Rate CFS, i.e. Power Plant)	0.0
13	TIN (Cooling Water Temperature Increase)	12°C
14	SITE (Power Plant Output and Input)	100 (Flow Out: n=5, m=36. Flow In: n=6, m=37)
15	Plotting Time	96 Hours
16	Program No.	12271
17	Date of Run	1/26/73

EXPERIMENTAL RUN 1 (NATURAL CONDITIONS FOR MODEL-
MEASUREMENT COMPARISON WITH NO POWER PLANT EFFECTS)

FIGURE 6.1. NARRAGANSETT MARINE LAB PIER LOCATION (8, 43)

<u>DATE</u>	<u>TIME</u>	<u>STATION</u>	<u>GRID</u>	<u>DEPTH</u> <u>AVERAGED</u> <u>MEASUREMENT</u>	<u>MODEL</u>
July 15	Morning	5	(3, 21)	23.00	22.9
July 15	0855	10	(9, 28)	21.40	21.8
July 15	0810	13	(8, 33)	20.60	21.7
July 16	0850	14	(13, 38)	18.5	20.2
July 16	1058	15	(8, 41)	18.75	18.50
July 16	1012	16	(8, 48)	17.90	18.50
July 16	0950	17	(12, 48)	17.10	18.50
July 17	1445	Narra- gansett Marine Lab	(8, 43)	21.0	19.50

TABLE 6.2. CRUISE III, HICKS (37) TEMPERATURE
MEASUREMENTS

FIGURE 6.2. DAILY TEMPERATURE PATTERN AT T.F.
GREEN AIRPORT (56)

average was 1.0°C above normal, wind speeds were in the 10-12 M.P.H. normal range and relative humidity was about 67 percent or within normal range for this measurement period.

Solar input, as recorded at the Eppley Laboratory, Newport, Rhode Island can be seen in Figure 6.3.

The solar input for this period is about 25 percent

FIGURE 6.3. SOLAR INPUT, EPPLEY LABORATORY,
NEWPORT, RHODE ISLAND

above the average monthly value of 1920 Btu/ft²-day.

D. EVALUATIONS

With the discrepancies in the predicted versus actual values of water temperature, it is certainly not clear that this form of verification is realistic or profitable. With regard to Masch et al (57), where comparisons between

detailed prototype, physical, and computer predictions were in error by 10 to 25 percent, the thermal model variances, of this magnitude, do not seem disappointing at all.

Let's begin with the discrepancies that occur at the Narragansett Marine Lab Pier. A referral to Figure 6.4 will clearly show general geographical area and the model grid system overlay.

FIGURE 6.4. NARRAGANSETT MARINE LAB PIER,
GENERAL LOCATION AND DEPTHS

The model can include grid (7,43) with a depth of 7.2 yards which would be a much better representation for the Narragansett Marine Lab than the originally chosen grid (8,43), with a depth of 15.6 yards. The temperatures in grid (7,42), directly north of a more desirable grid (7,43), averaged 0.5°C above those in grid (8,43). Since the proposed box would also be a corner box, the dispersion coefficient will strongly influence western diffusion of cooler Rhode Island Sound water during flow up the bay. This verification run has a high value of dispersion to insure a well mixed bay. Unfortunately, this inflated value increases the effect of the cool Rhode Island Sound flow past Narragansett Marine Lab Pier area.

In addition, the fixed boundary temperature for Rhode Island Sound is an approximation that complicates the prediction. It is felt that extensive development of the model with regard to a variable boundary condition for one tenth the dispersion coefficient used is necessary to improve comparison.

Although not certain, Dr. Hicks, by letter, has expressed a belief that the water temperature data at Marine Lab (38) was taken by a Bristol Recorder from a source at an unspecified depth below the surface and possibly flushed

through a holding tank with a capacity of several hundred gallons. It is interesting to note that the temperature data obtained by Hicks (37) shows that temperature differences at Narragansett Marine Lab Pier between top and bottom water for the period February 1952 to January 1958 averages 0.2°C . Referring back to Day (38) we also observe that temperature variations of a 4°C during the day at Narragansett Marine Lab Pier appear to be larger than common sense tidal flushing estimates. In Figure 6.5, it is seen for July 9 and 13 that with low solar input, temperature maximum decreases about 0.5°C while minimum temperature is unaffected. It appears that with this low solar input, we should be able to estimate depth of the water column if the solar energy is considered evenly distributed. We have,

$$\text{Solar Input} = 2000 \text{ Btu/ft}^2 \text{ (half day)} \quad (6.1)$$

$$= \text{Mass} * C_p * DT \quad (6.2)$$

where $DT = .5^{\circ}\text{C}$

$$\begin{aligned} \frac{1000 \text{ Btu}}{\text{ft}^2 \text{ (full day)}} &= \text{Depth} \times \text{Unit Area} \times \frac{64 \text{ lb}_m}{\text{ft}^3} \\ &\times \frac{1 \text{ Btu}}{\text{lb}_m^{\circ}\text{F}} \times \frac{.9^{\circ}\text{F}}{\text{Day}} \quad (6.3) \end{aligned}$$

after rearranging

FIGURE 6.5. NARRAGANSETT MARINE LAB TEMPERATURES (38)

Depth = 20 ft

(6.4)

With a measured depth of about 20 feet, we conclude that the water temperature variations do follow the above simplistic formulation. Also note in Figure 6.5 the unexplainable 2°C temperature increase of minimum temperature on July 17. This sudden increase of 2°C , in mean water temperature at the Narragansett Marine Lab Pier contributes substantially to the disagreement between the model and measurements because it increases the average water temperature by 1.5°C . This sudden change in water temperature shows the variability of taking measurements in shallow, inshore water.

This lengthy discussion on the Narragansett Marine Lab Pier temperature measurements can only be resolved by first conducting an extensive detailed area survey around the pier in conjunction with accurate Rhode Island Sound temperature boundary condition measurements. As will be true for all temperature measurements to be discussed, we would have to establish a meteorological station closer to the bay, preferably on the Narragansett Marine Lab Pier to more accurately represent the input conditions.

For the Newport Data (41) agreement was good while for Hicks (37) the data agreed if the vertical structure

was homogenous. It should be noted that if the 15-16°C bottom water temperatures for Rhode Island Sound stations were not included in vertical average the agreement between predicted and actual values would be closer.

E. CONCLUSION

This attempt at thermal model verification with field measurements while enlightening for general temperature variation shows quite clearly how formidable a task it is to have grid locations agree with temperature measurements to a ± 5 percent. Since the desired type of measurements for improved verification work would entail about 10 continuously operating data stations which are beyond the scope of department capability no further verification attempts were initiated. Dr. Eidinger (5) discusses the seemingly impossible task of the model verification with field measurements, an undertaking that no one has yet done successfully.

The lack of detailed model spatial agreement with measured temperature data should not detract from the information the model does predict of a more general nature.

VII. THERMAL MODEL PREDICTIONS

A. POWER PLANT LOCATION

The thermal model can place a heat source simulating an electric generating plant in any of the 314 non-boundary grids. The selection of the Rome Point area was made because the area is of local interest and the relative shallow water depth of 10 feet provides a good indication of the computational effectiveness of the model for a specific value of the dispersion coefficient. From a utility viewpoint, the surface discharge in the Rome Point grid, $n = 5$, $m = 36$, is inexpensive to construct and the land boundary at $n = 6$, $m = 36$ affords reentrainment protection from the intake grid located at $n = 6$, $m = 37$ or southeast of the intake.

The general geometry at the Rome Point site can be seen in Figure 7.1. The shaded area covers the most likely intake and discharge locations.

B. INTRODUCTION TO EXPERIMENTAL RUNS

The following experimental sections will contain various results that clearly show the effectiveness of the thermal model in predicting isothermal patterns around

FIGURE 7.1. ROME POINT AREA WITH MODEL GRIDS, DISCHARGE LOCATIONS AND DEPTHS

a particular heat source. The natural or non-power plant predictions show the thermal patterns that can be measured in the bay. The natural plus power plant predictions are an indication of the thermal pattern that would occur with a power plant in operation for the specified data.

The above ambient or natural condition that occurs if the effect of the power plant is isolated results in valuable plant siting information. To clearly demonstrate the effect of the power plant on the bay the natural temperature state is subtracted from the temperature state including the power plant. This shows quite clearly the effects of the power plant alone. This technique was formulated into a 'forced temperature rise above ambient' condition, where one sees only the effect of the power plant on the natural temperature state predicted by the model.

C. EXPERIMENTAL RUN 1 (THE NATURAL CONDITIONS IN NARRAGANSETT BAY AS PREDICTED BY THE THERMAL MODEL)

This first experimental run contains a listing of all variables in the program that must be defined. For experimental run 1, these are used to determine the natural temperature condition that occurs from July 14 to July 18, 1957 with no heat source included. In an effort to simplify

the discussion of the following experimental runs only the variables that are different from run 1 are listed.

TABLE 7.1. PROGRAM VARIABLES

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
1	YEAR	57.
2	DAY	195.
3	THR (HOUR)	17.
4	TMIN (MINUTE)	48.
5	TMHOPE (Temperature for the Mt. Hope Bay Boundary Condition, (B.C.))	21.75°C
6	TRIVER (Temperature for the River B.C.)	22.2°C
7	TSOUND (Temperature for the Rhode Island Sound B.C.)	18.50°C
8	TBNB (Temperature Field in the Bay)	21.0°C
9	IMODES (1-Upstream; 2-Central Differencing)	2
10	RDCNP (Temperature field read in, °C)	False

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
11	UPCON (Dispersion Coefficient Constant Times Elder's Value)	500
12	QIN (Source Flow Rate, cfs)	0.0
13	TIN (Cooling Water Temperature Increase Through Plant)	12.0°C
14	SITE (Power Plant Output and Input Grids Specified)	100 (Flow Out: n=5, m=36. Flow In: n=6, m=37)
15	DELTAT (Logical Variable. If true the model calculates forced temperature rise, if false it calculates natural condition with or without power plant.	True
16	Plotting Time	68 Hours
17	Program Number	12271
18	Date of Run	1/26/73

C.1. Comments

The temperature fields, as shown in Figure 7.1 and Figure 7.3, represent a typical display pattern. The relative similarity of isotherms with regard to shape and

AVERAGED TEMP. (DEGREES C TIMES 1000) FOR TIMESTEP 1020 AT TIME = 68.00 HRS																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0	0	22199	22199	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	22633	22412	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	22468	22421	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	22057	22054	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	22036	21998	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	21936	21862	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	21806	21758	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	21781	21718	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	21793	21677	21609	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	22199	21649	21602	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	22199	21623	21592	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	21548	21526	21616	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	21521	21488	21465	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	21493	21445	21410	21373	21354	21381	21465	0	0	0	0	0	0
15	0	0	0	0	0	0	21424	21376	21321	21279	21282	21302	0	0	0	0	0	0
16	0	0	0	0	0	0	0	21346	21242	21195	21206	21238	21209	0	0	0	0	0
17	0	0	0	0	0	0	0	21231	21089	21062	21157	21180	21164	0	0	0	0	0
18	0	0	0	0	0	0	0	21064	20934	20925	21082	21136	21137	0	0	0	0	0
19	0	0	0	0	0	0	0	20912	20889	20915	21002	21100	21109	0	0	0	0	0
20	0	21612	21500	21495	21481	0	0	20805	20831	20874	20975	21071	21048	0	21722	21448	0	0
21	0	21421	21288	21218	21118	20775	0	20696	20769	20828	20995	21057	21016	0	21201	21262	21308	0
22	0	21471	21318	21167	21023	20701	20570	20627	20710	0	21045	21028	20982	20938	20972	21187	21322	0
23	0	0	0	0	20902	20588	20540	20569	0	0	0	21009	20944	20878	20842	0	21390	21576
24	0	0	0	0	20750	20554	20459	20447	20292	0	0	20980	20891	20816	20751	20784	21105	21307
25	0	0	0	0	0	20473	20387	20342	20235	20136	0	0	0	20750	20658	20605	20930	0
26	0	0	0	0	0	20406	20304	20242	20160	20075	20001	19955	0	0	20460	20499	20686	0
27	0	0	0	0	0	20312	20212	20161	20084	20004	19941	19883	0	0	20261	20327	20509	0
28	0	0	0	0	0	20186	20115	20066	20018	19920	19859	19808	0	0	20131	20209	20342	0
29	0	0	0	0	0	20094	20022	19962	19919	19852	19805	19739	0	0	20014	20079	20176	0
30	0	0	0	0	0	19910	19872	19832	19780	19732	19678	0	0	19899	19940	19954	0	0
31	0	0	0	0	0	19778	19756	19752	19715	19676	19616	19548	19600	19741	19815	19884	0	0
32	0	0	0	0	19949	19671	19701	19674	19661	19671	19605	19548	19509	19573	19640	19713	0	0
33	0	0	0	19936	19802	19585	19605	19582	19595	0	19544	19478	19444	19500	19553	19608	0	0
34	0	0	0	19832	19727	19543	19533	19495	19504	0	19465	19411	19382	19422	19461	0	0	0
35	0	0	0	0	19668	19511	19466	19424	19426	0	0	19324	19292	19350	19409	0	0	0
36	0	0	0	0	19602	19488	19418	19365	19349	0	0	19252	19217	19276	19335	0	0	0
37	0	0	0	0	0	19434	19364	19304	19279	0	0	19177	19177	19208	19262	0	0	0
38	0	0	0	0	0	0	19309	19242	19214	0	0	19130	19126	19108	0	0	0	0
39	0	0	0	0	0	0	19220	19182	19157	0	0	19091	19069	19042	0	0	0	0
40	0	0	0	0	0	0	19128	19135	19104	0	0	0	19008	18997	18941	0	0	0
41	0	0	0	0	0	0	19076	19084	19065	19057	0	0	18960	18926	18915	0	0	0
42	0	0	0	0	0	0	19029	18999	18959	19025	0	0	18864	18886	18897	0	0	0
43	0	0	0	0	0	0	0	18941	18895	0	0	0	18806	18850	18864	0	0	0
44	0	0	0	0	0	0	0	18877	18824	0	0	18721	18760	18799	0	0	0	0
45	0	0	0	0	0	0	0	18756	18738	0	18648	18663	18715	0	0	0	0	0
46	0	0	0	0	0	0	0	18660	18650	0	18625	18623	18624	0	0	0	0	0
47	0	0	0	0	0	0	0	18572	18573	0	18545	18568	18565	0	0	0	0	0
48	0	0	0	0	0	0	0	18500	18500	0	18500	18500	18500	0	0	0	0	0

FIGURE 7.2. RUN 1 BAY TEMPERATURE AT 68 HOURS

Given: $Q = 2000 \text{ cfs}$, $T_{IN} = 0.0^{\circ}\text{C}$

ALL TEMPERATURES $^{\circ}\text{C} \times 100$

FIGURE 7.3. RUN 1, NATURAL THERMAL FIELD AT 68 HOURS NEAR
OUTFALL

position reveal important thermal characteristics of the bay. Spatial temperature variations after 68 hours of simulated time are minor between grids, with the highest values in the shallowest grids. Isotherm values agree spatially with general summer profiles one would expect for the July time period (Hicks, 58).

In addition, the temperature variations in the bay are strongly influenced by tidal flushing and meteorological conditions. Plotting selected temperature values versus time clearly shows the expected oscillatory behavior. The predicted change in temperature over time ratio for selected grids would aid the environmentalist in determining power plant impact.

D. EXPERIMENTAL RUN 2 (THE NATURAL CONDITIONS IN THE BAY WITH A POWER PLANT AS THE HEAT SOURCE)

The heat source is included by specifying a flowrate for the variable number 12. As previously mentioned, only the control parameters that are changed from Table 7.1 will be listed.

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
12	QIN (Source Flow Rate cfs)	2000

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
17	Program Number	11770
18	Date of Run	1/25/73

D.1. Comments

A typical model predicted heat source distribution in the natural environment can be seen in Figure 7.4. If one subtracts the natural conditions shown in Figure 7.3 from the power plant condition in Figure 7.4 one then obtains Figure 7.5 which shows the forced temperature rise resulting from the heat source in the model.

E. EXPERIMENTAL RUN 3 (THIS PREDICTS ONLY THE TEMPERATURE INCREASE DUE TO HEAT LOAD FROM A POWER PLANT OR FORCED TEMPERATURE RISE)

This run calculates only temperature excess above natural conditions by the variable changes listed below. If the formulation is correct, the thermal field prediction for run 3 should equal the difference in thermal fields between runs 2 and 1.

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
5	TMHOPE (Temperature Mt. Hope Bay)	0.00°C
6	TRIVER (Temperature of all Rivers)	0.00°C
7	TSOUND (Temperature for the Rhode Island Sound)	0.00°C
8	TBNB (Temperature Field in the Bay)	0.00°C
12	QIN (Source Flow Rate, cfs)	2000
15	DELTAT (Logical Variable. If true the model calculates forced temperature rise, if false it calculates natural conditions with or without power plant)	True

E.1. Comments

Figure 7.6 shows the result of the forced temperature rise without the natural conditions included. These values are nearly identical to Figure 7.5 and serve to prove the correctness of the forced temperature rise formulation in run 3.

AVERAGED TEMP. (DEGREES C TIMES 1000) FOR TIMESTEP 1020 AT TIME = 68.00 HRS																		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0	0	22199	22199	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	22366	22362	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	22426	22375	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	22027	22024	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	22007	21970	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	21911	21860	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	21787	21742	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	21764	21705	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	21780	21667	21602	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	22199	21642	21598	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	22199	21618	21590	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	21530	21625	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	21526	21478	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	21502	21427	21393	21377	21406	21486	0	0	0	0	0	0	0
15	0	0	0	0	0	0	21345	21345	21306	21303	21327	0	0	0	0	0	0	0
16	0	0	0	0	0	0	21372	21229	21229	21233	21264	21232	0	0	0	0	0	0
17	0	0	0	0	0	0	21271	21133	21196	21191	21207	21189	0	0	0	0	0	0
18	0	0	0	0	0	0	21119	20988	20980	21122	21164	21162	0	0	0	0	0	0
19	0	0	0	0	0	0	20941	20947	20971	21064	21129	21132	0	0	0	0	0	0
20	0	0	21644	21545	21555	0	0	20904	20901	20937	21025	21097	21070	0	21720	21448	0	0
21	0	0	21460	21342	21286	21203	20884	0	20709	20853	20899	21081	21036	0	21206	21265	21311	0
22	0	0	21514	21376	21243	21115	20815	20682	20729	20803	0	21076	21050	20953	20981	21191	21325	0
23	0	0	0	0	0	21010	20714	20658	20680	0	0	21027	20959	20892	20853	0	21394	21578
24	0	0	0	0	0	0	20872	20683	20595	20574	20433	0	20294	20905	20829	20764	20794	21112
25	0	0	0	0	0	0	20618	20345	20435	20383	20322	0	0	20762	20671	20617	20939	0
26	0	0	0	0	0	0	20562	20406	20400	20314	20223	20129	20074	0	20474	20513	20697	0
27	0	0	0	0	0	0	20495	20393	20331	20249	20151	20076	19999	0	20276	20341	20522	0
28	0	0	0	0	0	0	20398	20321	20253	20193	20065	19947	19915	0	20147	20225	20356	0
29	0	0	0	0	0	0	20320	20251	20174	20109	19992	19924	19838	0	20031	20096	20192	0
30	0	0	0	0	0	0	20174	20102	20023	19922	19850	19767	0	0	19917	19958	19971	0
31	0	0	0	0	0	0	20033	20014	19945	19863	19784	19696	19587	19624	19761	19834	19902	0
32	0	0	0	0	0	0	20066	20036	19949	19867	19813	19701	19618	19549	19596	19661	19733	0
33	0	0	0	0	0	0	20768	20661	20100	19993	19864	19729	0	19623	19535	19474	19523	19580
34	0	0	0	0	0	0	20727	20726	20164	19973	19815	19768	0	19524	19456	19410	19444	19482
35	0	0	0	0	0	0	20816	20244	19551	19767	19713	0	0	19359	19315	19371	19430	0
36	0	0	0	0	0	0	21360	20315	19911	19731	19547	0	0	19279	19233	19296	19355	0
37	0	0	0	0	0	0	20108	19537	19674	19584	0	0	0	19197	19195	19225	19231	0
38	0	0	0	0	0	0	19731	19579	19496	0	0	0	0	19146	19142	19123	0	0
39	0	0	0	0	0	0	19552	19479	19412	0	0	0	0	19136	19083	19056	0	0
40	0	0	0	0	0	0	19393	19402	19316	0	0	0	0	19023	19038	18951	0	0
41	0	0	0	0	0	0	19300	19317	19272	19221	0	0	0	18971	18936	18924	0	0
42	0	0	0	0	0	0	19227	19184	19114	19169	0	0	0	18872	18895	18906	0	0
43	0	0	0	0	0	0	19101	19027	0	0	0	0	0	18813	18857	18871	0	0
44	0	0	0	0	0	0	19010	18929	0	0	0	0	0	18726	18766	18806	0	0
45	0	0	0	0	0	0	18859	18815	0	0	0	0	0	18651	18667	18720	0	0
46	0	0	0	0	0	0	18709	18693	0	0	0	0	0	18627	18625	18627	0	0
47	0	0	0	0	0	0	18596	18596	0	18545	18569	18566	0	0	0	0	0	0
48	0	0	0	0	0	0	18500	18500	0	18503	18500	18503	0	0	0	0	0	0

FIGURE 7.4. RUN 2 THERMAL FIELD WITH HEAT SOURCE AT 68 HOURS FOR

NARRAGANSETT BAY

Given: $Q = 2000$ cfs, $T_{IN} = 12.0^{\circ}\text{C}$

FIGURE 7.5. FORCED TEMPERATURE RISE FROM RUNS 1 AND 2

The same procedure indicated for runs 1 through 3 was carried out for a forced temperature rise in the power plant outfall box of 6.5°C and again all the predictions for the forced temperature rise were equal to the difference between the natural plus heat source and natural conditions.

F. EXPERIMENTAL RUN 4 (FORCED TEMPERATURE RISE)

Same as run 3 with the following exceptions:

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
16	Plotting Interval	128-140 Hours

F.1. Introductory Comments

In this section, a detailed graphical presentation of seven predicted thermal fields is made. The purpose of this is to determine the tidal variations of the heat distribution in comparison with the tidally averaged field for all seven predictions.

The tidally averaged plot was obtained by adding the values at 130, 132, 134, 136, and 138 hours to one half the values at 128 and 140 hours and dividing by six. This weighting procedure was chosen because it allowed the

Given: $Q_{IN} = 2000$ cfs, $T_{IN} = 12^{\circ}\text{C}$

ALL TEMPERATURES $^{\circ}\text{C}$

FIGURE 7.6. FORCED TEMPERATURE RISE FROM RUN 3

desired velocity profile, shown in Figure 7.15, to be incorporated in the tidal average.

F.2. Graphical Presentation

The following series of figures (7.7 through 7.14) show the tidal influences on the thermal pattern for 1.0, 0.5, 0.4, 0.3, and 0.2°C. This is done by dividing all values in Figures 7.6 through 7.13 by 1000. The general area of Rome Point, as defined for these figures, encompasses 53 grids or about 17% of the total model area for Narragansett Bay.

F.3. Interpretation of the Graphical Output

The general tidal pattern during this interval can be seen in Figure 7.14. Comparison with Figure 7.15 of Hess (4) shows the peculiar but similar flow conditions for the west passage. In Table 7.1 one can see the pertinent physical variations that occur in the thermal field. Note that the approximate net non-tidal transport obtained from averaging representative velocity grids is of the order of +0.02 ft/sec (0.6 cm/sec) where "+" means up the bay. For a length scale of 3.5 nautical miles it would take a heated particle from Rome Point roughly two weeks to pass out of the Rome Point area if we assumed a net

Given: $Q_{IN} = 2000 \text{ cfs}$, $T_{IN} = 12^{\circ}\text{C}$

FIGURE 7.7. RUN 4, THERMAL FIELD AT 128 HOURS

ALL TEMPERATURES °C * 1000

Given: $Q_{IN} = 2000$ cfs, $T_{IN} = 12^{\circ}\text{C}$

FIGURE 7.8. RUN 4, THERMAL FIELD AT 130 HOURS

ALL TEMPERATURES $^{\circ}\text{C} \times 1000$

Given: $Q_{IN} = 2000 \text{ cfs}$, $T_{IN} = 12^{\circ}\text{C}$

FIGURE 7.9. RUN 4, THERMAL FIELD AT 132 HOURS

ALL TEMPERATURES $^{\circ}\text{C} \times 1000$

Given: $Q_{IN} = 2000 \text{ cfs}$, $T_{IN} = 12^{\circ}\text{C}$

FIGURE 7.10. RUN 4, THERMAL FIELD AT 134 HOURS

ALL TEMPERATURES °C x 1000

Given: $Q_{IN} = 2000 \text{ cfs}$, $T_{IN} = 12^{\circ}\text{C}$

FIGURE 7.11. RUN 4, THERMAL FIELD AT 136 HOURS

ALL TEMPERATURES $^{\circ}\text{C} \times 1000$

Given: $Q_{IN} = 2000 \text{ cfs}$, $T_{IN} = 12^{\circ}\text{C}$

FIGURE 7.12. RUN 4, THERMAL FIELD AT 138 HOURS

ALL TEMPERATURES $^{\circ}\text{C} \times 1000$

Given: $Q_{IN} = 2000$ cfs, $T_{IN} = 12^{\circ}\text{C}$

FIGURE 7.13. RUN 4, THERMAL FIELD AT 140 HOURS

ALL TEMPERATURES $^{\circ}\text{C} \times 1000$

Given: $QIN = 2000$ cfs, $TIN = 12^{\circ}C$

FIGURE 7.14. RUN 4, TIDAL AVERAGED THERMAL FIELD,

128-140 HOURS

ALL TEMPERATURES $^{\circ}C \times 1000$

FIGURE 7.15. RUN 4, TIDAL MOTION IN THE WEST PASSAGE

TABLE 7.2. RUN 4, GENERAL TIDAL AND THERMAL RESULTS FOR RUN 4

Length of Simulation (Hours)	Ft/Sec Tidal Velocity	Grids Within 1°C Isotherm	Grids Within 0.5°C Isotherm	Grid (9, 36) °C	Average North Boundary at Row 31 °C	Average South Boundary at Row 42 °C
128	-0.065	7	14	0.344	0.286	0.129
130	+1.12	8	17	0.353	0.243	0.179
132	+0.36	9	19	0.327	0.201	0.289
134	-0.55	8	19	0.430	0.199	0.284
136	-0.31	7	17	0.437	0.220	0.231
138	-0.44	7	17	0.421	0.234	0.186
140	-0.24	8	17	0.375	0.264	0.141
Tidal Average 128-140	+0.02	8	17	0.445	0.23	0.220

Grid Area = $1/4$ (nautical mile)²

average transport north of 0.02 ft/sec. In Rose (10) Figures 7a, 7b, and 7c, pages 13-15, one can see that net transport is variable and of the order of ± 0.14 ft/sec (4 cm/sec) depending on wind direction and magnitude. A net transport of 4 cm/sec would reduce particle residence time in Rome Point area to one or two days.

Evaluation of Table 7.2 leads to the following conclusions:

1. 1°C isotherm encompasses an area of 2 square nautical miles (S.N.M.).
2. 0.5°C isotherm encompasses an area of 4.25 S.N.M.
3. Average temperature for entire Rome Point area (13.25 S.N.M.) is 0.6°C above natural condition.
4. The average value of the upper and lower Rome Point area boundaries is 0.23°C .
5. Tidal variations cause minor variations in locations of isotherms (See Figure 7.16) below 1.0°C .

G. LONG TERM VARIATIONS IN SURFACE DISCHARGE BOX FOR A HIGH DISPERSION COEFFICIENT

The complexity of the flow pattern around the Rome Point area causes very interesting tidal variations in heat content for box $n = 5$, $m = 36$. Referring to Figure 7.17

one can appreciate the value of computer modeling especially when with large variations in temperature of the grid due to sudden high velocity conditions at the 78 hour mark.

H. EXPERIMENTAL RUN 5 (FORCED TEMPERATURE RISE WITH 50% INCREASE IN FLOWRATE)

Run 5 is the same as run 3 with the following exceptions:

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
12	QIN (Source Flow Rate, cfs)	3000
15	Plotting Interval (Hours)	36
16	Program Number	33225
17	Date of Run	6/2/73

H.1. Discussion

The thermal pattern for grid $n = 5$, $m = 36$, run 4, is compared with run 5 (Figure 7.18) to see what effect there will be in temperature field for a 50 percent increase in flowrate, from 2000 to 3000 cfs, for the same temperature increase through the condenser.

One can see from Figure 7.18 that the estimated

steady state value is $+9.0^{\circ}\text{C}$ or an 80 percent increase in forced temperature rise for grid $n = 5$, $m = 36$. Surrounding grid locations show a similar increase in heat content to balance the warmer input grid.

I. EXPERIMENTAL RUN 6, (FORCED TEMPERATURE RISE UPON
EQUALS 50)

Run 6 is the same as run 1 with the following exceptions:

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
11	UPCON (Dispersion Coefficient Constant Times Elders' Value)	50/1.93
16	Plotting Interval (Hours)	36
17	Program Number	33374
18	Date of Run	6/5/73

I.1. Discussion

The dispersion coefficient constant (control parameter) was lowered by 50 percent to see what effect this would have on the temperature field. The results have been plotted in Figure 7.18 and are of the same

Given: $QIN = 2000$ cfs, $TIN = 12^{\circ}C$

FIGURE 7.16. TIDAL EFFECTS ON THE $0.4^{\circ}C$ ISOTHERM

FIGURE 7.17. RUN 2, TEMPERATURE VARIATIONS FOR GRID $n = 5$, $m = 6$

FIGURE 7.18. RUN 4, $Q_{IN} = 2000$ CFS, $UPCON = 100$; RUN 5,
 $Q_{IN} = 3000$ CFS, $UPCON = 100$; RUN 6, $Q_{IN} = 2000$ CFS, $UPCON = 50$

magnitude as run 5.

J. INTERPRETATION OF AVERAGE AND WORST BAY CONDITIONS ON
THE SITING OF THE POWER PLANT

Average conditions for the bay might be summarized as some number of the following occurring:

1. Natural water temperature variations during year.
2. Expected marine population densities can be found by sampling.
3. Normal weather conditions.
4. Average water quality levels.
5. Average activity by fisheries and pleasure interests.
6. No major or unexpected fish kills.

Worst bay conditions would follow some of the following criteria occurring:

1. Extreme or biologically harmful temperatures in bay.
2. Unusual marine populations and unexpected migrations.
3. Very unusual weather patterns, storms, heat or cold spells, etc.
4. Very poor water quality levels.

5. Unusual activity of bay users.
6. Unexpected major fish kills.

K. GENERAL COMMENTS

In the presentation of the computational results this report has stressed the forced temperature rise method because it would be applicable for any period of the year. The warm water temperatures during mid summer coupled with peak power production by utility would create the highest temperatures in the outfall area. Whether the highest temperature and the worst temperature are synonymous remains a judgment for the biologist who must evaluate the thermal affects of the power plant on marine life throughout the year. The point here is to determine the need, if any, for temperature limitations that would be imposed on power plant operations for various air and water temperature values. Once the operating specifications have been determined, the environmental engineer can utilize his options to meet these criteria. Some engineering options available are:

1. Reduce plant output.
2. Increase flow rate through the plant.
3. Increase dilution in the discharge channel.

4. Change the outfall location by moving discharge into deeper water.
5. Dissipating heat near power plant through cooling towers or ponds.

Except for 1, these techniques do not reduce or "dissolve" the heat load on the bay environment but rather soften the impact by increasing the total area affected.

The upper temperature limit in the discharge grid would be the total temperature increase of condenser flow water for the entire grid. This value is somewhat fictitious, because with dilution in the normal tidal environment this value is not attainable. As a "worst case" it would be used in conjunction with the forced temperature rise analysis for any part of the year. With the 1800 megawatt sample plant at maximum output, the tidally averaged value for the discharge grid is approximately half the condenser temperature rise. This prediction was made with a value of the dispersion constant coefficient, UPCON, set at 50.

VIII. CONCLUSIONS

A. GENERAL

The thermal model can predict the general spatial temperature distribution in Narragansett Bay for either natural or man made conditions. When isotherms are sketched in by interpolation between grid temperatures, the effect of tidal flushing and heat sources are quite evident. The isotherms drawn for the forced temperature rise above ambient case serve as a valuable guide for environmental impact statements, because they dramatically display the effect of the heated effluent from a power plant. The heat content in a grid is vertically averaged but the Rome Point area is shallow enough to assume a high degree of vertical mixing for good model simulation. This mixing is further added by the variable current direction and magnitude during most of the tidal cycle.

Another challenging area comes from thermal field prediction or the attempt of the model to simulate bay boundary conditions in the form of a boundary value problem for temperature field calculation. The results obtained for the period of simulation, July 14-18, 1957, were of the same order of accuracy as those obtained by MASCH (57).

Long computer simulation runs of the order of a month would be required to pursue this verification procedure for the empirical heat exchange formulas and the variable boundary conditions. Verification improvements could be made by adjusting the empirical heat exchange formulas and the necessary variable boundary conditions.

When the Rome Point discharge grid temperature is plotted against time, one can observe the characteristic peaks and valleys of tidal flushing but the variations within a tidal cycle are most irregular. The sudden changes in temperature of the discharge grid, as seen in Figure 7.17, are important for physical impact studies. Knowing the general isothermal patterns around the discharge grid, the oceanographer now can make biological observations and recommendations.

The basic model can predict the spatial distribution of any dissolved constituent. For instance, the salinity distribution in the bay would be very valuable for biological models now being developed.

In general summary, the thermal model produces valuable temperature distribution information for both natural and man made conditions. The ability to predict thermal plume patterns for various input and output sites is of great

value to both the ecologist and the electric utility.

B. SPECIFIC

The verification of the model indicates no gross or unreasonable values are produced when the approximations used to formulate the model are evaluated. This model has been used to predict Jamaica Bay flushing characteristics and verification accuracy is comparable.

To limit this study, only one specific site at $m = 36$, $n = 5$ was chosen. This site enabled a verification of the forced temperature rise criterion. It is felt that this technique produces the most usable output for thermal impact studies.

In Chapter VII, the tidally averaged thermal field shown in Figure 7.14 clearly shows the scale of the spreading of the heat. The 0.5°C isotherm encompasses about eight to nine square nautical miles of bay. The tidally varying patterns appear to have surprising similarity beyond the 0.5°C isotherm mark. As discussed in earlier chapters, the higher the diffusion coefficient the less variation in heat content from box to box especially near the outfall area. In conclusion, the ground work has been laid for extensive development. Various physical

testing must be undertaken to pinpoint near field dispersion. This must of course be done in conjunction with computer runs that vary dispersion coefficient and site location.

IX. RECOMMENDATIONS

This thesis has established the value of the thermal model to make realistic spatial temperature distribution predictions. Before attempting to develop a better model that would more closely represent the three dimensional structure of Narragansett Bay, one should make salinity predictions. This would establish the ability of the difference scheme to predict the concentration of salinity without the use of the semi-empirical heat balance that occurs at the air-water interface.

As a prelude to a more sophisticated model, one should perform dye dispersion studies in conjunction with model predictions. These studies would indicate the importance of vertical structure on overall bay mixing. Finally, one could develop a two-dimensional width averaged vertically layered model. This would then reveal the importance of the vertical bay structure, especially in the deeper water grids.

It should be noted that Hess (59) is developing a three dimensional tidally averaged model for Narragansett Bay that shows considerable promise for understanding non-reacting constituent distribution of salt.

Research should be planned to bridge the gap between

the non-reacting concentration models to determine the differences predicted by vertical averaging, width averaging and time averaging on, for example, spatial distribution of salinity.

8. CONCLUSIONS

To summarize the objectives of this study, the purpose of the present program (1960-1962) was to develop a model of the physical processes in the ocean, and to compare the results with the results of the physical models.

The model was developed by using the physical processes in the ocean, and the results were compared with the results of the physical models. The model was developed by using the physical processes in the ocean, and the results were compared with the results of the physical models.

APPENDIX A

A. INTRODUCTION

The physical limitations on the amount of computer core and time available on the present operating computer required a reworking of the computer model into more manageable segments. This reworking enabled one to use a special storage unit, called a disk pack, to facilitate handling. In addition, the introduction of H level Fortran during the development stage offered a reduction of at least 50 percent in execution time, if the current batch processing mode was upgraded. That is to say, the program in its entirety exceeded the core requirement for Fortran H, optimization level 2, for the long runs, making segmentation and disk pack utilization a necessity.

B. TERMINOLOGY

To understand the workings of the disc pack a review of the technical language (I.B.M., (1) and Clayton, (3)) is presented.

Data Sets: A data set is a named, organized, logical collection of records. Generally, this consists of the main control segment,

subroutines, and the input data for starting model. A disk pack is used for the storage of data set records.

Sequential: Means an organized data set that is arranged in a logical, physical order of computational need. This is done to facilitate debugging by the user.

Direct: Each record in the model has independent address.

Partitioned: Combination of the sequential and direct organization. The grouping of these records is sequentially arranged into collections called "members".

OCEPAK: Name of the disk pack used for all computation.

Library: Sum of all the sets of partitioned data sets available in the disk pack that facilitate job execution.

OCESMODS: Name of all the partitioned data sets containing many members which are the source input.

OCECOMP: Name of all partitioned data sets containing compiled modules from OCESMODS.

OCEDATAS: Name of all the partitioned data sets that contain initialization and data information required for execution of the program. You do not compile this information. It is just read by the model.

C. DISK PACK USE

The job control language (JCL) for the library creation (IBM, 1a, 1b) is as follows:

```
//LIBRARY JOB (IN0100, 256,5,5,500), 'J.J.A.',  
MSGLEVEL=1 (A-1)  
//BLDSTEP EXEC PGM=IEBFBR14 (A-2)  
//NEWSRCE DD DS=OCESMODS (A-3)  
// DISP=(NEW,CATLG),VOL=SER=OCEPAK (A-4)  
// UNIT=2314,SPACE=(CYL,(15,5,20)), (A-5)  
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=3440) (A-6)  
//ADDSTEP EXEC PGM=IEBUPDTE (A-7)  
//SYSPRINT DD SYSOUT=A (A-8)  
//SYSUT1 DD DSN=OCESMODS,DISP=OLD,UNIT  
=2314,VOL=SER=OCEPAK (A-9)  
//SYSUT2 DD DSN=OCESMODS,DISP=OLD,UNIT  
=2314,VOL=SER=OCEPAK (A-10)  
//SYSIN DD * (A-11)
```

The following data cards for execution appear after the input program JCL:

```
./ ADD NAME=AMAIN,LIST=ALL (A-12)
```

```
./ NUMBER INCR=1000,NEW1=1000 (A-13)
```

```
DIMENSION.....
```

```
. AMAIN
```

```
. FORTRAN CARDS
```

```
END
```

```
./ ADD NAME=AINVAL,LIST=ALL (A-14)
```

```
./ NUMBER INCR=1000,NEW1=1000 (A-15)
```

```
SUBROUTINE AINVAL(.....
```

```
. AINVAL
```

```
. FORTRAN CARDS
```

```
END
```

One repeats the above procedure for the remaining modules:

APRINT, AHEATN, AOPBD, AUPNFH, AVPMFH, AVPMSH, AUPNSH,

AWTDEP, AWTIND, AAZ, AKURIH, ADIVE, AFIND, ADEPTH, ACHEZY,

AANLZE, ACHECK, APLOT and ADISPLY. This makes a total of

21 model modules.

To enter data for initialization of the model a partitioned data set, called OCEDATAS was created and filled in the same manner as OCESMODS with the following specific changes:

on line A-3, OCESMODS to OCEDATAS

A-5, SPACE=(CYL,(15,5,20))

(A-16)

A-9, OCESMODS to OCEDATAS

A-10, OCESMODS to OCEDATAS

OCEDATAS module names are: ADATA1, ADATA2, ADATA3,
ADATA4, AD191, AD192, AD193, for a total of seven.

To change or update the library the following is done:

on line A-7, ADDSTEP to CHNGSTEP

A-12, ADD replaced by CHANGE

A-13, Fortran statement(s) on IBM

card(s) with module line

number is columns 73 to 80, (A-17)

for the specified change in

module. It is important to

list the line numbers in

ascending order.

For obvious ease in handling changes it is desirable to
stay in the CHNSTEP mode once modules have been added to
the library. For any data change or update one should do
the following:

on line A-9, OCESMODS to OCEDATAS

A-10, OCESMODS to OCEDATAS

(A-18)

A-17, Specific changes desired

As an example, a typical deck layout for updating the library would be as follows:

lines A-1, LIBRARY JOB(.....

A-7, //CHNGSTEP

A-8, //SYSPRINT

A-9, //SYSUT1 .. OCESMODS ..

A-10, //SYSUT2 .. OCESMODS ..

A-11, // SYSIN DD *

./ CHANGE .. AMAIN

COL: 7 GO TO 10 .. 73 00046000

10 CONTINUE 00046900

etc.

A-7, //CHNGSTEP

A-8, //SYSPRINT

A-9, //SYSUT1, .. OCEDATAS ..

A-10, //SYSUT2, .. OCEDATAS ..

A-11, // SYSIN DD *

./ CHANGE .. ADATA1 ..

COL: 10 0010 .. 20 0020 ... 73 00007700

.

.

etc.

JCL FOR REMAINING PROGRAM

After creation of the input partitioned data sets, the next step is to create a third partitioned data set called OCECOMP. This is done by making the following changes:

on line A-3, OCESMODS to OCECOMP

A-5, SPACE=(CYL,(2,2,2)) (A-19)

A-6, final line

The primary function of this data set is to store all the compiled modules after they have been updated. Once a program has been compiled it need not be recompiled unless a change is made in the structure of the module. This results in a great saving in compilation time for each run. The necessary JCL is:

```
// EXEC FORTHOL, PARM.FORT-'OPT=2', PARM.LKED
```

```
= 'LET, LIST, NCAL, XREF' (A-20)
```

```
//FORT.SYSIN DD DSN=OCESMODS(AMAIN), DISP (A-23)
```

```
=SHR (A-21)
```

```
//LKED.SYSLMOD DD DSN=OCECOMP(MAIN), DISP
```

```
=OLD (A-22)
```

Repeat set A-23 for as many modules as needed in OCESMODS that have just been updated for a maximum of 21 compilations. Note here that AMAIN is the uncompiled module in OCESMODS while MAIN is the same module compiled and stored in OCECOMP.

Now that after all the modules are compiled they must be included in the object (functional) library through the LINK Editor as follows:

```
//LKED EXEC PGM=IEWL,PARM=(MAP,LET,LIST,OVLY,XREF)
```

(A-24)

```
//SYSLIB DD DSN=SYS1.FORTLIB,DISP=SHR
```

(A-25)

```
// DD DSN=URI.SSPLIB,DISP=SHR (A-26)
```

```
// DD DSN=URI.OPOTLIB,DISP=SHR (A-27)
```

```
//SYSPRINT DD SYSOUT=A (A-28)
```

```
//SYSLIN DD DDNAME=SYSIN (A-29)
```

```
//SYSLMOD DD DSN=&GOSET(MAIN),UNIT=SYSDA,DISP (A-35)
```

```
= (,PASS), (A-30)
```

```
// SPACE=(3072,(30,10,1)) (A-31)
```

```
//SYSUT1 DD DSN=&SYSUT1,UNIT=SYSDA,SPACE
```

```
=(1024,(200,20)),SEP=SYSLMOD (A-32)
```

```
//LKED.OBJLIB DD DSN=OCECOMP,DISP=SHR,VOL=SER
```

```
=OCEPAK,UNIT-2314 (A-33)
```

```
//LKED.SYSIN DD * (A-34)
```

Since the core restriction of 256 K is imposed on the fastest turn-around class it is necessary to follow up with the Overlay feature (IBM, (2)) that is specified in A-24. The modules in the program must be organized

into usable groups that minimize the core demand for any one executing group. See Figure A-1, Overlay Flow Chart, for details. Directly after A-34 are the instructions.

```
COL:  7 ENTRY    MAIN                                (A-36)
      INCLUDE    OBJLIB(MAIN)                        (A-37)
      OVERLAY    ONE                                (A-38)
      INCLUDE    OBJLIB(KURIH, HEATIN, DIVE, FIND, DEPTH,
                  CHEZY, CHECK, INVAL)                (A-39)
      OVERLAY    ONE                                (A-40)
      INCLUDE    OBJLIB(OPENBD, UPNFHT, VPMFHT, VPMSHT,
                  UPNSHT, WATDEP, WATIND)              (A-41)
      INCLUDE    OBJLIB(AZ, PRINT, DISPL, PLOT)        (A-42)
      OVERLAY    ONE                                (A-43)
      INCLUDE    OBJLIB(ANLYZE)                      (A-44)
```

The final JCL required for reading in the initialization values is:

```
//GO    EXEC    PGM=*.LKED.SYSLMOD                    (A-45)
//FT06F001 DD    SYSOUT=A                            (A-46)
//FT07F001 DD    SYSOUT=B                            (A-47)
//FT05F001 DD    DSN=OCEDATAS (ADATA2) , DISP=SHR, VOL
              =SER=OCEPAK                            (A-48)
//      UNIT=2314, LABEL=(, , , IN)                  (A-49)
```

FIGURE A.1. OVERLAY FLOW CHART


```

// DD DSN=OCEDATAS (ADATA3) , DISP=SHR, VOL=SER
    =OCEPAK. (A-50)
// UNIT=2314, LABEL=(, , IN) (A-51)
    etc.
//GO.FT13F001 DD DSN=&ALF, DISP=(NEW, DELETE) , UNIT
    =SYSDA, (A-52)
// SPACE=(TRK, (10, 10)) (A-53)
// (A-54)
/* (A-55)

```

where A-55 represents the physical end of the job deck.

D. DISK PACK UTILITIES

When using a disk pack it is necessary, on occasion, to compress (IBM, (1c)) or eliminate the old modules that have accumulated on the disk pack. The following deck should be submitted about once a week exactly as shown.

```

//COMPRESS JOB (IN0100, 256, 05, 10) , 'USERNAME' ,
    MSGLEVEL=1 (A-56)
// EXEC PGM=IEBCOPY (A-57)
//SYSPRINT DD SYSOUT=A (A-58)
//INOUT1 DD DSN=OCESMODS, DISP=OLD (A-59)
//INOUT2 DD DSN=OCECOMP, DISP=OLD (A-60)
//INOUT3 DD DSN=OCEDATAS, DISP=OLD (A-61)

```

//SYSIN DD * (A-62)

// (A-63)

/* (A-64)

From time to time it is convenient to have a total print and punch (IBM, (ld)) of the disk pack. The programs that will perform this function are described below.

//PTWOH JOB (IN0100,128,01,10,3500), 'USERNAME',
MSGLEVEL=1 (A-65)

// EXEC PGM=IEBPTPCH (A-66)

//SYSPRINT DD SYSOUT=A (A-67)

//SYSUT1 DD DSN=OCESMODS, DISP=(OLD, KEEP), VOL
=SER=OCEPAK, UNIT=2314 (A-68)

//SYSUT2 DD SYSOUT=A [Gives Printed Output
B [Gives Punched Output -Choose One] (A-69)

//SYSIN DD *

COL: 7

[Choose One -PRINT
PUNCH] TYPORG=PO, MAXFLDS=1 (A-70)

TITLE ITEM=(' PRINT AND PUNCH ALL
MEMBERS', 10) (A-71)

RECORD FIELD=(80,, , 5) (A-72)

// (A-73)

/* (A-74)

Note that one can obtain either punched or printed output (but not both) by picking the "A PRINT", or "B PUNCH" options.

E. ACKNOWLEDGMENT

Now that the model is fully operational in all modes it would be a great injustice not to cite the very valuable and timely assistance given to me by the entire computer center staff. Specifically, Dave "I can solve your problem" Clayton was undoubtedly the individual in the staff I must cite as instrumental in bringing the computer hardware into line. In addition to his daily assistance, he formalized all the above information into a special class especially for the Ocean Engineering Bay Model group.

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APPENDIX B

HYDRODYNAMIC FINITE DIFFERENCE EQUATIONS

A. HYDRODYNAMIC MODEL

The three basic equations, 2-32 through 2-35, may be expressed in finite difference form, using the notation outlined in Equations 2-36 through 2-44. The results are:

A.1 First Half Timestep

X - Momentum:

$$\begin{aligned}
 U^t + 1/2 &= U^t + \frac{1}{2} DT f \bar{V}^t - \frac{1}{2} \frac{DT}{DL} U^t + \frac{1}{2} \delta_x^* U^t \\
 &\quad - \frac{1}{2} \frac{DT}{DL} U^t + \frac{1}{2} \bar{V}^t \delta_y^* U^t - \frac{1}{2} \frac{DT}{DL} g \delta_x \eta^t + \frac{1}{2} \\
 &\quad - \frac{1}{2} DT R_{(x)}^t - \frac{1}{2} T F_{(x)}^t + \frac{1}{2},
 \end{aligned} \tag{B.1}$$

at $X_c + \frac{1}{2} DL, Y_c$.

Conservation of Mass:

$$\begin{aligned}
 \eta^t + 1/2 &= \eta^t - \frac{1}{2} \frac{DT}{DL} \delta_x \left[(\bar{h}^y + \bar{\eta}^x)^t + \frac{1}{2} U^t + \frac{1}{2} \right] \\
 &\quad - \frac{1}{2} \frac{DT}{DL} \delta_y \left[(\bar{h}^x + \bar{\eta}^y)^t v^t \right],
 \end{aligned} \tag{B.2}$$

at X_c, Y_c .

Y-Momentum:

$$\begin{aligned}
 v^t + 1/2 &= v^t - \frac{1}{2} \frac{DT}{DL} \delta_x^* v^t \bar{u}^t + 1/2 - \frac{1}{2} \frac{DT}{DL} \delta_y^* v^t v^t + 1/2 \\
 &\quad - \frac{1}{2} \frac{DT}{DL} g \delta_y \eta^t - \frac{1}{2} DT R_{(y)}^t + 1/2 - \frac{1}{2} DT F_{(y)}^t \quad (B.3) \\
 &\text{at } X_c, Y_c + \frac{1}{2} DL.
 \end{aligned}$$

A.2 Second Half Timestep

X - Momentum:

$$\begin{aligned}
 u^t + 1 &= u^t + 1/2 + \frac{1}{2} DT f \bar{v}^t + 1/2 - \frac{1}{2} \frac{DT}{DL} u^t + 1/2 \delta_x^* u^t + 1/2 \\
 &\quad - \frac{1}{2} \frac{DT}{DL} \bar{v}^t + 1 \delta_y^* u^t + 1/2 - \frac{1}{2} \frac{DT}{DL} g \delta_x \eta^t + 1/2 \\
 &\quad - \frac{DT}{DL} R_x^t + 1 - F_y^t + 1/2 \quad (B.4) \\
 &\text{at } X_c + \frac{1}{2} DL, Y_c.
 \end{aligned}$$

Conservation of Mass:

$$\begin{aligned}
 \eta^t + 1 &= \eta^t + 1/2 - \frac{DT}{DL} \delta_x \left[(\bar{h}^y + \bar{\eta}^x)^t + 1/2 \right] u^t + 1/2 \\
 &\quad - \frac{1}{2} \frac{DT}{DL} \delta_y \left[(\bar{h}^x + \bar{\eta}^y)^t + 1 \right] v^t + 1 \quad (B.5) \\
 &\text{at } X_c, Y_c.
 \end{aligned}$$

Y - Momentum:

$$\begin{aligned}
 v^{t+1} = v^{t+1/2} - \frac{1}{2} \frac{DT}{DL} f \bar{u}^{t+1/2} - \frac{1}{2} \frac{T}{L} \bar{u}^{t+1/2} \delta_x^* v^{t+1/2} \\
 - \frac{1}{2} \frac{DT}{DL} v^{t+1} \delta_y^* v^{t+1} - \frac{1}{2} \frac{DT}{DL} g \delta_y \eta^{t+1} \\
 - \frac{1}{2} \frac{DT}{DL} R_y^{t+1/2} - \frac{1}{2} \frac{DT}{DL} F_y^{t+1}
 \end{aligned} \tag{B.6}$$

at $X_c, Y_c + \frac{1}{2} L$

where the bottom stress term, R, is defined as:

$$R_x^t = g u^t \frac{[(u^t)^2 + (\bar{v}^t)^2]^{\frac{1}{2}}}{(\bar{h}^y + \bar{\eta}^x)^t (\bar{g}^x)^2} \tag{B.7}$$

$$R_y^{t+1/2} = g v^{t+1/2} \frac{[(\bar{u}^{t+1/2})^2 + (v^t)^2]^{\frac{1}{2}}}{(\bar{h}^x + \bar{\eta}^y)^{t+1/2} (\bar{c}^y)^2} \tag{B.8}$$

$$R_x^{t+1} = g u^{t+1} \frac{[(u^{t+1/2})^2 + (\bar{v}^{t+1})^2]^{\frac{1}{2}}}{(\bar{h}^y + \bar{\eta}^x)^{t+1/2} (\bar{c}^x)^2} \tag{B.9}$$

$$R_y^{t+1/2} = g v^{t+1/2} \frac{[(\bar{u}^{t+1/2})^2 + (v^{t+1/2})^2]^{\frac{1}{2}}}{(\bar{h}^x + \bar{\eta}^y)^{t+1/2} (\bar{u}^y)^2} \tag{B.10}$$

and the surface stress terms, f , are defined as

$$F_x^{t+1/2} = \frac{K (\omega_x^{t+1/2})^2}{(\bar{h}^y + \bar{\eta}^x)^t} \quad (B.11)$$

$$F_y^t = \frac{K (\omega_y^t)^2}{(\bar{h}^x + \bar{\eta}^y)^t} \quad (B.12)$$

$$F_x^{t+1/2} = \frac{K (\omega_x^{t+1/2})^2}{(\bar{h}^y + \bar{\eta}^x)^{t+1/2}} \quad (B.13)$$

$$F_y^{t+1} = \frac{K (\omega_y^{t+1})^2}{(\bar{h}^x + \bar{\eta}^y)^{t+1/2}} \quad (B.14)$$

where

$$K = \frac{k \rho_{air}}{\rho_{water}}$$

The conservation of mass equations, B.2 and B.6, contain the non-linearities $(\bar{\eta}^x)^{t+1/2}$ and $(\bar{\eta}^y)^{t+1}$, respectively, which are at the same time level as η on the left-hand side of the equations. In the solution, these terms are taken at the lower time level in the first approximation and at the same time level in succeeding iterations. The hydraulic portion of model does contain iterative procedure but is not used because the improvement in accuracy was negligible.

APPENDIX C

METHOD OF SOLUTION

The implicit method of solution for η and u in the first half of the time step is first presented. The solution of η and v in the second is analogous. Starting with equations B.2 and B.1 (in Appendix B), and writing out the finite-difference approximations, we have

$$-r_{m-1/2} u_{m-1/2} + \eta_m + r_{m+1/2} u_{m+1/2} = A_m \quad (C.1)$$

$$-r_m \eta_m + u_{m+1/2} + r_{m+1} \eta_{m+1} = B_{m+1/2} \quad (C.2)$$

where the coefficients r are

$$r_{m \pm 1/2} = \frac{1}{2} \frac{DT}{DL} (\bar{h}^y + \bar{\eta}^x)_{m \pm 1/2} \quad (C.3)$$

$$r_m = \frac{1}{2} \frac{DT}{DL} g \quad (C.4)$$

and A_m , B_m are the remaining terms in equations C.2 and C.1, respectively. Both η and u are at the $t + 1/2$ time level (except for $\bar{\eta}^x$ in C.3, which is at time t).

Suppose the first computational grid is at $m = 2$, and the last is $m = J$. Then the values of η occur with subscripts $m = 2, 3, \dots, J$, while u values have subscripts of $m = 1\frac{1}{2}, 2\frac{1}{2}, \dots, J + \frac{1}{2}$ (see Figure C.1).

Solving eq. C.1 for η_m at $m = 2$, gives

$$\eta_2 = A_2 + r_{1\frac{1}{2}} u_{1\frac{1}{2}}^* - r_{2\frac{1}{2}} u_{2\frac{1}{2}} \quad (C.5)$$

where $u_{1\frac{1}{2}}^*$ is the velocity at the boundary. For the case of a land boundary, $u_{1\frac{1}{2}}^*$ is zero. Equation C.5 may be rewritten as

$$\eta_2 = -p_2 u_{2\frac{1}{2}} + u_2 \quad (C.6)$$

$$\text{where } p_2 = r_{2\frac{1}{2}} \quad (C.7)$$

$$\text{and } \eta_2 = A_2 + r_{1\frac{1}{2}} u_{1\frac{1}{2}}^* \quad (C.8)$$

Equation C.2 at $m = 2$ is

$$u_{2\frac{1}{2}} = B_{2\frac{1}{2}} + r_2 \eta_2 - r_3 \eta_3 \quad (C.9)$$

Taking the expression for η_2 from eq. C.6, and substituting into the above,

$$u_{2\frac{1}{2}} = B_{2\frac{1}{2}} + r_2 (-p_2 u_{2\frac{1}{2}} + u_2) - r_3 \eta_3 \quad (C.10)$$

$$\text{or } u_{2\frac{1}{2}} = -R_2 \eta_3 + S_2 \quad (C.10a)$$

$$\text{where } R_2 = \frac{r_3}{1 + r_2 p_2} \quad (C.11)$$

$$S_2 = \frac{B_{2\frac{1}{2}} + r_2 u_2}{1 + r_2 p_2} \quad (C.12)$$

The next water level, η_3 , is (from eq. C.1 at $m = 3$)

$$\eta_3 = A_3 + r_{2\frac{1}{2}} u_{2\frac{1}{2}} - r_{3\frac{1}{2}} u_{3\frac{1}{2}} \quad (C.13)$$

and substituting the expression for $u_{2\frac{1}{2}}$ from eq. C.10a,

$$\eta_3 = A_3 + r_{2\frac{1}{2}} (-R_2 \eta_3 + S_2) - r_{3\frac{1}{2}} u_{3\frac{1}{2}}$$

$$\text{or} \quad \eta_3 = -p_3 u_{3\frac{1}{2}} + \eta_3 \quad (C.14)$$

$$\text{where} \quad p_3 = \frac{r_{3\frac{1}{2}}}{1 + r_{2\frac{1}{2}} H_2} \quad (C.15)$$

$$\text{and} \quad u_3 = \frac{A_3 + r_{2\frac{1}{2}} S_2}{1 + r_{2\frac{1}{2}} R_2} \quad (C.16)$$

The velocity $u_{3\frac{1}{2}}$ is obtained from eq. C.2 at $m = 3$:

$$u_{3\frac{1}{2}} = B_{3\frac{1}{2}} + r_3 \eta_3 - r_4 \eta_4 \quad (C.17)$$

$$\text{Or} \quad u_{3\frac{1}{2}} = -R_3 \eta_4 + S_3 \quad (C.18)$$

$$\text{where} \quad R_3 = \frac{r_4}{1 + r_3 p_3} \quad (C.19)$$

$$S_3 = \frac{B_{3\frac{1}{2}} + r_3 Q_3}{1 + r_3 p_3} \quad (C.20)$$

This procedure (calculation of p_m , Q_m , R_m , and S_m) is repeated for all m up to $m = J$, where, for a land boundary at $J + \frac{1}{2}$,

$$\eta_J = -p_J u_{J+\frac{1}{2}}^* + Q_J \quad (C.21)$$

and η_J is easily computed since $u_{J+\frac{1}{2}}^*$ is zero.

Suppose, however, that instead of land boundaries, the first ($m = 1$) and last ($m = J + 1$) are water boundaries, with either velocity or water level values given. For a first grid water level value, η_1^* , eq. C.2 gives

$$u_{1\frac{1}{2}} = B_{1\frac{1}{2}} + r_1 \eta_1^* - r_2 \eta_2 = -R_1 \eta_2 + S_1 \quad (C.22)$$

$$\text{where } R_1 = r_2 \quad (C.23)$$

$$\text{and } S_2 = B_{1\frac{1}{2}} + r_1 \eta_1^* \quad (C.24)$$

For a first grid velocity, $u_{1\frac{1}{2}}^*$, eq. B.5 will suffice. For the case of a last grid water level value, η_{J+1}^* , eq. C.2 leads to

$$\begin{aligned} u_{J+\frac{1}{2}} &= B_{J+\frac{1}{2}} + r_J \eta_J - r_{J+1} \eta_{J+1}^* \\ &= -R_J \eta_{J+1}^* + S_J \end{aligned} \quad (C.25)$$

There are three methods of specifying the last grid ($m = J + 1$) velocity. The first is to specify the value $u_{J+1+\frac{1}{2}}^*$, and

$$\eta_{J+1} = -p_{J+1} u_{J+1+\frac{1}{2}}^* + \frac{Q}{V}_{J+1} \quad (C.26)$$

which involves the calculation of η at the boundary grid ($\alpha = J$).

Secondly, it is possible to calculate $u_{J + \frac{1}{2}}$, from u_J^* using a flowrate conservation law. Finally, the velocity at $J + \frac{1}{2}$ could be specified and eq. C.21 used directly. This last method is the most efficient, and is the one used in the present model calculations.

In general, the coefficients can be written as:

$$P_m = \frac{r_m + \frac{1}{2}}{1 + r_m - \frac{1}{2} R_m - 1} \quad (C.27)$$

$$u_m = \frac{A_m + r_m + \frac{1}{2} S_m - 1}{1 + r_m - \frac{1}{2} R_m - 1} \quad (C.28)$$

$$R_m = \frac{r_m}{1 + r_m - \frac{1}{2} P_m} \quad (C.29)$$

$$S_m = \frac{B_m + \frac{1}{2} + r_m u_m}{1 + r_m - \frac{1}{2} P_m} \quad (C.30)$$

Starting at the lower boundary ($m = 1$), R_m and S_m are calculated, (from C.23 and C.24 for a water level boundary; $R_1 = S_1 = 0$ for a land boundary; $R_1 = 0$, $S_1 = u_1^* + \frac{1}{2}$ for a velocity boundary). Then at the computational levels ($m = 2$ to $m = J$) A_m , P_m , u_m , B_m , R_m , and S_m are calculated in that order for each m . At $m = J$, $u_{J + \frac{1}{2}}$ assumes its appropriate value (zero for a land boundary; the specified value for a velocity boundary; or computed from eq. C.25 for a water level boundary). The remaining values of η and u are then obtained from the recursive relations

$$\eta_m = -P_m u_m + \frac{1}{2} + Q_m \quad (C.31)$$

$$u_{m-1/2} = -R_m \eta_m + S_{m-1}$$

(C.32)

for m decreasing from $m = J$ to $m = 2$.

FIGURE C-13: SPATIAL ARRANGEMENT OF ELEMENTS IN COILS

FIGURE C-1: SPATIAL ARRANGEMENT OF VARIABLES ON GRIDS

APPENDIX D

MASS TRANSPORT MODEL

A. GENERAL

The solution of Eqs. (B.1) and (B.2) yields the x component of the water velocity and the water levels at the time level $\eta + \frac{1}{2}$. These values, along with the y component of the water velocity at time level η , are then used in Eq. (B.3) to solve for the constituent concentration at time level $\eta + \frac{1}{2}$. For the constituent, three unknown values are found at adjacent grid points in Eq. (B.3), and numerical procedures similar to those in the flow computation can be used to solve for these unknowns. This procedure is described in detail below.

B. EXPANSION OF THE FINITE-DIFFERENCE EQUATION

In the first operation at the time level going from t to $t + \frac{1}{2} Dt$, the constituents are computed in both directions. This information is used in the computation of the concentration for the second half time step. The finite-difference equation for the constituent, Eq. (B.3), can then be expanded in the form:

$$\begin{aligned} & [C_{j,k}^{t+\frac{1}{2}} (h_{j-\frac{1}{2}, k-\frac{1}{2}} + h_{j-\frac{1}{2}, k+\frac{1}{2}} + h_{j+\frac{1}{2}, k-\frac{1}{2}} + h_{j+\frac{1}{2}, k+\frac{1}{2}} + 4\eta_{j,k}^{t+\frac{1}{2}}) \\ & - C_{j,k}^t (h_{j-\frac{1}{2}, k-\frac{1}{2}} + h_{j-\frac{1}{2}, k+\frac{1}{2}} + h_{j+\frac{1}{2}, k-\frac{1}{2}} + h_{j+\frac{1}{2}, k+\frac{1}{2}} + 4\eta_{j,k}^t)] \frac{1}{2Dt} \\ & - [\bar{\eta}_{j-1, k}^t + \eta_{j, k}^t + h_{j-\frac{1}{2}, k-\frac{1}{2}} + h_{j-\frac{1}{2}, k+\frac{1}{2}}] u_{j-\frac{1}{2}, k}^{t+\frac{1}{2}} (C_{j-1, k}^{t+\frac{1}{2}} + C_{j, k}^{t+\frac{1}{2}}) \end{aligned}$$

$$\begin{aligned}
& - (\eta_{j, k}^t + \eta_{j+1, k}^t + h_{j+\frac{1}{2}, k-\frac{1}{2}} + h_{j+\frac{1}{2}, k+\frac{1}{2}}) u_{j+\frac{1}{2}, k}^{t+\frac{1}{2}} (C_{j, k}^{t+\frac{1}{2}} + C_{j+1, k}^{t+\frac{1}{2}}) \left(\frac{1}{4D_x} \right) \\
& - [\eta_{j, k-1}^t + \eta_{j, k}^t + h_{j-\frac{1}{2}, k-\frac{1}{2}} + h_{j+\frac{1}{2}, k-\frac{1}{2}}] v_{j, k-\frac{1}{2}}^t (C_{j, k-1}^t + C_{j, k}^t) \\
& - (\eta_{j, k}^t + \eta_{j, k+1}^t + h_{j-\frac{1}{2}, k+\frac{1}{2}} + h_{j+\frac{1}{2}, k+\frac{1}{2}}) v_{j, k+\frac{1}{2}}^t (C_{j, k+1}^t + C_{j, k}^t) \left(\frac{1}{4D_x} \right) \\
& + [\eta_{j-1, k}^{t+\frac{1}{2}} + \eta_{j, k}^{t+\frac{1}{2}} + h_{j-\frac{1}{2}, k-\frac{1}{2}} + h_{j-\frac{1}{2}, k+\frac{1}{2}}] D_{x, j-\frac{1}{2}, k}^{t+\frac{1}{2}} (C_{j, k}^{t+\frac{1}{2}} - C_{j-1, k}^{t+\frac{1}{2}}) \\
& - (\eta_{j, k}^{t+\frac{1}{2}} + \eta_{j+1, k}^{t+\frac{1}{2}} + h_{j+\frac{1}{2}, k-\frac{1}{2}} + h_{j+\frac{1}{2}, k+\frac{1}{2}}) D_{x, j+\frac{1}{2}, k}^{t+\frac{1}{2}} (C_{j+1, k}^{t+\frac{1}{2}} - C_{j, k}^{t+\frac{1}{2}}) \left[\frac{1}{2 (D_x)^2} \right] \\
& \quad \quad \quad (D.1)
\end{aligned}$$

$$\begin{aligned}
& + [(\eta_{j, k-1}^t + \eta_{j, k}^t + h_{j-\frac{1}{2}, k-\frac{1}{2}} + h_{j+\frac{1}{2}, k-\frac{1}{2}}) D_{y, j, k-\frac{1}{2}}^t (C_{j, k}^t - C_{j, k-1}^t) \\
& - (\eta_{j, k}^t + \eta_{j, k+1}^t + h_{j-\frac{1}{2}, k+\frac{1}{2}} + h_{j+\frac{1}{2}, k+\frac{1}{2}}) D_{y, j, k+\frac{1}{2}}^t (C_{j, k+1}^t - C_{j, k}^t) \left[\frac{1}{2 (D_y)^2} \right] \\
& + (h_{j+\frac{1}{2}, k+\frac{1}{2}} - h_{j+\frac{1}{2}, k-\frac{1}{2}} + h_{j-\frac{1}{2}, k+\frac{1}{2}} + h_{j-\frac{1}{2}, k-\frac{1}{2}} + 4\eta_{j, k}) \frac{S_{j, k}^t}{4} = 0
\end{aligned}$$

where $C_{j, k}^{t+\frac{1}{2}}$ is the concentration of constituent at the grid point j, k for time level $t + \frac{1}{2}$. The dispersion coefficients D_x, D_y and the source of constituent S can be both space- and time-varying functions in this formulation. Point sources of constituents, such as occur at a power plant outfall, can be included. These procedures used for this part of the computation are described in Leendertse⁽²⁾.

There are only three unknown variables in Eq. (D.1). They are:

$$C_{j, k}^{t+\frac{1}{2}} ; \quad C_{j-1, k}^{t+\frac{1}{2}} ; \quad \text{and} \quad C_{j+1, k}^{t+\frac{1}{2}} \quad (D.2)$$

Thus, rewriting Eq. (D.1) after multiplying through by $t_{an} = t/2$ yields

$$a_j C_{j-1, k}^{t+\frac{1}{2}} + b_j C_{j, k}^{t+\frac{1}{2}} + c_j C_{j+1, k}^{t+\frac{1}{2}} = D_j \quad (D.3)$$

where:

$$a_j = -(\eta_{j-1, k}^t + \eta_{j, k}^t + h_{j-\frac{1}{2}, k-\frac{1}{2}} + h_{j-\frac{1}{2}, k+\frac{1}{2}}) u_{j-\frac{1}{2}, k}^t \left(\frac{t_{an}}{4 Dx} \right) - (\eta_{j-1, k}^{t+\frac{1}{2}} + \eta_{j, k}^{t+\frac{1}{2}} + h_{j-\frac{1}{2}, k-\frac{1}{2}} + h_{j-\frac{1}{2}, k+\frac{1}{2}}) D_{x_{j-\frac{1}{2}, k}}^{t+\frac{1}{2}} \left[\frac{t_{an}}{2 (Dx)^2} \right] \quad (D.4)$$

$$c_j = -[(\eta_{j, k}^t + \eta_{j+1, k}^t + h_{j+\frac{1}{2}, k-\frac{1}{2}} + h_{j+\frac{1}{2}, k+\frac{1}{2}}) (-u_{j+\frac{1}{2}, k}^{t+\frac{1}{2}}) + (\eta_{j, k}^{t+\frac{1}{2}} + \eta_{j+1, k}^{t+\frac{1}{2}} + h_{j+\frac{1}{2}, k-\frac{1}{2}} + h_{j+\frac{1}{2}, k+\frac{1}{2}}) D_{x_{j+\frac{1}{2}, k}}^{t+\frac{1}{2}} \frac{2}{Dx}] \left(\frac{t_{an}}{4 Dx} \right) \quad (D.5)$$

$$b_j = \frac{1}{2} (h_{j-\frac{1}{2}, k-\frac{1}{2}} + h_{j-\frac{1}{2}, k+\frac{1}{2}} + h_{j+\frac{1}{2}, k-\frac{1}{2}} + h_{j+\frac{1}{2}, k+\frac{1}{2}}) + \eta_{j, k}^{t+\frac{1}{2}} - (\eta_{j-1, k}^t + \eta_{j, k}^t + h_{j-\frac{1}{2}, k-\frac{1}{2}} + h_{j-\frac{1}{2}, k+\frac{1}{2}}) u_{j-\frac{1}{2}, k}^t \left(\frac{t_{an}}{4 Dx} \right) + (\eta_{j, k}^t + \eta_{j+1, k}^t + h_{j+\frac{1}{2}, k-\frac{1}{2}} + h_{j+\frac{1}{2}, k+\frac{1}{2}}) u_{j+\frac{1}{2}, k}^t \left(\frac{t_{an}}{4 Dx} \right) + (\eta_{j-1, k}^{t+\frac{1}{2}} + \eta_{j, k}^{t+\frac{1}{2}} + h_{j-\frac{1}{2}, k-\frac{1}{2}} + h_{j-\frac{1}{2}, k+\frac{1}{2}}) D_{x_{j-\frac{1}{2}, k}}^{t+\frac{1}{2}} \left[\frac{t_{an}}{2 (Dx)^2} \right] + (\eta_{j, k}^{t+\frac{1}{2}} + \eta_{j+1, k}^{t+\frac{1}{2}} + h_{j+\frac{1}{2}, k-\frac{1}{2}} + h_{j+\frac{1}{2}, k+\frac{1}{2}}) D_{x_{j+\frac{1}{2}, k}}^{t+\frac{1}{2}} \left[\frac{t_{an}}{2 (Dx)^2} \right] \quad (D.6)$$

$$D_j = C_{j, k}^t \left[\frac{1}{2} (h_{j-\frac{1}{2}, k-\frac{1}{2}} + h_{j-\frac{1}{2}, k+\frac{1}{2}} + h_{j+\frac{1}{2}, k-\frac{1}{2}} + h_{j+\frac{1}{2}, k+\frac{1}{2}} + \eta_{j, k}^t) \right. \\ \left. + \left[(\eta_{j, k-1}^t + \eta_{j, k}^t + h_{j-\frac{1}{2}, k-\frac{1}{2}} + h_{j+\frac{1}{2}, k-\frac{1}{2}}) v_{j, k-\frac{1}{2}}^t (C_{j, k-1}^t + C_{j, k}^t) \right. \right. \\ \left. \left. - (\eta_{j, k}^t + \eta_{j, k+1}^t + h_{j-\frac{1}{2}, k+\frac{1}{2}} + h_{j+\frac{1}{2}, k+\frac{1}{2}}) v_{j, k+\frac{1}{2}}^t (C_{j, k+1}^t + C_{j, k}^t) \right] \left(\frac{t_{an}}{4 Dx} \right) \right] \quad (D.7)$$

$$- \left[(\eta_{j, k-1}^t + \eta_{j, k}^t + h_{j-\frac{1}{2}, k-\frac{1}{2}} + h_{j+\frac{1}{2}, k-\frac{1}{2}}) D_{y_{j, k-\frac{1}{2}}}^t (C_{j, k}^t - C_{j, k-1}^t) \right. \\ \left. - (\eta_{j, k}^t + \eta_{j, k+1}^t + h_{j-\frac{1}{2}, k+\frac{1}{2}} + h_{j+\frac{1}{2}, k+\frac{1}{2}}) D_{y_{j, k+\frac{1}{2}}}^t (C_{j, k+1}^t - C_{j, k}^t) \right] \left(\frac{t_{an}}{2 (Dx)^2} \right) \\ - \left[\frac{1}{2} (h_{j+\frac{1}{2}, k+\frac{1}{2}} + h_{j+\frac{1}{2}, k-\frac{1}{2}} + h_{j-\frac{1}{2}, k+\frac{1}{2}} + h_{j-\frac{1}{2}, k-\frac{1}{2}}) + \eta_{j, k}^t \right] S_{j, k}^t$$

For each row k , Eq. (D.7) can be written as:

$$a_j C_{j-1} + b_j C_j + e_j C_{j+1} = D_j \quad (D.8)$$

where the subscripts k and superscript $t + \frac{1}{2}$ are dropped for convenience.

Equation (D.8) can be solved for the concentration of constituent at each grid point along row k by a process of elimination of unknowns.

To illustrate the method, a closed left-hand boundary is assumed at some value of $j = J-1$, $k = K$, as shown in Figure D-1.

FIGURE D-1: LEFT CLOSED BOUNDARY

For this case, both the advective and dispersive transport of constituent through the cross section between grid points J-1 and J is zero. Thus $a_J = 0$, and Eq. (D.8) can be written as:

$$b_J C_J + e_J C_{J+1} = D_J \quad (D.9)$$

For the next point, $j = J+1$, along row $k = K$, Eq. (D.8) is written as:

$$a_{J+1} C_J + b_{J+1} C_{J+1} + e_{J+1} C_{J+2} = D_{J+1} \quad (D.10)$$

Solving Eq. (D.9) for C_J yields

$$C_J = E_{J+1} C_{J+1} + Q_{J+1} \quad (D.11)$$

where

$$E_{J+1} = - \frac{e_J}{b_J} ; \quad Q_{J+1} = \frac{D_J}{b_J} \quad (D.12)$$

Substituting Eq. (D.9) for C_J into Eq. (D.10) gives

$$a_{J+1} (E_{J+1} C_{J+1} + Q_{J+1}) + b_{J+1} C_{J+1} + e_{J+1} C_{J+2} = D_{J+1} \quad (D.13)$$

Solving for C_{J+1} yields

$$C_{J+1} = E_{J+2} C_{J+2} + Q_{J+2} \quad (D.14)$$

where

$$E_{J+2} = - \frac{e_{J+1}}{b_{J+1} + a_{J+1} E_{J+1}} ; \quad Q_{J+2} = \frac{D_{J+1} - a_{J+1} Q_{J+1}}{b_{J+1} + a_{J+1} E_{J+1}} \quad (D.15)$$

In general, the following recursion formulas are valid:

$$P_j = E_{j+1} C_{j+1} + Q_{j+1} \quad (D.16)$$

where

$$E_{j+1} = - \frac{e_j}{b_j + a_j E_j} \quad (D.17)$$

$$Q_{j+1} = \frac{D_j - a_j Q_j}{b_j + a_j E_j} \quad (D.18)$$

It is assumed that the right-hand boundary at $j = M$, $k = K$ is also a closed boundary, as shown in Figure D-2.

FIGURE D-2: RIGHT CLOSED BOUNDARY

The advective and diffusive transport of constituent through the cross section between $j = M$ and $j = M + 1$ is zero for this case, and therefore $e_M \equiv 0$. Equation (D.8) for $j = M$ then becomes

$$a_M C_{M-1} + b_M C_M = D_M \quad (D.19)$$

and solving for C_{M-1} yields

$$C_{M-1} = -\frac{b_M}{a_M} C_M + \frac{D_M}{a_M} \quad (D.20)$$

Writing the general recursion formula given by Eq. (D.17) for $j = M-1$ leads to

$$C_{M-1} = E_M P_M + Q_M \quad (D.21)$$

Using Eq. (D.21) in Eq. (D.22) gives

$$E_M C_M + Q_M = -\frac{b_M}{a_M} C_M + \frac{D_M}{a_M} \quad (D.22)$$

and solving for C_M yields

$$C_M = \frac{D_M - a_M Q_M}{b_M + a_M E_M} \equiv Q_{M+1} \quad (D.23)$$

The recursion factors E and Q are calculated in ascending order, starting with E_{J+1} and Q_{J+1} , given by Eq. (D.13). Equations (D.17) and (D.18) are used to calculate the remaining recursion factors to $j = M$, noting that $E_{M+1} \equiv 0$ since $e_M = 0$. The concentrations are then computed in descending order, starting with $j = M$, using Eq. (D.16).

If instead of a closed boundary at either end of the computational field, the geography of the region to be modeled requires an open boundary, then the above procedure must be modified slightly. As in the example given for the flow model, it is assumed that part of the left-

hand boundary, $j = 1$, of the computational field contains an open boundary, as shown in Figure D-3. For this case, E_2 is set equal to zero and Q_2 is set equal to the concentration of constituent 1 at the open boundary, C_1 . This concentration is a given input variable and is usually a function of time. The methods used to obtain C_1 for the sample calculations are explained in the next section.

FIGURE D-3: LEFT OPEN BOUNDARY

The rest of the recursion factors and concentrations are then calculated in the same way as for a closed boundary.

APPENDIX E

DIFFERENCING SCHEMES AND THEIR EFFECTS

Consider the one-dimensional convective-dispersion equation

$$\frac{\partial C}{\partial t} + \frac{\partial}{\partial x} (UC) = \frac{\partial}{\partial x} \left(D_x \frac{\partial C}{\partial x} \right) = 0 \quad (E-1)$$

For the case of constant velocity and dispersion coefficient, the finite difference formulation is

$$\begin{aligned} \frac{DC_m}{Dt} = \frac{D_x}{L^2} [C_{mp} - 2C_m + C_{mm}] - \frac{U}{L} [C_{mp} (1-A) + (A-B) C_m \\ - C_{mm} (1-B)] \end{aligned} \quad (E-2)$$

where L is the grid length, A and B are parameters with possible values of 0, $1/2$, or 1, $mm = m-1$ and $mp = m+1$.

Let us suppose a constant depth and width channel with unit concentration at grid M , and zero elsewhere in Figure E.1.

FIGURE E.1. ONE DIMENSIONAL DIFFERENCING SCHEME

Using a central spatial derivative in the convective term
($A = B = 1/2$), the rate of change of concentration, DC/Dt ,
may be computed as follows:

$$\text{at } M \quad \frac{DC_m}{Dt} = \frac{D}{L^2} [C_{mp} - 2C_m + C_{mm}] - \frac{u}{2L} [C_{mp} - C_{mm}] \quad (E-3)$$

which becomes, upon substitution of values of C from
Figure E-1,

$$\frac{DC_m}{Dt} = \frac{D}{L^2} [-2C_m] = - \frac{2D}{L^2} C_m \quad (E-4)$$

A	B	$\frac{DC_{mm}}{Dt}$	$\frac{DC_m}{Dt}$	$\frac{DC_{mp}}{Dt}$
1/2	1/2	$\frac{D}{L^2} - \frac{u}{2L}$	$-\frac{2D}{L^2} C_m$	$\frac{D}{L^2} + \frac{u}{2L}$
1	0	$\frac{D}{L^2}$	$-\frac{2D}{L^2} C_m - \frac{u}{L}$	$\frac{D}{L^2} + \frac{u}{L}$
0	1	$\frac{D}{L^2} - \frac{u}{L}$	$-\frac{2D}{L^2} C_m - \frac{u}{L}$	$\frac{D}{L^2}$

TABLE E.1. DIFFERENCING SCHEMES ON SPATIAL
CONCENTRATION GRID

The results for grids M, MM, and MP are given in the table.

If the dispersion coefficient, D_x , is small (less than 25 yd^2), this scheme results in a negative concentration at the grid immediately upstream from the grid with unit concentration.

To overcome this, the upstream differencing technique may be used to advantage. That is, instead of using a central difference in the spacial term, a backward difference is used (with velocity in (+) - x direction), which is obtained by setting $A = 1$, and $B = 0$. Applying this at M, we have

$$\frac{DC_m}{Dt} = \frac{D}{L^2} [-2C_m] - \frac{u}{L} [C_m - C_{mm}] \quad (E-5)$$

$$= -\frac{2D}{L^2} - \frac{u}{L} \quad (E-6)$$

The results for M, MM, and MP are shown in Table E.1. The upstream concentration is now positive. However, this scheme results in an increase in effective dispersion. This may be seen by making the substitution for $A = 1$, $B = 0$ into Equation E-1.

Consider the consequences of using a mixture of the two schemes. By adding the rates of increase of concentration for the three grids M, MM, MP for the upstream scheme

(A = 1, B = 0), the sum is zero, indicating that mass is conserved. However, if a central derivative is used at grid MP, its increase is

$$\frac{DC_{mp}}{Dt} = \frac{D}{L} \frac{x}{2} + \frac{u}{2L} \quad (E-7)$$

The sum for the three grids is then

$$- 1/2 \frac{U}{L} \quad (E-8)$$

indicating that mass is lost. Thus a mixture of the two schemes is to be avoided. For the velocity conditions below

$$\begin{array}{ll} \text{Case A} & u \text{ greater than } 0; \quad A = 1, B = 0 \\ & v \text{ greater than } 0; \quad A = 1, B = 0 \end{array} \quad (E-9)$$

$$\begin{array}{ll} \text{Case B} & u \text{ less than } 0; \quad A = 0, B = 1 \\ & v \text{ less than } 0; \quad A = 0, B = 1 \end{array} \quad (E-10)$$

the upstream differencing would be

$$\text{Case A} \quad \frac{\partial C}{\partial x} = \frac{1}{2L} [2C_m - 2C_{m-1}] \quad (E-11)$$

$$\text{Case B} \quad \frac{\partial C}{\partial x} = \frac{1}{2L} [2C_{m+1} - 2C_m] \quad (E-12)$$

where L = is length of grid

The second term in Equation E-4, $\frac{\partial}{\partial x} (UC)$ is now analyzed for $U \frac{\partial C}{\partial x}$ according to Figure E.2

FIGURE E.2. ONE DIMENSIONAL CONCENTRATION SCHEME

and we have

$$u \frac{\partial C}{\partial x} = u[(1 + A) C_{m+1} - 2(A-B) C_m - (1 - B) C_{m-1}] \frac{1}{2L} \quad (\text{E-13})$$

for centered derivative $A = 1/2$ and $B = 1/2$, we have

$$= (C_{m+1} - C_{m-1}) \frac{u}{2L} \quad (\text{E-14})$$

A. UPSTREAM DIFFERENCING IN A CONSISTENT DIVERGENT FLOW PATTERN

It was discovered that for the grid point $N = 10$, $M = 32$ the upstream differencing scheme is unstable. This is shown by first referring to Figure E.3., and noting the general divergent flow condition that exists especially with regard to their velocity component.

Since we have Case A, Equation E.1 is supposed to be applicable which it normally would be if the component was

FIGURE E.3. DIVERGENT FLOW AROUND THE NORTH TIP OF
CONANICUT ISLAND, JAMESTOWN, RHODE ISLAND

not plus (easterly) over 90% of the time. The result is that the C_{m-1} term is forced to change sign by the differencing scheme, which means that the $\frac{\partial C}{\partial x}$ term is larger than it should be, which in turn increases the net advective transport out of the box, giving the response shown in Figure E.4.

Considering the divergent flow and artificial diffusion enhancing properties of the upstream differencing scheme, it was decided to make initial prediction runs using the central differencing scheme.

FIGURE E.4. DIVERGENT FLOW INSTABILITY

B. CONSERVATION OF MASS

An attempt was made to check on the mass-conserving properties of several approximations to the convective-dispersion concentration equation

$$\frac{\partial C}{\partial t} + U \frac{\partial C}{\partial x} - D_x \frac{\partial^2 C}{\partial x^2} = 0 \quad (E-1.a)$$

which have been used in mathematical models. The approximations involve the use of various differencing schemes on the convective term, and modifications of the dispersion coefficient, D_x , if applicable.

In finite-difference form, the above equation may be written as

$$\frac{C_m^+ - C_m^0}{t} + \frac{U}{2L} [2(1 - A) C_{mp}^+ + 2(A - B) C_m^+]$$

$$- 2(1 - B) C_{mm}^+ - \frac{D}{L^2} [C_{mp}^+ - 2C_m^+ + C_{mm}^+] = 0 \quad (E-16)$$

where U , the velocity in the (+) x -direction, and the dispersion coefficient, D , are taken as constant over x (as they are in the uniform channel).

The terms C represent the concentrations at the center of each grid, with the superscript (+) denoting the upper time level, and the (0) the lower time level. The subscripts denote the grid number in the x -direction, with $MP = M+1$, $MM = M-1$. The above finite-difference equation is written for grid M .

The dispersion coefficient, (refer to Figure E.4), D , is calculated from the velocity, u , the depth, H , and the Chezy coefficient, C_z , in the general form

$$\frac{\partial C}{\partial t} = -u \frac{\partial C}{\partial x} = -u [(1 - A) C_{mp} + (A - B) C_m - (1 - B) C_{mm}] \frac{1}{L} \quad (E-9)$$

FIGURE E.5. ONE DIMENSIONAL FIVE GRID SCHEME

for $C_m \neq 0.0$, and $E = u/L$

$$C_{mp} = C_{mm} = 0 = C_{mpp} = C_{mmm}$$

Case I upstream: all M $A = 1, B = 0$

$$m = m \quad DC_m = - E(C_m - C_{mm}) = EC_m \quad (E-17)$$

$$m = mp \quad DC_{mp} = - E(C_{mp} - C_m) = + EC_m \quad (E-18)$$

$$m = mm \quad DC_{mm} = - E(C_{mmm} - C_{mm}) = 0 \quad (E-19)$$

Case II no upstream $A = B = 1/2$

$$mm \quad DC_{mm} = - (E/2) (C_m - C_{mmm}) = - EC_m/2 \quad (E-20)$$

$$m \quad DC_m = - (E/2) (C_{mp} - C_{mm}) = 0 \quad (E-21)$$

$$mp \quad DC_{mp} = - (E/2) (C_{mpp} - C_m) = + EC_m/2 \quad (E-22)$$

Case III upstream at mm only

$$mm \quad DC_{mm} = - E (C_{mm} - C_{mmm}) = 0 \quad (E-23)$$

$$m \quad DC_m = - (E/2) (C_{mp} - C_{mm}) = 0 \quad (E-24)$$

$$mp \quad DC_{mp} = - (E/2) (C_{mpp} - C_m) = + EC_m/2 \quad (E-25)$$

For Cases I and II mass is conserved if schemes are consistent, that is either upstream or central differencing is used exclusively in computational procedure. In Case III, one of many that might be tried, mass is not conserved when one applies the upstream scheme at grid mm only and central differencing in grids m and mp. It is a matter of judgment whether this loss, especially in the area of a source, will result in significantly less accuracy.

Model Segments


```

//LIBRARY JOB (100100,060,15,500),'JOH4 ALFANO',MSGLEVEL=1,CLASS=E          JOB 146
//CHNGSTEP EXEC PGM=IEBUPDTE
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD DSN=OCESMODS,DISP=OLD,UNIT=2314,VOL=SER=OCEPAK
//SYSUT2 DD DSN=OCESMODS,DISP=OLD,UNIT=2314,VOL=SER=OCEPAK
//SYSIN DD *
IEF2361 ALLOC. FOR LIBRARY CHNGSTEP
IEF2371 631 ALLOCATED TO SYSPRINT
IEF2371 241 ALLOCATED TO SYSUT1
IEF2371 241 ALLOCATED TO SYSUT2
IEF2371 601 ALLOCATED TO SYSIN
IEF2851 SYS73156.T003132.RF000.LIBRARY.R0000055      DELETED
IEF2851 VOL SER NOS=                                .
IEF2851 OCESMODS                                     KEPT
IEF2851 VOL SER NOS= OCEPAK.
IEF2851 OCESMODS                                     KEPT
IEF2851 VOL SER NOS= OCEPAK.
IEF2851 SYS73156.T003132.RF000.LIBRARY.R0000056      DELETED
IEF2851 VOL SER NOS=                                .
UR10011 STEP EXECUTION TIME .22 MINS.
// EXEC FORTHCL,PARM,FORT='OPT=2',PARM,LKED='LET,LIST,NCAL,XREF'
XXDEFAULT PRNC LIB1=SSP,LIB2=OPLOT                                00000100
XXFORT EXEC PGM=IEKAA00,REGION=228K                                00000200
XXSYSPRINT DD SYSOUT=A                                            00000300
XXSYSPLUNCH DD SYSOUT=B                                           00000400
XXSYSLIN DD DSNNAME=LOADSET,UNIT=SYSSQ,DISP=(MOD,PASS),          *00000500
IEF6531 SUBSTITUTION JCL - DSNNAME=LOADSET,UNIT=SYSSQ,DISP=(MOD,PASS),
XX SPACE=(1680,(50,10)),DCB=(RECFM=FB,BLKSIZE=1680,LRECL=80) 00000600
//FORT.SYSIN DD DSN=OCESMODS(AMAIN),DISP=SHR
IEF2361 ALLOC. FOR LIBRARY FORT
IEF2371 631 ALLOCATED TO SYSPRINT
IEF2371 660 ALLOCATED TO SYSPLUNCH
IEF2371 240 ALLOCATED TO SYSLIN
IEF2371 241 ALLOCATED TO SYSIN
IEF2851 SYS73156.T003132.RF000.LIBRARY.R0000057      DELETED
IEF2851 VOL SER NOS=                                .
IEF2851 SYS73156.T003132.RF000.LIBRARY.LOADSET        PASSED
IEF2851 VOL SER NOS= COB101.
IEF2851 OCESMODS                                     KEPT
IEF2851 VOL SER NOS= OCEPAK.
UR10011 STEP EXECUTION TIME .78 MINS.
XXLKED EXEC PGM=IEWL,REGION=96K,PARM=(MAP,LET,LIST),COND=(4,LT,FORT) 00000700
XXSYSLIB DD DSNNAME=SYS1.FORTLIB,DISP=SHR                    00000800
XX DD DSNNAME=URI.&LIB1.LIB,DISP=SHR                        00000900
IEF6531 SUBSTITUTION JCL - DSNNAME=URI.SSPLIB,DISP=SHR
XX DD DSNNAME=URI.&LIB2.LIB,DISP=SHR                        00001000
IEF6531 SUBSTITUTION JCL - DSNNAME=URI.OPLCTLIB,DISP=SHR
XXSYSPRINT DD SYSOUT=A                                         00001100
//LKED.SYSLMOD DD DSN=OCFECOMP(MAIN),DISP=CLD
X/SYSLMOD DD DSNNAME=GG0SET(MAIN),UNIT=SYSDA,DISP=(,PASS),      *00001200
IEF6531 SUBSTITUTION JCL - DSNNAME=GG0SET(MAIN),UNIT=SYSDA,DISP=(,PASS),
XX SPACE=(13072,(130,10,1))                                00001300
XXSYSLIN DD DSNNAME=LOADSET,DISP=(OLD,DELETE)                00001400
IEF6531 SUBSTITUTION JCL - DSNNAME=LOADSET,DISP=(OLD,DELETE)
XX DD DSNNAME=SYSIN                                           00001500
XXSYSLT1 DD DSNNAME=ESYSUT1,UNIT=SYSDA,SPACE=(1024,(200,20)),SEP=SYSLMOD 00001600
IEF6531 SUBSTITUTION JCL - DSNNAME=ESYSUT1,UNIT=SYSDA,SPACE=(1024,(200,20)),SEP=SYSLMOD
IEF2361 ALLOC. FOR LIBRARY LKED
IEF2371 130 ALLOCATED TO SYSLIB
IEF2371 244 ALLOCATED TO

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IEF2371 244 ALLOCATED TO
IEF2371 631 ALLOCATED TO SYSPRINT
IEF2371 241 ALLOCATED TO SYSMOD
IEF2371 240 ALLOCATED TO SYSLIN
IEF2371 133 ALLOCATED TO SYSUT1
IEF2851 SYS1.FORTLIB KEPT
IEF2851 VOL SER NOS= MFTRES.
IEF2851 URI.SSPL13 KEPT
IEF2851 VOL SER NOS= MFTLB1.
IEF2851 URI.OPLOTLIB KEPT
IEF2851 VOL SER NOS= MFTLB1.
IEF2851 SYS73156.T003132.RF000.LIBRARY.R0000059 DELETED
IEF2851 VOL SER NOS=
IEF2851 OCECOMP KEPT
IEF2851 VOL SER NOS= OCEPAK.
IEF2851 SYS73156.T003132.RF000.LIBRARY.LOADSET DELETED
IEF2851 VOL SER NOS= CJB101.
IEF2851 SYS73156.T003132.RF000.LIBRARY.SYSUT1 DELETED
IEF2851 VOL SER NOS= CEB1SK.
UR10011 STEP EXECUTION TIME .04 MINS.
//CHNGSTEP EXEC PGM=IEBUPDTE
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD DSN=OCEDATAS,DISP=OLD,UNIT=2314,VOL=SER=OCEPAK
//SYSUT2 DD DSN=OCEDATAS,DISP=OLD,UNIT=2314,VOL=SER=OCEPAK
//SYSUDUMP DD SYSOUT=A
//SYSIN DD *
IEF2361 ALLOC. FOR LIBRARY CHNGSTEP
IEF2371 631 ALLOCATED TO SYSPRINT
IEF2371 241 ALLOCATED TO SYSUT1
IEF2371 241 ALLOCATED TO SYSUT2
IEF2371 632 ALLOCATED TO SYSUDUMP
IEF2371 602 ALLOCATED TO SYSIN
IEF2851 SYS73156.T003132.RF000.LIBRARY.R0000060 DELETED
IEF2851 VOL SER NOS=
IEF2851 OCEDATAS KEPT
IEF2851 VOL SER NOS= OCEPAK.
IEF2851 OCEDATAS KEPT
IEF2851 VOL SER NOS= OCEPAK.
IEF2851 SYS73156.T003132.RF000.LIBRARY.R0000062 DELETED
IEF2851 VOL SER NOS=
UR10011 STEP EXECUTION TIME .19 MINS.
//LNED EXEC PGM=IEWL,PARM=(MAP,LET,LIST,OVLY,XREF)
//SYSLIB DD DSN=SYS1.FORTLIB,DISP=SHR
// DD DSN=URI.SSPL13,DISP=SHR
// DD DSN=URI.OPLOTLIB,DISP=SHR
//SYSPRINT DD SYSOUT=A
//SYSLIN DD DDNAME=SYSIN
//SYSMOD DD DSN=GOSET(MAIN),UNIT=SYSDA,DISP=(,PASS),
// SPACE=(13072,(30,10,1))
//SYSUT1 DD DSN=SYSUT1,UNIT=SYSDA,SPACE=(1024,(200,20)),SEP=SYSLMOD
//LKED.OBJLIB DD DSN=OCECOMP,DISP=SHR,VOL=SER=OCEPAK,UNIT=2314
//LKED.SYSIN DD *
IEF2361 ALLOC. FOR LIBRARY LKED
IEF2371 130 ALLOCATED TO SYSLIB
IEF2371 244 ALLOCATED TO
IEF2371 244 ALLOCATED TO
IEF2371 631 ALLOCATED TO SYSPRINT
IEF2371 603 ALLOCATED TO SYSLIN
IEF2371 242 ALLOCATED TO SYSMOD
IEF2371 130 ALLOCATED TO SYSUT1

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IEF2371 241 ALLOCATED TO DBJLIB
IEF2851 SYSL.FORTLIB KEPT
IEF2851 VOL SER NOS= MFTRES.
IEF2851 UNIT=35PLIB KEPT
IEF2851 VOL SER NOS= MFTLB1.
IEF2851 UNIT.CPLOTLIB KEPT
IEF2851 VOL SER NOS= MFTLB1.
IEF2851 SYS73156.T003132.RF000.LIBRARY.R0000063 DELETED
IEF2851 VOL SER NOS=
IEF2851 SYS73156.T003132.RF000.LIBRARY.R0000064 DELETED
IEF2851 VOL SER NOS=
IEF2851 SYS73156.T003132.RF000.LIBRARY.G0SET PASSED
IEF2851 VOL SER NOS= CHMPAK.
IEF2851 SYS73156.T003132.RF000.LIBRARY.SYSUT1 DELETED
IEF2851 VOL SER NOS= MFTRES.
IEF2851 DCECOMP KEPT
IEF2851 VOL SER NOS= OCEPAK.
UR10011 STEP EXECUTION TIME .15 MINS.
//G) EXEC PGM=*.LKED,SYSLMOD
//FT06F001 DD SYSOUT=A
//FT07F001 DD SYSOUT=B
//FT05F001 DD DSN=DCEDATAS(ADATA2),DISP=SHR,VOL=SER=OCEPAK,UNIT=2314,
// LABEL=(,,,IN)
// DD DSN=DCEDATAS(ADATA3),DISP=SHR,VOL=SER=OCEPAK,UNIT=2314,
// LABEL=(,,,IN)
// DD DSN=DCEDATAS(ADATA4),DISP=SHR,VOL=SER=OCEPAK,UNIT=2314,
// LABEL=(,,,IN)
// DD DSN=DCEDATAS(ADATA4),DISP=SHR,VOL=SER=OCEPAK,UNIT=2314,
// LABEL=(,,,IN)
//G) FT13F001 DD DSN=ALF,DISP=(NEW,DELETE),UNIT=SYSDA,
// SPACE=(TRK,(10,10))
//
IEF2361 ALLOC. FOR LIBRARY GO
IEF2371 242 ALLOCATED TO PGM=*.DD
IEF2371 631 ALLOCATED TO FT06F001
IEF2371 661 ALLOCATED TO FT07F001
IEF2371 241 ALLOCATED TO FT05F001
IEF2371 241 ALLOCATED TO
IEF2371 241 ALLOCATED TO
IEF2371 241 ALLOCATED TO
IEF2371 130 ALLOCATED TO FT13F001
IEF2851 SYS73156.T003132.RF000.LIBRARY.G0SET PASSED
IEF2851 VOL SER NOS= CHMPAK.
IEF2851 SYS73156.T003132.RF000.LIBRARY.R0000065 DELETED
IEF2851 VOL SER NOS=
IEF2851 SYS73156.T003132.RF000.LIBRARY.R0000066 DELETED
IEF2851 VOL SER NOS=
IEF2851 DCEDATAS KEPT
IEF2851 VOL SER NOS= OCEPAK.
IEF2851 DCEDATAS KEPT
IEF2851 VOL SER NOS= OCEPAK.
IEF2851 DCEDATAS KEPT
IEF2851 VOL SER NOS= OCEPAK.
IEF2851 DCEDATAS KEPT
IEF2851 VOL SER NOS= OCEPAK.
IEF2851 SYS73156.T003132.RF000.LIBRARY.ALF DELETED
IEF2851 VOL SER NOS= MFTRES.
UR1011 STEP EXECUTION TIME .49.26 MINS.
IEF2351 SYS73156.T003132.RF000.LIBRARY.G0SET DELETED
IEF2851 VOL SER NOS= CHMPAK.

```


./ CHANGE NAME=AMAIN,LIST=ALL

```

DIMENSION A(48),B(48),Q(48),R(48),S(48),T(48),P(48),
1KONVRT(21),NH(21),NPRINT(200),DAVG(80),
2NS(10),MS(10),SS(10),ZIF(0175),NTP(10),ZIH(0175),ZIG(0175)
00001000
00001100
00001200
00001300
C
COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),UI(21,48),UP(21,48),
1C(21,48),NBD(85),MBD(85),MUBD(4),NMBD(4),H(21,48),
00001400
2W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),
00001500
3ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),
00001600
4ZIA(0175),ZIB(0175),ZIC(0175),UAVG(21,48),VAVG(21,48),ZIE(0175),
00001700
5ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),
00001800
6IFIELD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175)
00001900
00002000
C
LOGICAL READIN,DOSAL,ROCNP,DELTAT
00002100
00002200
C
DATA YR,DAY,THR,TMIN /57.,195.,17.,48./
00002300
DATA MSQJRC,NSOURC /1,1/
00002400
DATA AL,AG,SALRIS,TMHOPE,TRIVER,T SOUND/L012.7,10.73,32.5,21.75,
00002500
122.2,18.50/
00002600
DATA HINV,SEINV,P1,CMANN,WX,WY,CORAG,CRHD /0.,0.,3.1415927,
00002700
1.015,0.,0.,.0025,.00114/
00002800
00002900
C
00003000
C
00003100
C
SET EXECUTION PARAMETERS
00003200
C
00003300
C
IMODES = 1 UPSTREAM DIFFERENCING
00003400
C
IMODES = 2 CENTRAL DIFFERENCING
00003500
C
00003600
C
IMODES=2
00003700
2871 IPUNCH=540
00003800
AT = 120.
00003900
EXTRA3=AT
00004000
C
IPRIND WILL SPECIFY TIME THAT VARIABLES ARE DISPLAYED
00004100
IPRIND=15
00004200
ILD=1
00004300
C
SUMMING MODES REQUIRED FOR DISPLAYS
00004400
SUMZIG=0.0
00004500
SUMZID=0.0
00004600
SUMZIF=0.0
00004700
SUMZIH=0.0
00004800
SUMAA=0.0
00004900
SUMBB=0.0
00005000
MAXST=540
00005100
NW=MAXST+1
00005200
IDY=1
00005300
HS1(IDY) = 2000.
00005400
ROCNP=.FALSE.
00005500
C
ROCNP FOR READING IN PREVIOUS VALUES OF CNP
00005600
READIN=.TRUE.
00005700
DOSAL=.TRUE.
00005800
IRMS=1000
00005900

```

IMODE1 = 1 00006000
 C 00006100
 C SET COMPUTATION PARAMETERS 00006200
 C 00006300
 C 00006400
 C IF DELTAT IS TRUE MODEL WILL CALCULATE TEMPERATURE ABOVE AMBIENT 00006500
 DELTAT=.TRUE. 00006600
 TRNB=21.0 00006700
 IF(DELTAT) GO TO 2873 00006800
 GO TO 2875 00006900
 2873 TRNB=0.00001 00007000
 TMHOPE=.00001 00007100
 TRIVER=.00001 00007200
 TSOUND=.00001 00007300
 2875 CONTINUE 00007400
 C DIFFUSION CONSTANT IS UPCON 00007500
 C FOR UPCON =500 THE ORDER OF MAGNITUDE OF HIGHEST DIFFUSION COEF 00007600
 C IS ABOUT 350 YDSQ/SEC 00007700
 C 00007800
 C UPCON=050. 00007900
 C 00008000
 C POWER PLANT 00008100
 C TIN =0.0 YOU WILL HAVE HYDRODYNAMICS OF POWER PLANT SITE BUT 00008200
 C NO THERMAL LOAD ON BAY 00008300
 C IF EFFECTS OF POWER PLANT ARE DESIRED SET TIN EQUAL TO 12. 00008400
 TIN=12. 00008500
 QIN=2000. 00008600
 C 00008700
 C SITE SELECTION. SEE HEATIN FOR DETAILS ON LOCATIONS 00008800
 C SITE=100. 00008900
 C 00009000
 C 00009100
 C LNL = 0 00009200
 C ARHO=27.*1.940*(1.00+0.000841*SALRIS-0.000100*TSOUND) 00009300
 C 00009400
 C 00009500
 C NMAX=19 00009600
 C MMAX=48 00009700
 C ANGLAT=41.6 00009800
 C NI=1 00009900
 C M0B0(1)=0103042 00010000
 C M0B0(2)=4808091 00010100
 C M0B0(3)=4811131 00010200
 C N0B0(1)=1923242 00010300
 C N0B0(2)=0410112 00010400
 C MIND0=4 00010500
 C NIND0=3 00010600
 C NSECT=80 00010700
 C 00010800
 C 87 CONTINUE 00010900
 ARG=ANGLAT*3.1415927/180. 00011000
 FF=3.1415927*SIN(ARG)/21600. 00011100


```

2080 NST=0
      IP=1
      C1=AT*AG/AL
      C2=AT/AL
      C3=AT/4.
      C4=8.*AT*AG
      C5=2.*27.*AL
C      27 IS FOR CUFT TO CUYDS CONVERSION AND 2 IS FOR DISPLAYING
C      ACTUAL CROSSSECTIONAL FLOW IN FOR RIVER
      C6=2.*CDRAG*CRHO*(1.687/3.)**2*AT
      C7=40.00*SQRT(AG)
      C8=1./AL
      C9=1./(AL**2)
      C10 = 0.
      C11=C7
      C12 = 0.
      C13=1./AT
      C14=1./(4.*AL)
      DO 8 M=1,MMAX
      DO 6 N=1,NMAX
      SE(N,M)=0.0
      SEP(N,M)=0.0
      CN(N,M)=0.0
      CNP(N,M)=0.0
      UAVG(N,M)=0.0
      VAVG(N,M)=0.0
      VP(N,M)=0.0
      UP(N,M)=0.0
      VN(M)=0.
      UN(M)=0.
      CN(M)=0.
      HN(M)=0.0
      6 FIN)=FF
      8 CONTINUE
      RA=0.0
      CALL KURIH(MAXST,AT,NTERM,FCHECK,YR,DAY,THR,TMIN,TS)
      CALL DIVE(NMAX,MMAX)
      CALL FIND(MIND,NIND,MMAX,NMAX,MINDO,NINDO,NSECT)
      CALL DEPTH(NMAX,MMAX)
      CALL CHEZY(NMAX,MMAX,CHANN)
      CALL CHECK(NMAX,MMAX)
      DO 26 I=1,5
      L=18*I
      M=18*(I-1)+1
      READ(5,25) (NPRINT(N),N=M,L)
      25 FORMAT(18I4)
      26 CONTINUE
      DO 62 M=1,MMAX
      DAVG(M)=0.0
      DEP=0.0
      DO 61 N=1,NMAX
      IF(HN(M).EQ.0.0) GO TO 61

```

```

00011200
00011300
00011400
00011500
00011600
00011700
00011800
00011900
00012000
00012100
00012200
00012300
00012400
00012500
00012600
00012700
00012800
00012900
00013000
00013100
00013200
00013300
00013400
00013500
00013600
00013700
00013800
00013900
00014000
00014100
00014200
00014300
00014400
00014500
00014600
00014700
00014750
00015000
00015100
00015200
00015300
00015400
00015500
00015600
00015700
00015800
00015900
00016000
00016100
00016200
00016300
00016400

```



```

      DAVG(M)=DAVG(M)+HIN,M)
      DEP=DEP+1.
61  CONTINUE
      DAVG(M)=3.*DAVG(M)/DEP
62  CONTINUE
      NUM=1
      DEP=0.0
      DEPSQ=0.0
      GRIDN1=0.0
7  IF(NUM.EQ.NIND) GO TO 3
      NSRCH=NBD(NUM)/1000000
      N   =NBD(NUM)/10000   -NSRCH*100
      MF  =NBD(NUM)/100-NSRCH*10000-M*100
      L   =NBD(NUM)-NSRCH*1000000-N*10000-MF*100
      NN=N-1
      K=MF
      GRID=L-K+1
      GRIDN2=GRID
      GRIDN1=GRIDN1+GRIDN2
C
C
C      USED ONLY IF NO SE VALUES ARE READ IN
      DO 2 M=K,L
      DEP=DEP+HIN,M)
      DEPSQ=DEPSQ+SQRT(H(N,M))
      DIM1=M
      DIM1=DIM1-1.
      CN(N,M)=TBNB
      CNP(N,M)=TBNB
      SEP(N,M)=SEINV*(1.-DIM1/46.)*HINV
2  SE(N,M)= SEINV*(1.-DIM1/46.)*HINV
      NUM=NUM+1
      GO TO 7
3  CONTINUE
      CN (3,1) = TBNB
      CNP(3,1) = TBNB
      CN (4,1) = TBNB
      CNP(4,1) = TBNB
      CN (19,23)=TBNB
      CNP(19,23)=TBNB
      CN (19,24)=TBNB
      CNP(19,24)=TBNB
      CN (08,48)=TBNB
      CNP(08,48)=TBNB
      CN (09,48)=TBNB
      CNP(09,48)=TBNB
      CN (11,48)=TBNB
      CNP(11,48)=TBNB
      CN (12,48)=TBNB
      CNP(12,48)=TBNB
      CN (13,48)=TBNB
      CNP(13,48)=TBNB

```

```

00016500
00016600
00016700
00016800
00016900
00017000
00017100
00017200
00017300
00017400
00017500
00017600
00017700
00017800
00017900
00018000
00018100
00018200
00018300
00018400
00018500
00018600
00018700
00018800
00018900
00019000
00019100
00019200
00019300
00019400
00019500
00019600
00019700
00019800
00019900
00020000
00020100
00020200
00020300
00020400
00020500
00020600
00020700
00020800
00020900
00021000
00021100
00021200
00021300
00021400
00021500
00021600

```

```

DEP=3.*DEP/GRIDN1
DEPSQ=DEPSQ/GRIDN1
DEPSQ=3.*(DEPSQ**2)
NA=1
5 IF(NA.EQ.NINDO) GO TO 31
M=MOBD(NA)/10000
NBDT =MOBD(NA)/1000 -M*100
NTOP =MOBD(NA)/10 -M*10000 -NBDT*100
DO 32 N=NBDT,NTOP
DIM1=M
DIM1=DIM1-1.
SEP(N,M)=SEINV*(1.-DIM1/46.)*HINV
32 SE(N,M)= SEINV*(1.-DIM1/46.)*HINV
NA=NA+1
GO TO 5
31 NA=1
33 IF(NA.EQ.NINDO) GO TO 34
N=NOBD(NA)/100000
MLEF =NOBD(NA)/1000 -N*100
MRIG =NOBD(NA)/10 -N*10000 -MLEF*100
DO 35 M=MLEF,MRIG
DIM1=M
DIM1=DIM1-1.
SEP(N,M)=SEINV*(1.-DIM1/46.)*HINV
35 SE(N,M)= SEINV*(1.-DIM1/46.)*HINV
NA=NA+1
GO TO 33
34 CONTINUE
C*****00024500
C 00024600
C CALL INVAL(MMAX,NMAX,GRIDN1,DEP,DEPSQ,READIN,RDCNP,DAVG) 00024700
C 00024800
C CALL HEAT(INNS,MS,SS,TIN,NZ,SITE,NINPUT,QIN) 00024850
C*****00024900
C 00025000
C WRITE(6,2050) NS(5),MS(5) 00025040
2050 FORMAT(//,5X,'NS(5) = ',I4,'MS(5) = ',I4) 00025060
40 ISTEP=2 00025100
C 00025200
C*****00025300
C 00025400
C CALL PRINT(ISTEP,NST,NPRINT,K,NMAX,MMAX,IP,AT,HTOT,HA,BH, 00025500
1HE,HC,SAVE,IPUNCH) 00025600
C 00025700
C*****00025800
C 00025900
C 88 ISTEP=1 00026000
NST=NST+1 00026100
K=2*NST-1 00026200
2001 IF(NST.GT.MAXST) GO TO 501 00026300
C 00026400
C*****00026500

```



```

C                                00026600
C      SET OPEN BOUNOS                                00026700
C                                00026800
C                                00026900
C      CALL OPENBDINST,IMODES,EXTRA1,KWRIT,K,KRT,IMODE1,T1,T2,T4,T5, 00027000
      INTERM,C5,TRIVER,TMHOPE,TSOUND,PI,THR,FCHECK,AT,TS,AL,QIN) 00027100
C                                00027200
C*****00027300
C                                00027400
C      COMPUTE UP AND SEP ON ROW N ( FIRST HALF TIMESTEP) 00027500
C                                00027600
C      CALL UPNFHT(WX,WY,C6,C1,C2,C4,AT,AG,NIND,F,NI) 00027700
C                                00027800
C*****00027900
C                                00028000
C      COMPUTE VP ON COLUMN M (FIRST HALF TIMESTEP) 00028100
C                                00028200
C      CALL VPMFHT(C2,C6,WX,WY,C4,AT,DOSAL,IMODES,NSOURC,MSOURC,C13, 00028300
      1C10,C7,C8,C9,C14,C1,MIND,F,NI,NST,NPRINT,IP,T8NB,KRT,NMAX,MMAX, 00028400
      2IDY,PI,DAY,THR,TMIN,HTOT,HA,BH,HE,HC,SAVE,NS,MS,SS, 00028500
      3QIN,TIN,NZ,NM,UPCON,VAR1,DELTAT,NINPUT,ZIG) 00028600
C                                00028700
C*****00028800
C                                00028900
C      CALL PRINT(IISTEP,NST,NPRINT,K,NMAX,MMAX,IP,AT,HTOT,HA,BH, 00029000
      IHE,HC,SAVE,IPUNCH) 00029100
C                                00029200
C*****00029300
C                                00029400
C      CALL OPENBD(INST,IMODES,EXTRA1,KWRIT,K,KRT,IMODE1,T1,T2,T4,T5, 00029500
      INTERM,C5,TRIVER,TMHOPE,TSOUND,PI,THR,FCHECK,AT,TS,AL,QIN) 00029600
C                                00029700
C*****00029800
C                                00029900
C      NXT=ILD 00029910
      IF(NXT.EQ.0) GO TO 2020 00029920
      2010 IF(NST.LT.90) GO TO 2040 00029930
      GO TO 2020 00029940
      2040 WRITE(6,2030)'NXT,CN(5,36),CNP(5,36),QIN,TIN,NS(1),MS(1),NZ, 00029950
      ININPUT,SS(1),Z1A(NXT),Z1B(NXT),Z1C(NXT),Z1E(NXT),Z1D(NXT), 00029955
      2AA(NXT),BB(NXT),SITE,NS(5),MS(5),NST 00029958
      2030 FORMAT(5X,'NST = ',I4,' CN(5,36) = ',E12.4,' CNP(5,36) = ', 00029960
      1E12.4,' QIN = ',E12.4,' TIN = ',E12.4,' NS = ',I4,' MS = ', 00029965
      2I4,'/5X,' NZ = ',I4,' ININPUT = ',I4,' SS(1) = ',E12.4, 00029970
      3'Z1A(NST) = ',E12.4,' Z1B(NST) = ',E12.4,'Z1C(NST)=',E12.4,'/5X, 00029975
      4'Z1E(NST) = ',E12.4,' Z1D(NST) = ',E12.4,'AA(NST) = ',E12.4, 00029980
      5'BB(NST) = ',E12.4,'/5X,' SITE = ',E12.4,' '(5) = ',I4, 00029985
      6'MS(5) = ',I4,'NST = ',I4) 00029987
      2020 CONTINUE 00029990
C*****00030000
      299 ISTEP=2 00030100
                        00030200

```



```

      K=2*NST
C
C
C      COMPUTE VP AND SEP ON COLUMN M (SECOND HALF TIMESTEP)
C
C      CALL VPMSHT (WX,WY,C6,C1,C2,C4,AT,AG,MIND,F,NI)
C
C*****
C      CALL UPMSHT (C2,C6,WX,WY,C4,AT,DOSAL,IMODES,NSOURC,MSOURC,C13,
1C10,C7,C8,C9,C14,C1,MIND,F,NI,NST,NPRINT,IP,TBNS,KRT,NMAX,MMAX,
2 IDY,P1,DAY,NS,MS,SS,QIN,TIN,NZ,THR,TMIN,HTOT,NW,UPCON,VARI,
3NINPUT)
C
C      SUM1=0.
C      GRID1 = 0.0
C
C      SUM=0.0
C
C
C      BAY AREA
C
C      NUM=1
17 IF (NUM.EQ.NIND) GO TO 36
   NSRCH=NBD(NJM)/1000000
   N      =NBD(NJM)/10000 -NSRCH*100
   MF     =NBD(NJM)/100-NSRCH*10000-N*100
   L      =NBD(NJM)-NSRCH*1000000-N*10000-MF*100
   NN=N-1
   NGRID = L-MF*1
   GRIDN2=NGRID
   GRID1=GRID1+GRIDN2
   DO 22 M=MF,L
   MM= M-1
   SUMTWT =CNP(N,M)*( (.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM)+SEP(N,M)))
1*3.0
   SUM=SUM+SUMTWT
   SUM1=SUM1+CNP(N,M)
22 CONTINUE
   NUM=NUM+1
   GO TO 17
36 SUMZIG=SUM1/GRID1 + SUMZIG
C   CONSTA SHOULD EQUAL (AL**2)*9*DENS*9/5
   CONSTA=1.00
   SUMZID=CONSTA*SUM+SUMZID
   IF (MOD(NST,IPRIN).EQ.0) GO TO 45
   GO TO 41
45 IPRINZ=IPRIND
   IF (DELTAT) GO TO 47
   IPRINZ=IPRINZ*10**4
47 ZID(IID)=SUMZID/IPRINZ
   ZIG(IID)=SUMZIG/IPRINZ
   SUMZIG=0.0

```

```

00030300
00030400
00030500
00030600
00030700
00030800
00030900
00031000
00031100
00031200
00031300
00031400
00031500
00031600
00031700
00031800
00031900
00032000
00032100
00032200
00032300
00032400
00032500
00032600
00032700
00032800
00032900
00033000
00033100
00033200
00033300
00033400
00033500
00033600
00033700
00033800
00033900
00034000
00034100
00034200
00034300
00034400
00034500
00034600
00034700
00034800
00034900
00035000
00035100
00035200
00035300
00035400

```

SUMZID=0.0
 41 CONTINUE
 SUM=0.
 SUM1=0.0
 NUM=1
 GRID3=0.0
 NTP(1)= NBD(8)
 NTP(2)= NBD(11)
 NTP(3)= NBD(14)
 NTP(4)= NBD(16)
 NTP(5)= NBD(17)
 NTP(6)= NBD(19)

C
 C
 C
 POWER PLANT AREA

300 IF(NUM.EQ.07) GO TO 310
 312 NSRCH=NTP(NUM)/1000000
 N=NTP(NUM)/10000-NSRCH*100
 MF=NTP(NUM)/100-NSRCH*10000-N*100
 L=NTP(NUM)-NSRCH*1000000-N*10000-MF*100
 IF(MF.LT.32) MF=32
 IF(L.GT.42) L=42
 NN=N-1
 NNGD=L-MF+1
 GRT4=NNGD
 GRID3=GRID3+GRT4
 DD 330 M=MF,L
 MM=M-1
 SUMTPT =CNP(N,M)*(0.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM)+SEP(N,M)))
 1*3.0
 SUM1=SUM1+CNP(N,M)
 330 SUM=SUM+SUMTPT
 60 SUMZIF=CONSTA*SUM+SUMZIF
 SUMZIH=SUM41/GRID3 + SUMZIH
 IF(MOD(NST,IPRIND).EQ.0) GO TO 65
 GO TO 70
 65 IPRINZ=IPRIND
 IF(DELTA) GO TO 67
 IPRINZ=IPRINZ*10**2
 67 ZIF(ILD)=SUMZIF/IPRINZ
 ZIH(ILD)=SUMZIH/IPRINZ
 SUMZIF=0.0
 SUMZIH=0.0
 70 CONTINUE
 NUM=NUM+1
 GO TO 300
 310 CONTINUE

C
 C
 C
 VELOCITY COMPONENTS IN OUTFALL AREA

SUM=0.0
 SUM1=0.0

00035500
 00035600
 00035700
 00035800
 00035900
 00036000
 00036100
 00036200
 00036300
 00036400
 00036500
 00036600
 00036700
 00036800
 00036900
 00037000
 00037100
 00037200
 00037300
 00037400
 00037500
 00037600
 00037700
 00037800
 00037900
 00038000
 00038100
 00038200
 00038300
 00038400
 00038500
 00038600
 00038700
 00038800
 00038900
 00039000
 00039100
 00039200
 00039300
 00039400
 00039500
 00039600
 00039700
 00039800
 00039900
 00040000
 00040100
 00040200
 00040300
 00040400
 00040500
 00040600


```

316 NZ=1                                00040700
      INS=NS(INZ)                        00040800
      IMS=MS(INZ)                        00040900
C    CHANGE 5 TO NS(2) AND 36 TO MS(1) WHEN YOU RUN POWER PLANT 00041000
      SUM=UP(INS,IMS)+SUM                00041100
      SUM1=VP(INS,IMS)+SUM1              00041200
375 CONTINUE                             00041300
      ANZ=NZ                             00041400
      SUM=SUM/ANZ                         00041500
      SUM1=SUM1/ANZ                      00041600
      SUMAA=SUM + SUMAA                  00041700
      SUMBB=SUM1+SUMBB                   00041900
      IF(MOD(INST,IPRIND).EQ.0) GO TO 75 00042000
      GO TO 80                           00042100
75  AA(ILD)=SUMAA/IPRIND                  00042200
      BB(ILD)=SUMBB/IPRIND                00042300
      SUMAA=0.0                           00042400
      SUMBB=0.0                           00042500
      IF(MOD(INST,IPRIND).EQ.0) ILD=ILD+1 00042600
      NXT=ILD-1                           00042650
80  CONTINUE                             00042700
C                                         00042800
      WRITE(6,2070) ZID(NXT),ZIG(NXT),ZIF(NXT),ZIH(NXT) 00042850
2070 FORMAT(//,5X,'ZID(NXT) = ',E12.4,'ZIG(NXT) = ',E12.4, 00042860
1,'ZIF(NXT) = ',E12.4,'ZIH(NXT) = ',E12.4) 00042890
C    AVERAGE VELOCITY IN WEST PASSAGE 00042900
      ZIE(ILD)=(UP(8,47)+UP(9,47))/2.    00043000
      CALL DISPLY(INST,MAXST,TBNB,ZIF,ZIG,ZIH,IPRIND) 00043400
C                                         00043500
      IF(INST.LT.MAXST) GO TO 40          00043600
110 CALL PRINT(ISTEP,NST,NPRINT,K,NMAX,MMAX,IP,AT,HTOT,HA,BH, 00043700
1HE,HC,SAVE,IPUNCH)                     00043800
C                                         00043900
C*****00044000
C                                         00044100
C                                         00044200
C                                         00044300
C    END OF MAIN COMPUTATIONAL SCHEME 00044400
C                                         00044500
C                                         00044600
C*****00044700
C                                         00044800
C    501 CONTINUE                        00044900
      CALL ANALYZE(MAXST,NTERM,AT,NST,ZIF) 00045000
      RETURN                             00045100
      END                                00045200

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IE08161 MEMBER NAME (AMAIN) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.


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SUBROUTINE VPMFHT(C2, C6, WX, WY, C4, AT, DUSAL, IMODES, NSOURC,
1MSOURC, C13, C10, C7, C8, C9, C14, C1, MIND, F, NI, NST, NPRINT, IP, TBNB, KRT,
2NMAX, MMAX, IDY, PI, DAY, THR, TMIN, HTOT, MA, RH, HE, HC, SAVE, NS, MS, SS,
3QIN, TIN, NZ, NW, UPCON, VAR1, DELTAT, NINPUT, ZIG)
COMMON SE(21,48), SEP(21,48), V(21,48), VP(21,48), UI(21,48), UP(21,48),
1C(21,48), NHD(85), MBD(85), M0BD(4), N0BD(4), H(21,48),
2W(20), F2(20), Z(20), E(20), HP(20), EP(20), HB(20), ER(20),
3ARN(20), ARGP(20), ARG8(20), ARG8(20), HL(20), EL(20),
4Z1A(0175), Z1B(0175), Z1C(0175), UAVG(21,48), VAVG(21,48), Z1E(0175),
5ACOSMT(6), ASINMT(6), CN(21,48), CNP(21,48),
6F1E(0121,48), HS1(015), HS2(015), Z10(0175), AA(0175), BB(0175)
DIMENSION A(790), B(48), P(48), Q(48), R(48), S(48), F(48),
1KONVRT(21), NH(21), NPRINT(200), DAVG(80),
2MS(10), NS(10), SS(10), ZIG(1)
EXTRAL=1.0
NUM=1
NZ=1
LOGICAL DUSAL, DELTAT
1 IF(NUM.EQ.MIND) GO TO 202
* * * * *
5 CONTINUE
* * * * *
MSRCH=MBD(NUM)/1000000
M =MBD(NUM)/10000 -MSRCH*100
NF =MHD(NUM)/100 -MSRCH*10000 -M*100
L =MRD(NUM) -MSRCH*1000000-M*10000-NF*100
LLL=L+1
LL=L-1
NFF=NF-1
MM=M+1
MM=M-1
IA=MSRCH/10
IB=MSRCH-10*IA
3 CONTINUE
DO 220 N=NF, L
NN=N-1
NNN=N+1

ALFAC=.5
BETAC=.5
GAMMAC=.5
DELTAC=.5
IF(N.EQ.NF) GO TO 206
IF(N.EQ.L) GO TO 210
CONTINUE
BETA=0.5
TEMP4=C2*((1.-BETA)*(V(NNN,M)-V(N,M))+BETA*(V(N,M)-V(NN,M)))
TEMP1=V(N,M)**2+((UP(N,M)+UP(NNN,M)+UP(N,MM)+UP(NNN,MM))**2)/
116.)
TEMP2=(SEP(N,M)+SEP(NNN,M)+H(N,MM)+H(N,M))*C(N,M)+
1C(NNN,M)**2

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TEMP12=C6*W4**2/(SE(N,M)+SE(NNN,M)+H(N,MM)+H(N,M))
TEMP3=1.+C4*SQRT(TEMP1)/TEMP2+TEMP4+TEMP12
TEMP3=1./TEMP3
DELTA=0.5
TEMP10=V(N,MM)
IF(TEMP10.EQ.0.) TEMP10= V(N,MM)
TEMP11=V(N,MM)
IF(TEMP11.EQ.0.) TEMP11= V(N,MM)
TEMP1=(AT*F(N)+(1.-DELTA)*C2*(TEMP10-V(N,M))+DELTA*C2*
1(V(N,M)-TEMP11))*0.25
204 VPIN,M)=TEMP3*
1(V(N,M)-TEMP1*(UP(N,M)+UP(NNN,M)+UP(N,MM)+UP(NNN,MM))
2- C1*(SE(NNN,M)-SE(N,M)))
C COMPUTE CNP ON ROW M (SECOND HALF TIMESTEP )
212 CONTINUE
IF(DOSAL) GO TO 213
GO TO 220
213 CONTINUE
IF(IMODES.EQ.1) GO TO 7096
GO TO 7098
7096 ALFAC=0.0
BETAC=1.0
GAMMAC=0.0
DELTAC=1.0
IF(U(N,M).GT.0.0) ALFAC=1.0
IF(U(N,M).GT.0.0) BETAC=0.0
IF(V(N,M).GT.0.0) GAMMAC=1.0
GO TO 7099
C NEXT TIME I WILL CHANGE A1,A2,B1,B2 TO = 1.
7098 A1=1.
A2=1.
C B1 = B2 = 1.02
ALFAC=.5
BETAC=.5
GAMMAC=.5
DELTAC=.5
B1 = 0.
B2 = 0.
7099 CONTINUE
IF(N.EQ.NS(NZ).OR.M.EQ.MS(NZ)) GO TO 510
GO TO 520
510 CONTINUE
IF(M.EQ.MS(NZ)) GO TO 512
GO TO 515
512 CONTINUE
IF(NNN.EQ.NS(NZ).AND.V(N,M).GT.0.0) GAMMAC=1.0
IF(NN.EQ.NS(NZ).AND.V(N,M).LT.0.0) DELTAC=1.0
IF(N.EQ.NS(NZ)) GO TO 514
GO TO 520
514 IF(U(N,M).GT.0.0) BETAC=0.0
IF(U(N,M).LT.0.0) ALFAC=0.0
IF(V(N,M).LT.0.0) DELTAC=0.0

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00006100
0J006200
00006300
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0J006600
00006700
00006800
00006900
00007000
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00009000
00009100
00009200
00009300
00009400
00009500
0J009600
0J009700
00009800
00009850
00009900
00010000
00010100
00010200
0J010300
00010400
00010500
00010600
00010700
00010800
00010900
00011000
00011100

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      IF (V(N,M).LT.0.0) GAMMAC=0.0
      GO TO 520
515  IF (MM.EQ.MS(NZ).AND.U(N,M).LT.0.0) RETAC=1.0
      IF (MM.EQ.MS(NZ).AND.U(N,M).GT.0.0) ALFAC=1.0
520  CONTINUE
230  CONTINUE
C
      TEMP1=(.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM)))*SEP(N,M))*C13
      TEMP2=(.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM)))*SE(N,M))*C13
      TEMP3=.5*(H(NN,M)+H(NN,MM)+SE(N,M)+SE(NN,M))
      TEMP4=.5*(H(N,M)+H(N,MM)+SE(N,M)+SE(NNN,M))
      TEMP5=.5*(H(N,MM)+H(NN,MM)+SE(N,M)+SE(N,MM))
      TEMP6=.5*(H(N,M)+H(NN,M)+SE(N,M)+SE(N,MM))
      TEMP7=.5*(H(NN,M)+H(NN,MM)+SEP(N,M)+SEP(NN,M))
      TEMP8=.5*(H(N,M)+H(N,MM)+SEP(NN,M)+SEP(N,M))
C
      DYNM=C7*ABS(VP(N,M))*TEMP8/(.5*(C(N,M)+C(NNN,M)))*C10
      DYNM=C7*ABS(VP(NN,M))*TEMP8/(.5*(C(N,M)+C(NN,M)))*C10
      DXNM=C7*ABS(U(N,M))*TEMP6/(.5*(C(N,M)+C(N,MM)))*C10
      DXNM=C7*ABS(U(N,MM))*TEMP5/(.5*(C(N,M)+C(N,MM)))*C10
      DYNM=DYNM*UPCON
      DYNM=DYNM*UPCON
      DXNM=DXNM*UPCON
      DXNM=DXNM*UPCON
C
      TEMP20=TEMP3*A2*VP(NN,M)*C8
      TEMP21=TEMP4*A2*VP(N,M)*C8
      TEMP22=TEMP4*A2*VP(N,M)*C8
      TEMP23=TEMP5*OYNM*C9
      TEMP24=TEMP5*A1*U(N,MM)*C8
      TEMP25=TEMP5*DXNM*C9
      TEMP26=TEMP6*A1*U(N,M)*C8
      TEMP27=TEMP6*DXNM*C9
C
      TEMP30=SEP(NNN,M)
      IF (TEMP30.EQ.0.) TEMP30=2.*SEP(N,M)-SEP(NN,M)
      TEMP31=SEP(NN,M)
      IF (TEMP31.EQ.0.) TEMP31=2.*SEP(N,M)-SEP(NNN,M)
      TEMP32=SE(N,MM)
      IF (TEMP32.EQ.0.) TEMP32=2.*SE(N,M)-SE(N,MM)
      TEMP33=SE(N,MM)
      IF (TEMP33.EQ.0.) TEMP33=2.*SE(N,M)-SE(N,MM)
C
      P(N)=-(1.-DELTAC)*TEMP20+TEMP21
      Q(N)=TEMP1+GAMMAC*TEMP22+TEMP23-DELTAC*TEMP20+TEMP21
1    -B2*C14*(VP(NN,M)+VP(N,M))*(TEMP30-TEMP31)
      R(N)=(1.-GAMMAC)*TEMP22-TEMP23
      S(N)=-CN(N,MM)*(1.-BETAC)*TEMP24+TEMP25
1    +CN(N,M)*(-TEMP2+ALFAC*TEMP26-BETAC*TEMP24+TEMP27+TEMP25)
2    -B1*C14*(U(N,M)+U(N,MM))*(TEMP32-TEMP33)
3    +CN(N,MM)*(1.-ALFAC)*TEMP26-TEMP27
1806 CONTINUE

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00011200
00011300
00011400
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00015000
00015100
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00015300
00015400
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00015600
00015700
00015800
00015900
00016000
00016100
00016200
00019900

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      INS=NS(NINPUT)
      IMS=MS(NINPUT)
      IF (INS(NZ).EQ.N.AND.MS(NZ).EQ.M) GO TO 525
      GO TO 530
525  S(N) = S(N)-SS(NZ)*(TIN + CNP(INS,IMS))
      NPLUS=NPRINT(IP) -29
      IF (NST.EQ.NPLUS) GO TO 1903
      IF (NST.EQ.1) GO TO 1903
      GO TO 1904
1903 ISUM=0.0
      SDXNM=0.0
      SDYNM=0.0
      SDXNM=0.0
      SDYNM=0.0
1904 SDXNM=SDXNM+DXNM
      SDYNM=SDYNM+DYNM
      SDXNM=SDXNM+DXNM
      SDYNM=SDYNM+DYNM
      ISUM=ISUM+1
1907 IF (NST.EQ.NPRINT(IP)) GO TO 1909
      IF (NST.EQ.MAXST) GO TO 1909
      GO TO 1908
1909 SDYNM=SDYNM/ISUM
      SDXNM=SDXNM/ISUM
      SDYNM = SDYNM/ISUM
      SDXNM = SDXNM/ISUM
      ANS=NS(NZ)
      MMS=MS(NZ)
      WRITE(6,7121) NNS,MMS,SDXNM,SDYNM,SDXNM,SDYNM
7121 FORMAT(5X, 'AV. DIFFUSION COEF IS',3X,'DXNM(',12,' ',12,' ) = ',
      1E12.4,3X, 'DYNM = ',1E12.4,3X,'DXNM = ',1E12.4,3X, 'DYNM = ',
      2E12.4)
1908 CONTINUE
530 CONTINUE
      IF (N.EQ.INS.AND.M.EQ.IMS) GO TO 526
      GO TO 527
526  S(N) = S(N)+SS(NZ)*CNP(INS,IMS)
      NZ=NZ+1
527 CONTINUE
C
C   HEAT EXCHANGE CALCULATIONS
C
      EXTRAL = EXTRAL + 1.
      IF (EXTRAL.EQ.44.) GO TO 1730
      GO TO 1732
1730 SAVE = S(N)
1732 IF (EXTRAL.EQ.2.) GO TO 3035
      GO TO 1508
3035 CONTINUE
C   MORE TEMP CALCULATIONS YEA AAAA
      IF (NST.EQ.NPRINT(IP)) GO TO 1500
      IXA = NPRINT(IP) - 15

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00020200
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00020450
00020460
00020500
00020600
00020700
00020800
00020900
00021000
00021100
00021200
00021300
00021400
00021500
00021600
00021900
00021950
00022000
00022100
00022200
00022300
00022400
00022500
00022600
00022700
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00022900
00023000
00023100
00023200
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      IF (INST.EQ.1XA) GO TO 1500
      GO TO 1508
1500 IF (INST.EQ.1) GO TO 15C2
      GO TO 1506
1502 TWBAY=TBND
      TEQ=TBND
      TEQ=1.8*TEQ + 32.
1506 CONTINUE
      CALL WATIND(IDY,AT,PI,DAY,TBND,TA,WA,WB,WC,WFACT,RH,
1CLOCVR,ANG, EXTRA1,TIME, BC,HA,EA,PMH,NST,EXTRA2,THR,THIN)
1515 TW=(CNP(11,17)+ CNP(9,27)+CNP(6,26)+CNP(8,37)+CNP(13,37))/5.
      CALL WATDEP(TBND,TA,TW,EA,BH,ES,EXTRA3,SUMONE,HE,HC,S,
      HTOT,EXTRA4,N,NST, IDY,WA,WB,WC,WFACT,HA,ANG,TEMP5,TEMP6,DELTA1)
1508 CONTINUE
      CALL AZ(ZONE1,ZONE2,ZCNE3,ZONE4,ZONE5,ZONE6,TWBAY,NMAX,MHAX,NST,
C      IKRT)
      TWBAY = 1.0
      WC = ABS(WA*COS(ANG/57.1))
      IF (TEQ.LE.70.) GO TO 25
      GO TO 30
25 BETA = .5553
      CBETA = -20.15
      GO TO 40
30 BETA = .7774
      CBETA = -33.60
40 CONTINUE
      SUMCNE = 73. + 7.3*((WC**2+WB**2)**.5)*WFACT
      X = 15.7 + (0.26+BETA)*SUMONE
      EE = ES
      TA=1.8*TA + 32.
      TW=TW+1.8 + 32.
      SIGN1 = EE-EA
      IF (SIGN1.LE.0.) SIGN1=0.0
      HR = 1801.+(TEQ/460.+1.)*.4 + SUMONE*(SIGN1) +.26*SUMONE*(TEQ-TA)
      TEQ = (HR-1801.)/X+(X-15.7)/X*(.26*TA/(0.26+BETA)+(EA-CBETA)/
      1(.26+BETA))
      HTEQ = -(15.7 + (.26+BETA)*(SUMONE))*(TW-TEQ) - .05*(TW**2+TEQ**2)
      TA=(TA-32.)*5./9.
      TW=(TW-32.)*5./9.
      HTQE = HTEQ/(64.*24.*3600.*3.)
      HTQE=HTQE*5.0/9.0
      IF (INST.EQ.NPRINT(IP)) GO TO 1533
      IF (INST.EQ.1XA) GO TO 1533
      GO TO 1511
1533 CONTINUE
      IF (EXTRA1.NE.2.) GO TO 1511
1536 CONTINUE
      HTOT = HTOT+1.1
      WRITE(6,1535) BC,PMH,EA,WC, SUMONE, X, ES,HTOT,HA,BH,HE,HC,TW
C
C      1535 FORMAT(4X,' CALCULATED VALUES',3X,'BC = ',F6.2,3X, 'PMH = ',F6.2,
      13X, 'EA = ',F6.2,3X, 'WC = ',F6.2, 3X,'SUMONE = ',F6.2,3X,'X = ',F00030100

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26.2, ES = ,P6.2/,3X,HEAT EX VAL',2X,HTOT = ,E9.3,2X,HA = ,00030200
3E9.3,2X,BH = ,E9.3, 2X, HE = ,E9.3,2X,HC = ,E9.3, 2X, 00030300
4TW = ,E9.3) 00030400
1511 CONTINUE 00030500
C 00030600
C HEAT INPUT 00030700
C 00030800
C HEAT INPUT CONVERTED INTO TEMPERATURE 00030900
C 00031000
C HTOT=HTOT*1.1 00031200
HTPRBX=HTOT*(CNP(N,M)+.000001/NST)/(TW+.00010/NST) 00031300
HTPRBX=HTOT 00031350
S(N)=S(N) - HTPRBX 00031400
220 CONTINUE 00031500
IF(DGSAL) GO TO 1131 00031600
GO TO 214 00031700
1131 CONTINUE 00031800
A(NFF)=CNP(NFF,M) 00031900
IF(MSRCH.EQ.0) A(NFF)=0. 00032000
B(NFF)=0. 00032100
DO 232 N=NF,L 00032200
NN=N-1 00032300
F1=Q(N)-P(N)*B(NN) 00032400
A(N)=(-S(N)-P(N)*A(NN))/F1 00032500
B(N)=R(N)/F1 00032600
232 CONTINUE 00032700
CNP(L,M)=A(L)-R(L)*CNP(LL,M) 00032800
NX=L-NF 00032900
DO 233 J=1,NX 00033000
IF(MSRCH.EQ.0) CNP(L,M)=A(L) 00033100
N=L-J 00033200
NP=N+1 00033300
CNP(N,M)=A(N)-B(N)*CNP(NP,M) 00033400
233 CONTINUE 00033500
GO TO 214 00033600
210 CONTINUE 00033700
IF(1B.EQ.0) TEMPI=0. 00033800
IF(1B.EQ.2) TEMPI=VP(L,M) 00033900
IF(1B.EQ.1) GO TO 205 00034000
GO TO 209 00034100
205 TEMPI0=V(L,MMM) 00034200
IF(VIN,M).GT.0.0) GAMMAC=1.0 00034300
IF(TEMPI0.EQ.0.) TEMPI0= V(L,MM) 00034400
TEMPI1= V(L,MM) 00034500
IF(TEMPI1.EQ.0.) TEMPI1= V(L,MMM) 00034600
933 LLL=L+1 00034700
BETA =0. 00034800
LL =L-1 00034900
TEMP4=C2*BETA*(V(L,M)-V(LL,M)) 00035000
TEMPI=V(L,M)**2+(((UP(L,M)+UP(L,MM))**2)/16.) 00035100
TEMP2=(SEPI1,M)+SEP(LL,M)+H(L,MM)+H(L,M))*(C(L,M)+C(LL,M))**2 00035200
TEMP12=C6*NX**2/(SEP(NFF,M)+SEP(NF,M)+H(NFF,M)+H(NFF,MM)) 00035300

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SYSIN

NEW MASTER

TERUPDTF LOG PAGE 0016

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TEMP3=1.+C4*SQRT(TEMP1)/TEMP2+TEMP4+TEMP12      00035400
TEMP3=1./TEMP3      00035500
DELTA=0.5      00035600
TEMP1=.25*(AT*F(N)+(1.-DELTA)*C2*(TEMP10-V(L,M))+DELTA*C2*      00035700
1(V(L,M)-TEMP1))
TEMP1=TEMP3*(V(L,M)-TEMP1*(UP(L,M)+UP(L,MM)))      00035800
1-C1*(SE(LLL,M)-SE(L,M)))      00035900
209 VP(L,M)=TEMP1      00036000
GO TO 212      00036100
206 CONTINUE      00036200
IF(IA.EQ.0) TEMP1=0.      00036300
IF(IA.EQ.2) TEMP1=VP(NFF,M)      00036400
IF(IA.EQ.1) GO TO 207      00036500
GO TO 208      00036600
207 NFF=N-1      00036700
IF(V(N,M).LT.0.0) DELTAC=1.0      00036800
C TEMP10=V(NFF,MMM)      00036900
IF(TEMP10.EQ.0.) TEMP10= V(NFF,MM)      00037000
936 TEMP11=V(NFF,MM)      00037100
IF(TEMP11.EQ.0.) TEMP11= V(NFF,MMM)      00037200
938 BETA=1.      00037300
TEMP4=C2*(1.-BETA)*(V(NF,M)-V(NFF,M))      00037400
TEMP1=V(NFF,M)**2+((UP(NF,M)+UP(NF,MM))**2)/16.)      00037500
TEMP2=(SEP(NFF,M)+SEP(NF,M)+H(NFF,M)+H(NFF,MM))*      00037600
1(C(NF,M)+C(NFF,M))**2      00037700
TEMP3=1.+C4*SQRT(TEMP1)/TEMP2+TEMP4      00037800
TEMP3=1./TEMP3      00037900
DELTA=.5      00038000
TEMP1=.25*(AT*F(N)+(1.-DELTA)*C2*(TEMP10-V(NFF,M))      00038100
1 +DELTA*C2*(V(NFF,M)-TEMP1))      00038200
TEMP1=TEMP3*(V(NFF,M)-TEMP1*(UP(NF,M)+UP(NF,MM)))      00038300
1 -C1*(SE(NF,M)-SE(NFF,M)))      00038400
208 VP(NFF,M)=TEMP1      00038500
GO TO 211      00038600
214 NUM=NUM+1      00038700
GO TO 201      00038800
202 CONTINUE      00038900
RETURN      00039000
END      00039100

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1EB9161 MEMBER NAME (AVPMFH) FOUND IN AM DIRECTORY. TTH IS NOW ALTERED.

0/ CHANGE NAME=AUPNSH,LIST=ALL

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SUBROUTINE UPNSHT(C2, C6, WX, WY, C4, AT, D0SAL, TMODES, NSOURC, MSOURC, 00001000
1C13, C10, C7, C8, C9, C14, C1, NIND, F, NI, NST, NPRINT, IP, TBNB, KRT, 00001100
2NMAX, MMAX, IDY, PI, DAY, NS, MS, SS, QIN, TIN, NZ, THR, THIN, HTOT, NM, 00001200
3UPCCN, VAR1, NINPUT) 00001300
COMMON SE(21,48), SEP(21,48), V(21,48), VP(21,48), U(21,48), UPI(21,48), 00001400
1 C(21,48), N3D(85), M3D(85), M3D(4), N3D(4), H(21,48), 00001500
2 W(20), F2(20), Z(20), E(20), HP(20), EP(20), HB(20), EB(20), 00001600
3 ARN(20), ARGP(20), ARGH(20), ARGHB(20), HL(20), EL(20), 00001700
4 Z1A(0175), Z1B(0175), Z1C(0175), UAVG(21,48), VAVG(21,48), Z1E(0175), 00001800
5 ACOSMT(6), ASINMT(6), CN(21,48), CNP(21,48), 00001900
6 IFIELD(21,48), HS1(015), HS2(015), Z1D(0175), AA(0175), BB(0175) 00002000
DIMENS ION A(790), B(48), P(48), Q(48), R(48), S(48), F(48), 00002100
1KUNVRT(21), NH(21), NPRINT(200), OAVG(80), AHOLD(48), 00002200
2NS(10), MS(10), SS(10) 00002300
LOGICAL D0SAL 00002400
EXTRA1=1.0 00002500
NUM=1 00002600
NZ=1 00002700
340 IF(NUM.EQ.NIND) GO TO 402 00002800
1021 NSRCH=NBD(NUM)/1000000 00002900
N =NBD(NUM)/10000 -NSRCH*100 00003000
MF =NBD(NUM)/100-NSRCH*10000-N*100 00003100
L =NBD(NUM)-NSRCH*1000000-N*10000-MF*100 00003200
IA=NSRCH/10 00003300
IB=NSRCH-10*IA 00003400
NN=N-1 00003500
NNN=N+1 00003600
LL=L-1 00003700
LLL=L+1 00003800
MFF =MF-1 00003900
DO 420 M=MF,L 00004000
MMM=M+1 00004100
MM=M-1 00004200
C 00004300
DELTAC=.5 00004400
GAMMAC=.5 00004500
BETAC=.5 00004600
ALFAC=.5 00004700
IF(M.EQ.MF) GO TO 406 00004800
IF(M.EQ.L) GO TO 410 00004900
411 CONTINUE 00005000
ALPHA=0.5 00005100
TEMP4=C2*( (1.-ALPHA)*(U(N,MMM)-U(N,M)) +ALPHA*(U(N,M)-U(N,MM))) 00005200
TEMP1 =U(N,M)**2+((V(N,M)+V(N,MMM)+V(NN,M)+V(NN,MMM))**2)/16. 00005300
TEMP2=(SEP(N,M)+SEP(N,MMM)+H(N,M)+H(NN,M))*(C(N,M)+C(N,MMM))**2 00005400
TEMP12=C6*WY**2/(SEP(N,M)+SEP(N,MMM)+H(N,M)+H(NN,M)) 00005500
TEMP3=1.+C4*SQR(TEMP1)/TEMP2+TEMP4+TEMP12 00005600
TEMP3=1./TEMP3 00005700
GAMMA=0.5 00005800
TEMP10=U(NNN,M) 00005900
IF(TEMP10.EQ.D.) TEMP10= U(NN,M) 00006000

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978 TEMP11=U(NN,M)
 IF(TEMP11.EQ.0.) TEMP11= U(NNN,M)
 980 TEMP1=AT*F(N)-(1.-GAMMA)*C2*(TEMP10-U(N,M))
 1-GAMMA*C2*(U(N,M)-TEMP11)
 TEMP1=.25*TEMP1
 404 UP(N,M)=TEMP3*
 1 (U(N,M)+TEMP1*(VP(N,M)+VP(N,MMH)+VP(NN,M)+VP(NN,MMH))
 2- C1*(SE(N,MMH)-SE(N,M)))
 C COMPUTE CNP ON ROW N (FIRST HALF TIMESTEP)
 412 CONTINUE
 IF(COSAL) GO TO 413
 GO TO 423
 413 CONTINUE
 IF(MODES.EQ.1) GO TO 7196
 GO TO 7198
 7196 ALFAC=0.3
 BETAC=1.0
 GAMMAC=0.0
 DELTAC=1.0
 IF(U(N,M).GT.0.0) ALFAC=1.0
 IF(U(N,M).GT.0.0) BETAC=0.0
 IF(V(N,M).GT.0.0) GAMMAC=1.0
 IF(V(N,M).GT.0.0) DELTAC=0.0
 GO TO 7199
 7198 A1=1.0
 A2=1.0
 C CHANGED B1 AND B2
 ALFAC=.5
 BETAC=.5
 GAMMAC=.5
 DELTAC=.5
 B1 = 0.
 B2 = 0.
 7199 CONTINUE
 IF(N.EQ.NS(NZ).OR.M.EQ.MS(NZ)) GO TO 510
 GO TO 520
 510 CONTINUE
 IF(N.EQ.MS(NZ)) GO TO 512
 GO TO 515
 512 CONTINUE
 IF(NNN.EQ.NS(NZ).AND.V(N,M).GT.0.0) GAMMAC=1.0
 IF(NN.EQ.NS(NZ).AND.V(N,M).LT.0.0) DELTAC=1.0
 IF(N.EQ.NS(NZ)) GO TO 514
 GO TO 520
 514 IF(U(N,M).GT.0.0) BETAC=0.0
 IF(U(N,M).LT.0.0) ALFAC=0.0
 IF(V(N,M).LT.0.0) DELTAC=0.0
 IF(V(N,M).LT.0.0) GAMMAC=0.0
 GO TO 520
 515 IF(MM.EQ.MS(NZ).AND.U(N,M).LT.0.0) BETAC=1.0
 IF(MMM.EQ.MS(NZ).AND.U(N,M).GT.0.0) ALFAC=1.0
 520 CONTINUE

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 00009800
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430 CONTINUE

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C      TEMP1=(.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM))*SEP(N,M))*C13
      TEMP2=(.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM))*SE(N,M))*C13
      TEMP3=.5*(H(N,MM)+H(NN,MM)+SE(N,M)+SF(N,MM))
      TEMP4=.5*(H(N,M)+H(NN,M)+SE(N,M)+SE(N,MM))
      TEMP5=.5*(H(NN,M)+H(NN,MM)+SE(N,M)+SE(NN,M))
      TEMP6=.5*(H(N,M)+H(N,MM)+SE(N,M)+SE(NNN,M))
      TEMP7=.5*(H(N,MM)+H(NN,MM)+SEP(N,M)+SEP(N,MM))
      TEMP8=.5*(H(N,M)+H(NN,M)+SEP(N,M)+SEP(N,MM))

C      DXNM=C7*ABS(UP(N,M))*TEMP8/(.5*(C(N,M)+C(N,MM)))+C10
      DXNM=C7*ABS(UP(N,MM))*TEMP8/(.5*(C(N,M)+C(N,MM)))+C10
      DYNM=C7*ABS(V(N,M))*TEMP6/(.5*(C(N,M)+C(NNN,M)))+C10
      DYNM=C7*ABS(V(NN,M))*TEMP5/(.5*(C(N,M)+C(NN,M)))+C10
      DXNM=DXNM*UPCON
      DXNM=DXNM*UPCON
      DYNM=DYNM*UPCON
      DYNM=DYNM*UPCON

C      TEMP20=TEMP3*A1*UP(N,MM)*C8
      TEMP21=TEMP4*DXNM*C9
      TEMP22=TEMP4*A1*UP(N,M)*C8
      TEMP23=TEMP4*DXNM*C9
      TEMP24=TEMP5*A2*V(NN,M)*C8
      TEMP25=TEMP5*DYNM*C9
      TEMP26=TEMP6*A2*V(N,M)*C8
      TEMP27=TEMP6*DYNM*C9

C      TEMP30=SEP(N,MM)
      IF(TEMP30.EQ.0.) TEMP30=2.*SEP(N,M)-SEP(N,MM)
      TEMP31=SEP(N,MM)
      IF(TEMP31.EQ.0.) TEMP31=2.*SEP(N,M)-SEP(N,MM)
      TEMP32=SE(NNN,M)
      IF(TEMP32.EQ.0.) TEMP32=2.*SE(N,M)-SE(NN,M)
      TEMP33=SE(NN,M)
      IF(TEMP33.EQ.0.) TEMP33=2.*SF(N,M)-SE(NNN,M)

C      P(M)=((1.-BETAC)*TEMP20+TEMP21)
      Q(M)=TEMP1+ALFAC*TEMP22+TEMP23-BETAC*TEMP20+TEMP21-B1*C14*
1      (UP(N,MM)+UP(N,M))*(TEMP30-TEMP31)
      R(M)=((1.-ALFAC)*TEMP22-TEMP23
      S(M)=-CN(NN,M)*((1.-DELTAC)*TEMP24+TEMP25)
      1*CN(N,M)*(-TEMP2+GAMMAC*TEMP26-DELTAC*TEMP24+TEMP27+TEMP25
      2 -B2*C14*(V(N,M)+V(NN,M))*(TEMP32-TEMP33))
      3*CN(NNN,M)*((1.-GAMMAC)*TEMP26-TEMP27)

C      NOTE DISCOVERED ON 31 JULY 72 THAT LINE 0953/3 HAD CN(N,MM)
C      INSTEAD OF CN(NNN,M)
      INS=NS(NINPUT)
      IMS=MS(NINPUT)
      IF(NS(NZ).EQ.N.AND.M.EQ.MS(NZ)) GO TO 525
      GO TO 530

```

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00011100
00011200
00011300
00011400
00011500
00011600
00011700
00011800
00011900
00012000
00012100
00012200
00012300
00012400
00012500
00012600
00012700
00012800
00012900
00013000
00013100
00013200
00013300
00013400
00013500
00013600
00013700
00013800
00013900
00014000
00014100
00014200
00014300
00014400
00014500
00014600
00014700
00014800
00014900
00015000
00015100
00015200
00015300
00015400
00015500
00015600
00015700
00015800
00015900
00016000
00016100
00016200

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525 S(M) = S(M) - SS(NZ) * (TIM + CNP(INS,IMS))
530 CONTINUE
    IF(N.EQ.INS.AND.M.EQ.IMS) GO TO 526
    GO TO 527
526 S(M) = S(M) + SS(NZ) * CNP(INS,IMS)
    NZ=NZ+1
527 CONTINUE
C
    TW=(CNP(11,17)+CNP(9,27)+CNP(6,26)+CNP(8,37)+CNP(13,37))/5.
    HTPRBX=HTDT*(CN(N,M)+.000001/NST)/(TW+.00010/NST)
    HTPRBX=HTDT
    S(M)=S(M) - HTPRBX
420 CONTINUE
    IF(DOSAL) GO TO 1115
    GO TO 414
1115 CONTINUE
    A(MFF)=CNP(N,MFF)
    IF(INSRCH.EQ.0) A(MFF)=0.
    B(MFF)=0.
    DO 432 M=MF,L
        MM=M-1
        F1=C(M)-P(M)*B(MM)
        A(M)=-S(M)+P(M)*A(MM)/F1
        B(M)=R(M)/F1
432 CONTINUE
    CNP(N,L)=A(L)-B(L)*CNP(N,LLL)
    IF(INSRCH.EQ.0) CNP(N,L)=A(L)
    MX=L-MF
    DO 433 J=1,MX
        M=L-J
        MP=M+1
        CNP(N,M)=A(M)-B(M)*CNP(N,MP)
433 CONTINUE
    GO TO 414
410 CONTINUE
    IF(18.EQ.2) TEMP1=UP(N,L)
    IF(18.EQ.3) TEMP1=0.
    IF(18.EQ.1) GO TO 405
    GO TO 409
405 TEMP10=U(NNN,L)
    IF(U(N,M).GT.0.0) ALFAC=1.0
    IF(TEMP10.EQ.0.) TEMP10= U(NN,L)
1001 TEMP11=U(NN,L)
C
    INSERTED FOLLOWING TWO CARDS 24 AUG
    IF(TEMP11.EQ.0.) TEMP11=U(NNN,L)
    ALFA=0.
    TEMP4=C2*ALPHA*(U(N,L)-U(N,LL))
    TEMP1=U(N,L)**2+(((V(N,L)+V(NN,L))**2)/16.)
    TEMP2=(SEP(N,L)+SEP(N,LLL)+H(N,L)+H(NN,L))*(C(N,L)+C(N,LLL))**2
    TEMP12=SEP(N,L)+SEP(N,LLL)+H(N,L)+H(NN,L)
    TEMP12=C6*WY**2/TEMP12
    TEMP3=1.+C4*SQR(TEMP1)/TEMP2+TEMP4+TEMP12

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00016300
00016400
00016500
00016600
00016700
00016800
00016900
00017000
00017100
00017200
00017250
00017300
00017400
00017500
00017600
00017700
00017800
00017900
00018000
00018100
00018200
00018300
00018400
00018500
00018600
00018700
00018800
00018900
00019000
00019100
00019200
00019300
00019400
00019500
00019600
00019700
00019800
00019900
00020000
00020100
00020200
00020300
00020400
00020500
00020600
00020700
00020800
00020900
00021000
00021100
00021200
00021300

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SYSIN

NEW MASTER

ICRUPDTE LOG PAGE 0021

```

TEMP3=1./TEMP1
GAMMA=0.5
TEMP1=.25*(AT+F(N)-(1.-GAMMA)*C2*(TEMP10-U(N,L))-GAMMA*C2*
1(U(N,L)-TEMP11))
TEMP1 =TEMP3*(U(N,L)+TEMP1*(VP(N,L)+VP(NN,L)))
1-C1*(SE(N,LLL)-SE(N,L)))
409 UP(N,L)=TEMP1
GO TO 412
406 IF(IA.EQ.1) GO TO 407
IF(IA.EQ.2) TEMP1=UP(N,MFF)
IF(IA.EQ.0) TEMP1=0.
GO TO 408
407 MFF=M-1
C IF(U(N,M).LT.0.0) BETAC=1.0
TEMP10=U(NNN,MFF)
IF(TEMP10.EQ.0.) TEMP10= U(NN,MFF)
1006 TEMP11=U(NN,MFF)
IF(TEMP11.EQ.0.) TEMP11= U(NNN,MFF)
1008 ALPHA=1.
TEMP4=C2*(1.-ALPHA)*(U(N,MF)-U(N,MFF))
TEMP1=U(N,MFF)**2+((V(N,MF)+V(NN,MF))**2)/16.)
TEMP2=(SEP(N,MFF)+SEP(N,MF)+H(N,MFF)+H(NN,MFF))*(C(N,MF)+C(N,MFF)
1)**2
TEMP12=SEP(N,MFF)+SEP(N,MF)+H(N,MFF)+H(NN,MFF)
TEMP12=C6*WY**2/TEMP12
TEMP3=1.+C4*SQRT(TEMP11)/TEMP2+TEMP4 +TEMP12
TEMP3=1./TEMP3
GAMMA=0.5
TEMP1=.25*(AT+F(N)-(1.-GAMMA)*C2*(TEMP10-U(N,MFF))-GAMMA*C2*
1(U(N,MFF)-TEMP11))
TEMP1 =TEMP3*(U(N,MFF)+TEMP1*(VP(N,MF)+VP(NN,MF)))
1-C1*(SE(N,MF)-SE(N,MFF)))
408 UP(N,MFF)=TEMP1
GO TO 411
414 NUM=NUM+1
GO TO 340
402 CONTINUE
RETURN
END

```

IEB8161 MEMBER NAME (AUPNSH) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.

SYSTN

NEW MASTER

IEBUPDTE LOG PAGE 0022

// CHANGE NAME=AWTDEP,LIST=ALL
// NUMBER INCR=100,NEW1=1000

```

SUBROUTINE WATDEP(TBNB,TA,TW,EA,BH,ES,EXTRA3,SUMONE,HE,HC,S,      00001000
1HTOT,EXTRA4,N,NST,TCY,WA,WB,WC,WFACT,HA,ANG,TEMP5,TEMP6,DEL TAT) 00001100
COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),UI(21,48),UP(21,48),00001200
1C(21,48),NBD(85),MBC(85),MOBD( 4),NORBD( 4),H(21,48),      00001300
2      H(20),F2(20),Z(20),F(20),HP(20),EP(20),HB(20),EB(20),      00001400
3 ARN(20),ARGB(20),ARGB(20),ARGLB(20),HL(20),EL(20),      00001500
4 ZIA(0175),ZIB(0175),ZIC(0175),UAVG(21,48),VAVG(21,48),ZIE(0175),00001600
5 ACCSMT(6),ASINMT(6),CNI(21,48),CNP(21,48),      00001700
6 IFIFLU(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175) 00001800
DIMENSION S(48)      00001900
LOGICAL DELTAT      00002000
C      TEMP CALCUALTIONS      00002100
C      WB = WIND FROM Y DIRECTION      00002200
C      WC = WIND FROM X DIRECTION      00002300
WC = ABS(WA*COS(ANG/57.1))      00002400
WB = ABS(WA*SIN(ANG/57.1))      00002500
EXTRA4= 0.0      00002600
2969 TA=1.8*TA+32.      00002700
IF(DELTAT) GO TO 100      00002800
GO TO 200      00002900
100 TW = 1.8*TW      00003000
BH = .97*4.2E-8*4.0*(459.7+3)*TW      00003100
BETA = .67      00003200
SUMONE=11.4*WA      00003300
HE = SUMONE*BETA*TW      00003400
IF(HE.LT.0.0) HE=0.0      00003500
HC=.26*SUMONE*TW      00003600
HA = 0.0      00003700
ES=0.0      00003800
HS2(10Y) = 0.0      00003900
TW=TW*5.0/9.0      00004000
GO TO 300      00004100
200 A=457.9      00004200
TW= 1.8*TW+32.      00004300
BH=(.97*4.2E-8)*((TW+A )**4)      00004400
C      ES=99.-96.*COS(.14*((TW-30.)/50.)*33.+7.1/180.)      00004500
SUMCNE=73.+7.3*((WC**2+WB**2)**.5)*WFACT      00004600
SUMONE=11.4*WA      00004700
HC=.26*SUMONE*(TW-TA)      00004800
C      HE=SUMONE*(ES-EA)      00004900
SIGN = ES-EA      00005000
IF(SIGN.LT.0.0) HE=0.      00005100
TW=(TW-32.)*5.0/9.0      00005200
300 CONTINUE      00005300
HTOT = HS2(10Y) + HA - BH - HE -HC      00005400
HTOT = HTOT/164.*24.*3600.*3.      00005500
C      CONVERTING HTOT INTO DEG CENT      00005600
HTOT = HTOT*5.0/9.0      00005700
HTOT = HTOT*5.0/9.0      00005800
HTOT = HTOT*5.0/9.0      00005900

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SYSIN

NEW MASTER

IEBUPDTE LOG PAGE 0023

C

TA = (TA - 32.) * 5.0/9.0
RETURN
END

IEB0161 MEMBER NAME (AWTDEP) FOUND IN AM DIRECTORY. TTR IS NOW ALTERED.

00006000
00006100
00006200
00006300

// CHANGE NAME=AWTIND,LIST=ALL
 // NUMBER INCR=100,NEW1=1000

```

SUBROUTINE WATIND(ICY,AT,PI,DAY,TDNB,TA,WA,WH,W,WC,WFACT,RH,
ICLDCVR,ANG, EXTRAL,TIME, BC,HA,EA,PMH,NST,EXTRA2,THR,TMIN)
COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48),
IC(21,48),NB(185),MB(185),MOBD( 4),NORBD( 4),H(21,48),
2 W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),
3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),
4 ZIA(0175),ZIB(0175),ZIC(0175), UAVG(21,48),VAVG(21,48),ZIE(0175),
5 ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),
6 IFIELD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175)
725 READ(5,6JJ) TA,RH,HS2(1),WA,ANG,CLDCVR
600 FORMAT(6F5.1)
C GRM-CAL/CM**2 * .2 SCALE FACTOR DIVIDED BY .27 CONVERSION FACTOR
HS2(1) = HS2(1)*.745
C CONVERT TO BTU/FT**2 - DAY
HS2(1) = HS2(1)*24.
C FINALLY WE HAVE HS2(1) = HS2(1)*17.85
HS2(1) = HS2(1)*17.85
WRITE(6,65U) TA,RH,HS2(1),WA,ANG,CLDCVR
650 FORMAT( 2X, ' METEOROLOGICAL DATA READ IN (WATIND)',2X,'TA = ', F0002800
16.2,2X,'RH = ',F6.2,2X,'HS(1) = ',F8.2,2X,'WA = ',F6.2,2X,'ANG = '00002900
2 ',F6.2,2X,'CLDCVR = ',F6.2)
WA= WA*1.152
WA= WA*1.152
WFACT = 1.0
KTIK = 0
EXTRA2= 0.0
100 CONTINUE
IDY=1
HS1(IDY)=100.
GO TO 5300
C REMOVE IF NO SOLAR INPUT GO TO 5300
1540 KTIK = KTIK + 1
C INITIAL TIME = 7 OCLCK
IF(KTIK.GT.1) GO TO 2883
2872 TIMEX= THR+TMIN/60.0
2883 TIMEX= TIMEX+AT/3600.
2891 XONE = TIMEX- 7.0
IF(XONE.GT.0.) GO TO 2865
2865 IF(XONE.LT.12.) GO TO 2963
2963 D=HS1(IDY)/(1.7*(HS1(IDY)-100.)/350.)
G=2.*PI*(TIMEX-6.*11. +.2*EXP(-3.*(182.-ABS(DAY-182.))/182.)))
T= 24.*(1.-.2*COS(2.*PI*DAY/365.))
HS2(IDY)=D*SIN(G/T)
HS2(IDY)= 17.85*HS2(IDY)
C FIGURE SOLAR ENERGY INPUT ON PER HOUR BASIS, MULTIPLY BY 12 50
C YOU AVERAGE IN ON PER DAY BASIS
300 TA = TBNB + 10.*(SIN(3.14*(TIMEX-2.)/24.))*3
5300 CONTINUE
5214 IF(.NOT.(TA.GE.60.00.AND.TA.LE.79.99)) GO TO 5218
5215 PMH = 94.5-90.*COS(PI*((TA-30.)/70.)*51.+4.)/180.)

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SYSIN

NEW MASTER

IEDUPOTE LOG PAGE 0025

GO TO 5240	00006000
5218 IF (.NOT. (TA .GE. 80.00 .AND. TA .LE. 89.99)) GO TO 5222	00006100
5222 PMM = 94.5 - 90. * COS (PI * (((TA - 30.) / 70.) * 61. - 3.) / 180.))	00006200
5240 EA = (PMM - (((TA - 30.) / 70.) * 3.5 + 1.)) * (RH - 10.) / 90. + ((TA - 30.) / 70.) * 3.5 +	00006300
11.	00006400
BC = .74 - ((3.5 * (96. - TA) * 1.67) / 10 * ((4. + 3. * CLOCVR))	00006500
HA = (4.E-8) * ((TA + 460.) * 4) * (8C + .031 * (EA + .5))	00006600
TA = (TA - 32.) * 5.0 / 9.0	00006700
200 CONTINUE	00006800
RETURN	00006900
END	00007000

IE00161 MEMBER NAME (AWTIND) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.

// CHANGE NAME=AAZ,LIST=ALL
 // NUMBER INCR=100,NEW1=1000

```

SUBROUTINE AZ(ZONE1,ZONE2,ZONE3,ZONE4,ZONE5,ZONE6,TWBY,NMAX,MMAX,00001000
INST,KRT)                                00001100
COMMON SE(21,48),SEPI(21,48),VE(21,48),VP(21,48),UE(21,48),UPI(21,48),00001200
1C(21,48),NB(185),MRC(185),MODU( 4),NOBD( 4),HI(21,48),00001300
2 W(20),F2(20),Z(20),F(20),HPI(20),EPI(20),HMT(20),EB(20),00001400
3 ARN(20),ARGP(20),ARGR(20),ARGLB(20),HL(20),EL(20),00001500
4 Z(4(0175),Z1B(0175),ZIC(0175),UAVG(21,48),VAVG(21,48),ZIE(0175),00001600
5 ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),00001700
6 IFIELD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175)00001800
C TEMP OF BAY DETERMINATION FROM SIX ARBITRARY ZONES 00001900
ZONE1A = CNP( 7,38)+CNP( 7,37)+CNP( 7,40)+CNP( 7,41)+CNP( 7,42)+ 00002000
1CNP( 8,38)+CNP( 8,39)+CNP( 8,40)+CNP( 8,41)+CNP( 8,42)+CNP( 8,43)+00002100
2CNP( 8,44)+CNP( 8,45)+CNP( 8,46)+CNP( 8,47)+CNP( 8,48)+CNP( 9,38)+00002200
3CNP( 9,39)+CNP( 9,40)+CNP( 9,41)+CNP( 9,42)+CNP( 9,43)+CNP( 9,44)+00002300
4CNP( 9,45)+CNP( 9,46)+CNP( 9,47)+CNP( 9,48)+CNP(10,41)+CNP(10,42) 00002400
ZONE1B = CNP( 5,35)+CNP( 6,35)+CNP( 6,36)+CNP( 6,37)+CNP( 7,35)+ 00002500
1CNP( 7,36)+ CNP( 7,37)+CNP( 8,35)+CNP( 8,36)+CNP( 8,37)+00002600
2CNP( 9,35)+CNP( 9,36)+CNP( 9,37) 00002700
ZONE1C = CNP( 4,33)+CNP( 4,34)+CNP( 5,32)+CNP( 5,33)+CNP( 5,34)+ 00002800
1CNP( 6,32)+CNP( 6,33)+CNP( 6,34)+CNP( 7,31)+CNP( 7,32)+CNP( 7,33)+00002900
2CNP( 7,34)+CNP( 8,31)+CNP( 8,32)+CNP( 8,33)+CNP( 8,34)+CNP( 9,31)+00003000
3CNP( 9,32)+CNP( 9,33)+CNP( 9,34) 00003100
ZONE1 = (ZONE1A/29. + ZONE1B/13. + ZONE1C/20. )/3.00 00003200
ZONE2A = CNP(11,45)+CNP(11,46)+CNP(11,47)+CNP(11,48)+CNP(12,44)+ 00003300
1CNP(12,45)+CNP(12,46)+CNP(12,47)+CNP(12,48)+CNP(13,40)+CNP(13,41)+00003400
2CNP(13,42)+CNP(13,43)+CNP(13,44)+CNP(13,45)+CNP(13,46)+CNP(13,47)+00003500
3CNP(13,48)+CNP(14,40)+CNP(14,41)+CNP(14,42)+CNP(14,43)+CNP(14,44)+00003600
4CNP(15,40)+CNP(15,41)+CNP(15,42)+CNP(15,43) 00003700
ZONE2B = CNP(10,31)+CNP(10,32)+CNP(11,31)+CNP(11,32)+CNP(11,33)+ 00003800
1CNP(11,34)+CNP(12,31)+CNP(12,32)+CNP(12,33)+CNP(12,34)+CNP(12,35)+00003900
2CNP(12,36)+CNP(12,37)+CNP(12,38)+CNP(12,39)+CNP(13,31)+CNP(13,32)+00004000
3CNP(13,33)+ CNP(13,34)+CNP(13,35)+CNP(13,36)+CNP(13,37)+00004100
4CNP(13,38)+CNP(13,39)+CNP(14,31)+CNP(14,32)+CNP(14,33)+CNP(14,34)+00004200
5CNP(14,35)+CNP(14,36)+CNP(14,37)+ CNP(14,38)+CNP(14,39)+00004300
6CNP(15,31)+CNP(15,32)+CNP(15,33)+CNP(15,34)+CNP(15,35)+CNP(15,36)+00004400
7CNP(15,37)+CNP(16,31)+CNP(16,32)+CNP(16,33)+CNP(17,31) 00004500
ZONE2 = (ZONE2A/27. + ZONE2B/44. )/2.00 00004600
ZONE3A = CNP( 6,26)+CNP( 6,27)+CNP( 6,28)+CNP( 6,29)+CNP( 7,26)+ 00004700
1CNP( 7,27)+CNP( 7,28)+CNP( 7,29)+CNP( 7,30)+CNP( 8,26)+CNP( 8,27)+00004800
2CNP( 8,28)+CNP( 8,29)+CNP( 8,30)+CNP( 9,26)+CNP( 9,27)+CNP( 9,28)+00004900
3CNP( 9,29)+CNP( 9,30)+CNP(10,26)+CNP(10,27)+CNP(10,28)+CNP(10,29)+00005000
4CNP(10,30)+CNP(11,26)+CNP(11,27)+CNP(11,28)+CNP(11,29)+CNP(11,30)+00005100
5CNP(12,26)+CNP(12,27)+CNP(12,28)+CNP(12,29)+CNP(12,30) 00005200
ZONE3B = CNP( 2,20)+CNP( 2,21)+CNP( 2,22)+CNP( 3,20)+CNP( 3,21)+ 00005300
1CNP( 3,22)+CNP( 4,20)+CNP( 4,21)+CNP( 4,22)+CNP( 5,20)+CNP( 5,21)+00005400
2CNP( 5,22)+CNP( 5,23)+CNP( 5,24)+CNP( 6,21)+CNP( 6,22)+CNP( 6,23)+00005500
3CNP( 6,24)+CNP( 6,25)+CNP( 7,22)+CNP( 7,23)+CNP( 7,24)+CNP( 7,25)+00005600
4CNP( 8,22)+CNP( 8,23)+CNP( 8,24)+CNP( 8,25)+CNP( 9,22)+CNP( 9,24)+00005700
5CNP( 9,25 )+CNP(10,25) 00005800
ZONE3 = (ZONE3A/34. + ZONE3B/31. )/2.00 00005900

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ZONE4 = CNP(14,21)+CNP(14,23)+CNP(14,24)+CNP(14,25)+CNP(15,20)+ 00006000
1CNP(15,21)+CNP(15,22)+CNP(15,23)+CNP(15,24)+CNP(15,25)+CNP(15,26)+00006100
2CNP(15,27)+CNP(15,28)+CNP(15,29)+CNP(15,30)+CNP(16,20)+CNP(16,21)+00006200
3CNP(16,22)+CNP(16,24)+CNP(16,25)+CNP(16,26)+CNP(16,27)+CNP(16,28)+00006300
4CNP(16,29)+CNP(16,30)+CNP(17,21)+CNP(17,22)+CNP(17,23)+CNP(17,24)+00006400
5CNP(17,25)+CNP(17,26)+CNP(17,27)+CNP(17,28)+CNP(17,29)+CNP(17,30)+00006500
6CNP(18,23)+CNP(18,24)+CNP(19,23)+CNP(19,24) 00006600
ZONE4 = ZONE4/39. 00006700
ZONE5A = CNP( 8,16)+CNP( 8,17)+CNP( 8,18)+CNP( 8,19)+CNP( 8,20)+ 00006800
1CNP( 8,21)+CNP( 9,14)+CNP( 9,15)+CNP( 9,16)+CNP( 9,17)+CNP( 9,18)+00006900
2CNP( 9,19)+CNP( 9,20)+CNP( 9,21)+CNP(10,14)+CNP(10,15)+CNP(10,16)+00007000
3CNP(10,17)+CNP(10,18)+ CNP(10,19)+CNP(10,20)+CNP(10,21) 00007100
ZONE5B = CNP(11,14)+CNP(11,15)+CNP(11,16)+CNP(11,17)+CNP(11,18)+ 00007200
1CNP(11,19)+CNP(11,20)+CNP(11,21)+CNP(11,22)+CNP(12,14)+CNP(12,15)+00007300
2CNP(12,16)+CNP(12,17)+CNP(12,18)+CNP(12,19)+CNP(12,20)+CNP(12,21)+00007400
3CNP(12,22)+CNP(12,23)+CNP(12,24)+CNP(13,16)+CNP(13,17)+ 00007500
4CNP(13,18)+ CNP(13,19)+CNP(13,20)+CNP(13,21)+CNP(13,22)+00007600
5CNP(13,23)+CNP(13,24) 00007700
ZONE5 = (ZONE5A/22. + ZONE5B/29.)/2.00 00007800
ZONE6 = CNP( 2,4 )+CNP( 2,5 )+CNP( 3,1 )+CNP( 3,2 )+CNP( 3,3)+ 00007900
1CNP( 3,4)+CNP( 3,5 )+CNP( 3,6 )+CNP( 4,1)+CNP( 4,2)+CNP( 4,3)+00008000
2CNP( 4,6)+CNP( 4,7)+CNP( 4,8)+CNP( 4,9)+CNP( 4,10)+CNP( 4,11)+00008100
3CNP( 5,7)+CNP( 5,8 )+CNP( 5,9)+CNP( 5,10)+CNP( 5,11)+CNP( 6,9)+00008200
4CNP( 6,10)+CNP( 6,11)+CNP( 6,12)+CNP( 6,13)+CNP( 6,14)+CNP( 7,12)+00008300
5CNP( 7,13)+CNP( 7,14)+CNP( 7,15)+CNP( 8,12)+CNP( 8,13)+CNP( 8,14)+00008400
6CNP( 8,15) 00008500
ZONE6 = ZONE6/36. 00008600
TWDAY = (ZONE1*62. + ZONE2*71. + ZONE3*65. + ZONE4*39. + ZONE5*51.+00008700
1ZONE6*36.)/324. 00008800
SUM = 0.0 00008900
DO 10 M=1,MMAX 00009000
DO 10 N=2,MMAX 00009100
IF( IFIELD(N,M).EQ.0) GO TO 10 00009200
NN = N-1 00009300
MM = M-1 00009400
IF(M.EQ.1) MM=M 00009500
SUM = SUM + CNP(N,M)*((H(N,M) +H(NN,M) +H(NN,MM)+ H(N,MM))*-.25 + 00009600
1SEP(N,M)) 00009700
IF( INST.GT.1) GO TO 300 00009800
300 CONTINUE 00009900
10 CONTINUE 00010000
IF( KRT.EQ.0) GO TO 400 00010100
400 CONTINUE 00010200
RETURN 00010300
END 00010400

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IE88161 MEMBER NAME (AAZ) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.

SYSIN

NEW MASTER

IEBUPOTE LOG PAGE 0028

./ CHANGE NAME=ADIVE,LIST=ALL

```

C  SUBROUTINE CIVE                                00001000
    SUBROUTINE CIVE(NMAX,MMAX)                    00001100
    COMMON SE(21,48),SEPI(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48), 00001200
    1C(21,48),NBD(85),MBD(85),MOBD( 4),NOBD( 4),H(21,48), 00001300
    2 W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20), 00001400
    3 ARN(20),ARGP(20),ARGH(20),ARGLB(20),HL(20),EL(20), 00001500
    4 ZIA(0175),ZIB(0175),ZIC(0175),UAVG(21,48),VAVG(21,48),ZIE(0175), 00001600
    5 ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48), 00001700
    6 IFIELD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175) 00001800
    DIMENSION NO(40) 00001900
    WRITE(6,5) 00002000
    DO 1 N=1,NMAX 00002100
    TNI=SN1/CS1 00002200
    1 NO(N)=N 00002300
    WRITE(6,6) M,(NO(N),N=1,NMAX) 00002400
    DO 2 M=1,MMAX 00002500
    READ(5,3) (IFIELD(N,M),N=1,NMAX) 00002600
    DO 10 N=1,NMAX 00002700
    NBD(N)=IFIELD(N,M) 00002800
    IF(NBD(N).EQ.2) NBD(N)=0 00002900
    10 CONTINUE 00003000
    WRITE(6,4) M,(NBD(N),N=1,NMAX) 00003100
    DO 2 N=1,NMAX 00003200
    2 H(N,M)=FLOAT(NBD(N)) 00003300
    RETURN 00003400
    3 FORMAT(32I2) 00003500
    4 FORMAT(1H ,12,3X,32I2) 00003600
    5 FORMAT(1H1,10X,21H WATER LEVELS IN FIELD) 00003700
    6 FORMAT(1H0,2H M,3X,32I2) 00003800
    END 00003900

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IEB8161 MEMBER NAME (ADIVE) FOUND IN AM DIRECTORY. TTR IS NOW ALTERED.

./ CHANGE NAME=APLOT,LIST=ALL

```

C SUBROUTINE PLOT(NO,A,N,M,NL,NS) 00001000
C COMMON SE(21,48),SEP(21,48),VI(21,48),VP(21,48),UI(21,48),UP(21,48),00001100
1 C(21,48),NBD(85),MPD(85),MODD(4),NOBD(4),H(21,48),00001200
2 W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),00001300
3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),00001400
4 ZIA(0175),ZIB(0175),ZIC(0175),UAVG(21,48),VAVG(21,48),ZIE(0175),00001500
5 ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),00001600
6 IFIFLU(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175) 00001700
C ..... 00001800
C ..... 00001900
C ..... 00002000
C SUBROUTINE PLOT 00002100
C ..... 00002200
C PURPOSE 00002300
C PLOT SEVERAL CROSS-VARIABLES VERSUS A BASE VARIABLE 00002400
C ..... 00002500
C USAGE 00002600
C CALL PLOT (NO,A,N,M,NL,NS) 00002700
C ..... 00002800
C DESCRIPTION OF PARAMETERS 00002900
C NO - CHART NUMBER (3 DIGITS MAXIMUM) 00003000
C A - MATRIX OF DATA TO BE PLOTTED. FIRST COLUMN REPRESENTS 00003100
C BASE VARIABLE AND SUCCESSIVE COLUMNS ARE THE CROSS- 00003200
C VARIABLES (MAXIMUM IS 9). 00003300
C N - NUMBER OF ROWS IN MATRIX A 00003400
C M - NUMBER OF COLUMNS IN MATRIX A (EQUAL TO THE TOTAL 00003500
C NUMBER OF VARIABLES). MAXIMUM IS 10. 00003600
C NL - NUMBER OF LINES IN THE PLOT. IF 0 IS SPECIFIED, 50 00003700
C LINES ARE USED. 00003800
C NS - CODE FOR SORTING THE BASE VARIABLE DATA IN ASCENDING 00003900
C ORDER 00004000
C 0 SORTING IS NOT NECESSARY (ALREADY IN ASCENDING 00004100
C ORDER). 00004200
C 1 SORTING IS NECESSARY. 00004300
C ..... 00004400
C REMARKS 00004500
C NONE 00004600
C ..... 00004700
C SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED 00004800
C NONE 00004900
C ..... 00005000
C ..... 00005100
C ..... 00005200
C DIMENSION OUT(101),YPR(11),ANG(9),A(1) 00005300
C ..... 00005400
1 FORMAT(//////////,60X,7H CHART ,13,//////////) 00005500
2 FORMAT(1H ,F11.4,5X,101A1) 00005600
3 FORMAT(1H ) 00005700
4 FORMAT(10H 123456789) 00005800
5 FORMAT(10A1) 00005900
7 FORMAT(1H ,16X,101H. . . . .) 00006000

```

	1	00006100
	8 FORMAT(1H0,9X,11F10.4)	00006200
C		00006300
C		00006400
C		00006500
	ALL=NL	00006600
	IOUM = N*M	00006700
C		00006800
	IF(NS) 16, 16, 10	00006900
C		00007000
C	SORT BASE VARIABLE DATA IN ASCENDING ORDER	00007100
C		00007200
	10 DO 15 I=1,N	00007300
	DO 14 J=1,N	00007400
	IF(A(I)-A(J)) 14, 14, 11	00007500
	11 L=I-N	00007600
	LL=J-N	00007700
	DO 12 K=1,M	00007800
	L=L+N	00007900
	LL=LL+N	00008000
	F=A(L)	00008100
	A(LL)=A(LL)	00008200
	12 A(LL)=F	00008300
	14 CONTINUE	00008400
	15 CONTINUE	00008500
C		00008600
C	TEST NLL	00008700
C		00008800
	16 IF(NLL) 20, 18, 20	00008900
	18 NLL=50	00009000
C		00009100
C	PRINT TITLE	00009200
C		00009300
	20 WRITE(6,1)NO	00009400
C		00009500
C	DEVELOP BLANK AND DIGITS FOR PRINTING	00009600
C		00009700
	REWIND 13	00009800
	WRITE (13,4)	00009900
	REWIND 13	00010000
	READ (13,5) BLANK,(ANG(I),I=1,9)	00010100
	REWIND 13	00010200
C		00010300
C	FIND SCALE FOR BASE VARIABLE	00010400
C		00010500
	XSCAL=(A(N)-A(1))/(FLOAT(NLL-1))	00010600
	WRITE(6,100) XSCAL	00010700
	100 FORMAT(9X,'XSCAL = ',E12.4)	00010800
C		00010900
C	FIND SCALE FOR CROSS-VARIABLES	00011000
C		00011100
	M1=N+1	00011200

	YMIN=A(M1)	00011300
	YMAX=YMIN	00011400
	M2=M*N	00011500
	DO 40 J=M1,M2	00011600
	IF(A(J)-YMIN) 28,26,26	00011700
26	IF(A(J)-YMAX) 40,40,30	00011800
28	YMIN=A(J)	00011900
	GO TO 40	00012000
30	YMAX=A(J)	00012100
40	CONTINUE	00012200
	YSCAL=(YMAX-YMIN)/100.0	00012300
	WRITE(6,110) YSCAL	00012400
110	FORMAT(5X,'YSCAL = ',E12.4,//)	00012500
C		00012600
C	FIND BASE VARIABLE PRINT POSITION	00012700
C		00012800
	XB=A(1)	00012900
	L=1	00013000
	MY=M-1	00013100
	I=1	00013200
45	F=1-1	00013300
	XPR=XB+F*XSCAL	00013400
	IF(A(L)-XPR) 50,50,70	00013500
C		00013600
C	FIND CROSS-VARIABLES	00013700
C		00013800
50	DO 55 IX=1,101	00013900
55	OUT(IX)=BLANK	00014000
	DO 60 J=1,MY	00014100
	LL=L+J*N	00014200
	JP=((A(LL)-YMIN)/YSCAL)+1.0	00014300
	OUT(JP)=ANG(J)	00014400
60	CONTINUE	00014500
C		00014600
C	PRINT LINE AND CLEAR, OR SKIP	00014700
C		00014800
	WRITE(6,2)XPR,(OUT(IZ),IZ=1,101)	00014900
	L=L+1	00015000
	GO TO 80	00015100
70	WRITE(6,3)	00015200
80	I=I+1	00015300
	IF(I-NLL) 45, 84, 86	00015400
84	XPR=A(N)	00015500
	GO TO 50	00015600
C		00015700
C	PRINT CROSS-VARIABLES NUMBERS	00015800
C		00015900
86	WRITE(6,7)	00016000
	YPR(1)=YMIN	00016100
	DO 90 KN=1,9	00016200
90	YPR(KN+1)=YPR(KN)+YSCAL*10.0	00016300
	YPR(11)=YMAX	00016400

SYSIN

NEW MASTER

IEBUPDTE LOG PAGE 0032

WRITE(6,81)PR(IP),IP=1,11)
RETURN
END

IEB8161 MEMBER NAME (APLOT) FOUND IN NM DIRECTORY. YTR IS NOW ALTERED.

00016500
00016600
00016700

// CHANGE NAME=ADISPLY,LIST=ALL

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SUBROUTINE DISPLY(NST,MAXST,TBNB,ZIF,ZIG,ZIH,IPRIND)      00001000
COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),UI(21,48),UP(21,48),00001100
1C(21,48),NH0(85),M8C(85),MORD1 4),NOBD1 4),H(21,48),      00001200
2      W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),      00001300
3  ARN(20),ARGP(20),ARGB(20),ARCLB(20),HL(20),EL(20),      00001400
4  ZIA(0175),ZIB(0175),ZIC(0175),UAVG(21,48),VAVG(21,48),ZIE(0175),00001500
5  ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),      00001600
6  IFIELD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175)      00001700
DIMENSION T536(125),T636(125), T637(125),T535(125),T635(125),      00001800
1T735(125), T736(125),T737(125), T534(125),T634(125), T734(125),      00001900
2T834(125), T835(125), T836(125),T837(125),T838(125),A(1250),      00002000
3ZIF(1),ZIG(1),ZIH(1)      00002100
C      00002200
C      INNER TEMPERATURES AROUND ROME PT      00002300
C      00002400
      NHOLD=NST      00002500
      IF(NST.EQ.1) MD=1      00002600
410 CONTINUE      00002700
      IF(MOD(NST,IPRIND).EQ.0) GO TO 409      00002800
      GO TO 600      00002900
409 NST=MD      00003000
      IF(TBNB.EQ.0.00001) TBNB=1.0      00003100
      T536(NST)=CNP(5,36)/TBNB      00003200
      T636(NST)=CNP(6,36)/TBNB      00003300
      T637(NST)=CNP(6,37)/TBNB      00003400
      T535(NST)=CNP(5,35)/TBNB      00003500
      T635(NST)=CNP(6,35)/TBNB      00003600
      T735(NST)=CNP(7,35)/TBNB      00003700
      T736(NST)=CNP(7,36)/TBNB      00003800
      T737(NST)=CNP(7,37)/TBNB      00003900
C      00004000
C      OUTER TEMPERATURES AROUND ROME PT      00004100
      T534(NST)=CNP(5,34)/TBNB      00004200
      T534(NST)=CNP(5,34)/TBNB      00004300
      T634(NST)=CNP(6,34)/TBNB      00004400
      T734(NST)=CNP(7,34)/TBNB      00004500
      T834(NST)=CNP(8,34)/TBNB      00004600
      T835(NST)=CNP(8,35)/TBNB      00004700
      T836(NST)=CNP(8,36)/TBNB      00004800
      T837(NST)=CNP(8,37)/TBNB      00004900
      T838(NST)=CNP(8,38)/TBNB      00005000
      MD=MD+1      00005100
C      00005200
C      00005600
      IF(NHOLD.EQ.MAXST) GO TO 301      00005700
      GO TO 400      00005800
301 CONTINUE      00005900
      ND= 1      00006000
      M=9      00006100
      N=NST      00006200
      NL=NST      00006300

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NS=0
DO 100 N=1,NST
N1=NST+N
N2=NST+2+N
N3=NST+3+N
N4=NST+4+N
N5=NST+5+N
N6=NST+6+N
N7=NST+7+N
N8=NST+8+N
A(N)=N
A(N1)=T536(N)
A(N2)=T636(N)
A(N3)=T637(N)
A(N4)=T535(N)
A(N5)=T635(N)
A(N6)=T735(N)
A(N7)=T736(N)
A(N8)=T737(N)
100 CONTINUE
WRITE(6,120)
120 FORMAT(1H1,25X,' ALL OF THE FOLLOWING TEMPERATURES ARE ON THE INNO0008500
1ER RADIUS OF THE RCME PT AREA')
WRITE(6,125)
125 FORMAT(
5X,' ALL OF THE FOLLOWING TEMPERATURES ARE IN DEG C,
1DIVIDED BY TBNB IF TBNB NE 0.,//.5X,'1 = TEMP IN (5,36)',10X,
2'2 = TEMP IN (6,36)',10X,'3 = TEMP IN (6,37)',10X,
3'4 = TEMP IN (6,35)',10X,'.5X,'5 = TEMP IN (7,35)',10X,
4'6 = TEMP IN (7,35)',11X,'7 = TEMP IN (7,36)',12X,'8 = TEMP IN (7,37)')
5 (7,37)')
N=NST
CALL PLOT(N0,A,N,M,NL,0)
DO 200 N=1,NST
N1=NST+N
N2=NST+2+N
N3=NST+3+N
N4=NST+4+N
N5=NST+5+N
N6=NST+6+N
N7=NST+7+N
N8=NST+8+N
A(N)=N
A(N1)=T534(N)
A(N2)=T634(N)
A(N3)=T734(N)
A(N4)=T834(N)
A(N5)=T835(N)
A(N6)=T836(N)
A(N7)=T837(N)
A(N8)=T838(N)
200 CONTINUE
WRITE(6,240)

```

```

03C06400
00006500
00C06600
00C06700
00006800
00006900
00007000
00007100
00007200
00007300
00007400
00007500
00007600
00007700
00007800
00007900
00008000
00008100
00008200
00008300
00008400
000008500
00008600
00008700
00008800
00008900
00009000
00009100
00009200
00009300
00009800
00009900
00010000
00010100
00010200
00010300
00010400
00010500
00010600
00010700
00010800
00010900
00011000
00011100
00011200
00011300
00011400
00011500
00011600
00011700
00011800
00011900

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240 FORMAT(1H1,25X, ' ALL OF THE FOLLOWING TEMPERATURES ARE ON THE OUT00012000
    1ER RADIUS OF THE ROME PT AREA')                                00012100
    WRITE(6,250)                                                    00012200
250 FORMAT(    5X,'ALL OF THE FOLLOWING TEMPERATURES ARE IN DEG C, 00012300
    1DIVIDED BY TBNB IF TBNB NE 0.,//,5X,'1 = TEMP IN (5,34)',10X, 00012400
    2'2 = TEMP IN (6,34)',10X,'3 = TEMP IN (7,34)', 10X,' 4 = TEMP IN 00012500
    3(8,34)', /,5X, '5 = TEMP IN (8,35)',10X, '6 = TEMP IN (8,36)', '00012600
    4      7 = TEMP IN (8,37)', 11X,'8 = TEMP IN (8,38)')
    N=NST                                                            00012700
    NO=2                                                            00013200
    CALL PLOT(NO,A,N,M,NL,0)                                       00013250
    WRITE(6,350)                                                    00013300
350 FORMAT(1H1,5X,'1 = WEIGHTED AVERAGE ALL TEMP IN BAY (DEG C)',/5X, 00013400
    1' 2 = WEIGHTED AV. CF ALL TEMP AROUND ROME PT.(DEG C/10.)',/, 00013500
    25X, ' 3 = AVERAGE UP VELOCITY IN WEST PASSAGE IN YDS/SEC', 00013600
    3/,5X, ' 4 = AVERAGE UP VELOCITY IN OUTFALL AREA BOXS 00013700
    4',/5X, ' 5 = AVERAGE VP VELOCITY IN OUTFALL AREA',/5X, 00013800
    5 ' 6 = AVERAGE TEMP IN BAY(DEG C*10.)',/5X,' 7 = AVERAGE TEPP IN00014000
    6 ROME PT AREA(DEG C*100.)')
    NO=3                                                            00014100
    N=NST                                                            00014200
    M=8                                                             00014300
    NL=NST                                                           00014400
    DO 340 N=1,NST                                                 00014500
    N1=NST+N                                                         00014600
    N2=2*NST+N                                                       00014700
    N3 = 3*NST+N                                                     00014800
    N4 = 4*NST+N                                                     00014900
    N5=5*NST+N                                                       00015000
    N6=6*NST+N                                                       00015100
    N7=7*NST+N                                                       00015200
    A(N) = N                                                         00015300
    A(N1) = ZID(N)                                                   00015400
    A(N2)=ZIF(N)/10.                                                 00015500
    A(N3) = ZIE(N)                                                   00015600
    A(N4) = AA(N)                                                     00015700
    A(N5)= BB(N)                                                     00015800
    A(N6) = ZIG(NST)*10.                                             00015900
    A(N7) = ZIH(NST)*100.                                           00016000
340 N=NST                                                           00016100
    CALL PLCT(NO,A,N,M,NL,0)                                       00016200
C    BB=TWBAY THEN TEQ                                             00016300
C    AA= HTOT THEN HTQE                                             00016400
C    ZID = AVERAGE HT IN EACH BOX(MAIN), ZIE= VELOCITY AT MOUTH OF 00016500
C    WEST PASSAGE(VPMFHT)                                           00016600
C    NCTE THAT AA(N) IS DIVIDED BY 10**-3                          00016700
C    NOTE THAT ZIE(N) IS DIVIDED BY 100.                          00016800
C                                                                    00016900
400 CONTINUE                                                       00017500
600 NST=NHOLD                                                       00017600
    IF(TBNB.EQ.1.) TBNB=0.00001                                    00017700
    RETURN                                                           00017800
    END                                                             00017900

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IEB816I MEMBER NAME (ADISPLY) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.

// CHANGE NAME=AANLZE,LIST=ALL

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SUBROUTINE ANLYZE(MAXST,NTERM,AT,NST,ZIF)
COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48),
1C(21,48),NBD(85),MBD(85),MUBDI(4),NOBD(4),H(21,48),
2 W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),
3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),
4 ZIA(0175),ZIB(0175),ZIC(0175),UAVG(21,48),VAVG(21,48),ZIE(0175),
5 ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),
6 IFIELD(21,48),HS1(015),HS2(015),ZIDI(0175),AA(0175),BB(0175)
DIMENSION XIA(0175),ALINE(65),ZIF(1)
DATA BLANK,DOT,STAR/' ','.',',','*','/'
NSTEP=1800./AT
DO 10 K=1,61
10 ALINE(K)=BLANK
C
T=0.
IF(MAXST.GT.175) MAXST=175
DO 30 N=1,MAXST,NSTEP
S=0.
DO 20 I=1,17
20 S= F2(I)*Z(I)*COS(W(I)*T+ARN(I))+S
XIA(N)=S
30 T=T+1.0
ZA=0.
DO 40 N=1,MAXST,NSTEP
IF(ABS(ZIA(N)).GT.Z) ZA=ABS(ZIA(N))
40 IF(ABS(XIA(N)).GT.Z) ZA=ABS(XIA(N))
ZS=ZA
WRITE(6,45)
WRITE(6,46)
DO 60 N=1,MAXST,NSTEP
ALINE(31)=DOT
JM=31.+(ZIA(N)/ZS)*30.
JS=31.+(XIA(N)/ZS)*30.
ALINE(JM)=STAR
ALINE(JS)=DOT
WRITE(6,50) N,ZIA(N),XIA(N),(ALINE(J),J=1,61)
ALINE(JM)=BLANK
ALINE(JS)=BLANK
60 CONTINUE
C
T=0.0
DO 90 N=1,MAXST,NSTEP
SB=0.0
DO 80 I=1,17
80 SB=F2(I)*HB(I)*COS(W(I)*T+ARGB(I))+SB
XIA(N)=SB
90 T=T+1.0
ZA=0.
DO 100 N=1,MAXST,NSTEP
IF(ABS(ZIB(N)).GT.Z) ZA=ABS(ZIB(N))
100 IF(ABS(XIA(N)).GT.Z) ZA=ABS(XIA(N))

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```

      ZS=ZA
      WRITE(6,45)
      WRITE(6,65)
      DO 110 N=1,MAXST,NSTEP
      ALINE(31)=DOT
      JM=31.+(ZIB(N)/ZS)*30.
      JS=31.+(XIA(N)/ZS)*30.
      ALINE(JM)=STAR
      ALINE(JS)=DOT
      WRITE(6,50) N,ZIB(N),XIA(N),(ALINE(J),J=1,61)
      ALINE(JS)=BLANK
      ALINE(JM)=BLANK
110  CONTINUE
C
      T=0.
      DO 150 N=1,MAXST,NSTEP
      SP=0.0
      DO 140 I=1,17
140  SP=F2(I)*HP(I)*COS(W(I)*T+ARGP(I))*SP
      XIA(N)=SP
150  T=T+1.0
      ZA=0.0
      DO 160 N=1,MAXST,NSTEP
      IF(ABS(ZIC(N)).GT.ZA) ZA=ABS(ZIC(N))
160  IF(ABS(XIA(N)).GT.ZA) ZA=ABS(XIA(N))
      ZS=ZA
      WRITE(6,45)
      WRITE(6,48)
      DO 170 N=1,MAXST,NSTEP
      ALINE(31)=DOT
      JS=31.+(XIA(N)/ZS)*30.
      JM=31.+(ZIC(N)/ZS)*30.
      ALINE(JM)=STAR
      ALINE(JS)=DOT
      WRITE(6,50) N,ZIC(N),XIA(N),(ALINE(J),J=1,61)
      ALINE(JS)=BLANK
      ALINE(JM)=BLANK
170  CONTINUE
C
      45  FORMAT(1H1,/,12X,'MODEL(*)',4X,'SERIES(*)',10X,'WATER LEVEL AT')
      46  FORMAT(52X,'NEWPORT')
      48  FORMAT(52X,'PROVIDENCE')
      65  FORMAT(52X,'BRISTOL')
      50  FORMAT(5X,14,5X,2(F6.2,3X),',',1',61A1,',')
      RETURN
      END

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IE88161 MEMBER NAME (AANLZE) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.
 IE88181 HIGHEST CONDITION CODE WAS 00000000
 IE88191 END OF JOB IEBUPDTE.

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 00010400
 00010500

COMPILER OPTIONS - NAME= MAIN,CPT=02,LINECNT=60,SIZE=0000K,
 SOURCE,EBCDIC,NULIST,NODECK,LCAD,MAP,NOEDIT,NOID,NOXREF

ISN 0002		DIMENSION A(048),B(48),Q(48),R(48),S(48), F(48),P(48),	00001000
		1KONVRT(21),NH(21),NPRINT(200),DAVG(80), AHOL(0148),NT(30),	00001100
		2NS(10),MS(10),SS(10),ZIF(0175),NTP(10),ZIH(0175),ZIG(0175)	00001200
			00001300
ISN 0003	C	COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48),	00001400
		1 C(21,48),NBD(85),MBD(85),M0BD(4),N0BD(4),H(21,48),	00001500
		2 W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),	00001600
		3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),	00001700
		4 ZIA(0175),ZIB(0175),ZIC(0175),UAVG(21,48),VAVG(21,48),ZIE(0175),	00001740
		5 ACDSMT(6),ASINMT(6),CN(21,48),CNP(21,48),	00001900
		6 IFIFLD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175)	00002000
			00002100
ISN 0004	C	LOGICAL READIN,DOSAL,RDCNP,DELTAT	00002200
			00002300
ISN 0005	C	DATA YR,DAY,THR,TMIN /57.,195.,17.,48./	00002400
ISN 0006		DATA MSDURC,NSOURC /1,1/	00002500
ISN 0007		DATA AL,AG,SALRIS,TMHOPE,TRIVER,TSOUND/1012.7,10.73,32.5,21.75,	00002600
		122.2,18.50/	00002700
ISN 0008		DATA HINV,SEINV,PI,CMANN,WX,WY,CORAG,CRHO /0.,0.,3.1415927,	00002800
		1.015,0.,0.,.0025,.00114/	00002900
	C		00003000
	C		00003100
	C	SET EXECUTION PARAMETERS	00003200
	C		00003300
	C	IMODES = 1 UPSTREAM DIFFERENCING	00003400
	C	IMODES = 2 CENTRAL DIFFERENCING	00003500
	C		00003600
	C		00003650
ISN 0009		IMODES=2	00003700
ISN 0010	2871	IPUNCH=540	00003800
ISN 0011		AT = 120.	00003900
ISN 0012		EXTRA3=AT	00004000
	C	IPRIND WILL SPECIFY TIME THAT VARIABLES ARE DISPLAYED	00004100
ISN 0013		IPRIND=15	00004200
ISN 0014		ILO=1	00004300
	C	SUMMING MODES REQUIRED FOR DISPLAYS	00004400
ISN 0015		SUMZIG=0.0	00004500
ISN 0016		SUMZIO=0.0	00004600
ISN 0017		SUMZIF=0.0	00004700
ISN 0018		SUMZIH=0.0	00004800
ISN 0019		SUMAA=0.0	00004900
ISN 0020		SUMBB=0.0	00005000
ISN 0021		MAXST=540	00005100
ISN 0022		NW=MAXST+1	00005200
ISN 0023		IDY=1	00005300
ISN 0024		HS1(IDY) = 2000.	00005400
ISN 0025		RDCNP=.FALSE.	00005500
	C	RDCNP FOR READING IN PREVIOUS VALUES OF CNP	00005600
ISN 0026		READIN=.TRUE.	00005700
ISN 0027		DOSAL=.TRUE.	00005800
ISN 0028		IRMS=1000	00005900
ISN 0029		IMODE1 = 1	00006000
	C		00006100
	C	SET COMPUTATION PARAMETERS	00006200
	C		00006300
	C		00006400

ISN 0030	C	IF DELTAT IS TRUE MODEL WILL CALCULATE TEMPERATURE ABOVE AMBIENT	00006500
ISN 0031		DELTA=.TRUE.	00006600
ISN 0032		TEN9=21.0	00006700
ISN 0033		IF(DELTA) GO TO 2873	00006800
ISN 0034		GO TO 2875	00006900
ISN 0035	2873	TEN8=0.00001	00007000
ISN 0036		TEN9=.00001	00007100
ISN 0037		TRIVER=.00001	00007200
ISN 0038		TSOUND=.00001	00007300
ISN 0039	2875	CONTINUE	00007400
	C	DIFFUSION CONSTANT IS UPCON	00007500
	C	FOR UPCON =500 THE ORDER OF MAGNITUDE OF HIGHEST DIFFUSION COEF	00007600
	C	IS ABOUT 350 YDSQ/SEC	00007700
	C		00007800
ISN 0040		UPCON=.050.	00007900
	C		00008000
	C	POWER PLANT	00008100
	C	TIN =0.0 YOU WILL HAVE HYDRODYNAMICS OF POWER PLANT SITE BUT	00008200
	C	NO THERMAL LOAD ON BAY	00008300
	C	IF EFFECTS OF POWER PLANT ARE DESIRED SET TIN EQUAL TO 12.	00008400
ISN 0041		TIN=12.	00008500
ISN 0042		QIN=2000.	00008600
	C		00008700
	C	SITE SELECTION. SEE HEATIN FOR DETAILS ON LOCATIONS	00008800
ISN 0043		SITE=100.	00008900
	C		00009000
	C		00009100
ISN 0044		LNL = 0	00009200
ISN 0045		ARHO=27.*1.940*(1.00+0.000841*SALRIS-0.000100*TSOUND)	00009300
	C		00009400
	C		00009500
ISN 0046		NMAX=19	00009600
ISN 0047		MMAX=48	00009700
ISN 0048		ANGLAT=41.6	00009800
ISN 0049		NT=1	00009900
ISN 0050		NOBD(1)=0103042	00010000
ISN 0051		NOBD(2)=4808091	00010100
ISN 0052		NOBD(3)=4811131	00010200
ISN 0053		NOBD(1)=1923242	00010300
ISN 0054		NOBD(2)=0410112	00010400
ISN 0055		MIND0=4	00010500
ISN 0056		NIND0=3	00010600
ISN 0057		NSECT=80	00010700
	C		00010800
ISN 0058	87	CONTINUE	00010900
ISN 0059		ARG=ANGLAT*3.1415927/180.	00011000
ISN 0060		FF=3.1415927*SIN(ARG)/21600.	00011100
ISN 0061	2080	NSI=0	00011200
ISN 0062		IP=1	00011300
ISN 0063		C1=AT*AG/AL	00011400
ISN 0064		C2=AT/AL	00011500
ISN 0065		C3=AT/4.	00011600
ISN 0066		C4=8.*AT*AG	00011700
ISN 0067		C5=2.*27.*AL	00011800
	C	27 IS FOR CFT TO CUYDS CONVERSION AND 2 IS FOR DISPLAYING	00011900
	C	ACTUAL CROSSSECTIONAL FLOW IN FOR RIVER	00012000
ISN 0068		C6=2.*CDRAG*CRHO*(1.687/3.1)**2*AT	00012100
ISN 0069		C7=40.00*SQRT(AG)	00012200

ISN 0070 C8=1./AL
 ISN 0071 C9=1./AL**2)
 ISN 0072 C10 = 0.
 ISN 0073 C11=C7
 ISN 0074 C12 = 0.
 ISN 0075 C13=1./AT
 ISN 0076 C14=1./14.*AL)
 ISN 0077 DO 8 M=1,MMAX
 ISN 0078 DO 6 N=1,NMAX
 ISN 0079 SE(N,M)=0.0
 ISN 0080 SEP(N,M)=0.0
 ISN 0081 CN(N,M)=0.0
 ISN 0082 CNP(N,M)=0.0
 ISN 0083 UAVG(N,M)=0.0
 ISN 0084 VAVG(N,M)=0.0
 ISN 0085 VP(N,M)=0.0
 ISN 0086 UP(N,M)=0.0
 ISN 0087 V(N,M)=0.
 ISN 0088 U(N,M)=0.
 ISN 0089 C(N,M)=0.
 ISN 0090 H(N,M)=0.0
 ISN 0091 6 F(N)=FF
 ISN 0092 8 CONTINUE
 ISN 0093 RA=0.0
 ISN 0094 CALL KURIH(MAXST,AT,NTerm,PCHECK,YR,CAY,TPr,TMin,TS)
 ISN 0095 CALL DIVE(NMAX,MMAX)
 ISN 0096 CALL FIND(MIND,NIND,MMAX,NMAX,MINDO,NINDO,NSECT)
 ISN 0097 CALL DEPTH(NMAX,MMAX)
 ISN 0098 CALL CHEZY(NMAX,MMAX,CMANN)
 ISN 0099 CALL CHECK(NMAX,MMAX)
 ISN 0100 DO 26 I=1,5
 ISN 0101 L=18*I
 ISN 0102 M=18*(I-1) +1
 ISN 0103 READ(5,25) (NPRINT(N),N=M,L)
 ISN 0104 25 FORMAT(18I4)
 ISN 0105 26 CONTINUE
 ISN 0106 DO 62 M=1,MMAX
 ISN 0107 DAVG(M)=0.0
 ISN 0108 DEP=0.0
 ISN 0109 DO 61 N=1,NMAX
 ISN 0110 IF(H(N,M).EQ.0.0) GO TO 61
 ISN 0111 DAVG(M)=DAVG(M)+H(N,M)
 ISN 0112 DEP=DEP+1.
 ISN 0113 61 CONTINUE
 ISN 0114 DAVG(M)=3.*DAVG(M)/DEP
 ISN 0115 62 CONTINUE
 ISN 0116 NUM=1
 ISN 0117 DEP=0.0
 ISN 0118 DEPSQ=0.0
 ISN 0119 GRION1=0.0
 ISN 0120 7 IF(NUM.EQ.NIND) GO TO 3
 ISN 0121 NSRCH=NBD(NUM)/1000000 -NSRCH*100
 ISN 0122 N =NBD(NUM)/10000
 ISN 0123 MF =NBD(NUM)/100-NSRCH*10000-N*100
 ISN 0124 L =NBD(NUM)-NSRCH*1000000-N*10000-MF*100
 ISN 0125 NN=N-1
 ISN 0126 K=MF
 ISN 0127 NGRID=L-K+1
 ISN 0128
 ISN 0129

00012300
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 00017900
 00018000
 00018100

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ISN 0130      GR1DN2=NGRID
ISN 0131      GR1DN1=GR1DN1+GR1DN2

C
C
C      USED ONLY IF NO SE VALUES ARE READ IN

ISN 0132      DO 2 M=K,L
ISN 0133      DEP=DEP+H(N,M)
ISN 0134      DEPSQ=DEPSQ+SQR(H(N,M))
ISN 0135      DIM1=M
ISN 0136      DIM1=DIM1-1.
ISN 0137      CN(N,M)=TBNS
ISN 0138      CNP(N,M)=TBNS
ISN 0139      SEP(N,M)=SEINV*(1.-DIM1/46.)*HINV
ISN 0140      2 SE(N,M)= SEINV*(1.-DIM1/46.)*HINV
ISN 0141      NUM=NUM+1
ISN 0142      GO TO 7
ISN 0143      3 CONTINUE
ISN 0144      CN (3,1) = TBNS
ISN 0145      CNP(3,1) = TBNS
ISN 0146      CN (4,1) = TBNS
ISN 0147      CNP(4,1) = TBNS
ISN 0148      CN (19,23)=TBNS
ISN 0149      CNP(19,23)=TBNS
ISN 0150      CN (19,24)=TBNS
ISN 0151      CNP(19,24)=TBNS
ISN 0152      CN (08,48)=TBNS
ISN 0153      CNP(08,48)=TBNS
ISN 0154      CN (09,48)=TBNS
ISN 0155      CNP(09,48)=TBNS
ISN 0156      CN (11,48)=TBNS
ISN 0157      CNP(11,48)=TBNS
ISN 0158      CN (12,48)=TBNS
ISN 0159      CNP(12,48)=TBNS
ISN 0160      CN (13,48)=TBNS
ISN 0161      CNP(13,48)=TBNS
ISN 0162      DEP=3.*DEP/GR1DN1
ISN 0163      DEPSQ=DEPSQ/GR1DN1
ISN 0164      DEPSQ=3.*(DEPSQ**2)
ISN 0165      NA=1
ISN 0166      5 IF(NA.EQ.MINDO) GO TO 31
ISN 0167      M=MOBD(NA)/100000
ISN 0168      NBOT =MOBD(NA)/1000 -M*100
ISN 0169      NTOP =MOBD(NA)/10 -M*10000 -NBOT*100
ISN 0170      DO 32 N=NBOT,NTOP
ISN 0171      DIM1=M
ISN 0172      DIM1=DIM1-1.
ISN 0173      SEP(N,M)=SEINV*(1.-DIM1/46.)*HINV
ISN 0174      SEP(N,M)=SEINV*(1.-DIM1/46.)*HINV
ISN 0175      32 SE(N,M)= SEINV*(1.-DIM1/46.)*HINV
ISN 0176      NA=NA+1
ISN 0177      GO TO 5
ISN 0178      31 NA=1
ISN 0179      33 IF(NA.EQ.NINDO) GO TO 34
ISN 0180      N=NOBD(NA)/100000
ISN 0181      MLEF =NOBD(NA)/1000 -N*100
ISN 0182      MRIG =NOBD(NA)/10 -N*10000 -MLEF*100
ISN 0183      DO 35 M=MLEF,MRIG
ISN 0184      DIM1=M
ISN 0185      DIM1=DIM1-1.
ISN 0186

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00018200
00018300
00018400
00018500
00018600
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00019500
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00020000
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00022400
00022500
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00022900
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00023100
00023200
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00023800
00023900

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ISN 0187      SEP(N,M)=SEINV*(1.-DIM1/46.)*HINV      00024000
ISN 0188      35 SE(N,M)= SEINV*(1.-DIM1/46.)*HINV      00024100
ISN 0189      NA=NA+1      00024200
ISN 0190      GO TO 33      00024300
ISN 0191      34 CONTINUE      00024400
C*****      00024500
C      00024600
ISN 0192      CALL INVAL(MMAX,NMAX,GRIDN1 ,DEP,DEPSQ,READIN,ROCNP,DAVG)      00024700
C      00024800
ISN 0193      CALL HEATININS,MS,SS,TIN,NZ,SITE,NINPUT,QIN)      00024850
C*****      00024900
C      00025000
ISN 0194      WRITE(6,2050) NS(5),MS(5)      00025040
ISN 0195      2050 FORMAT(//,5X,'NS(5) = ',I4 , 'MS(5) = ',I4)      00025060
ISN 0196      40 ISTEP=2      00025100
C      00025200
C*****      00025300
C      00025400
ISN 0197      CALL PRINT(ISTEP,NST,NPRINT,K,NMAX,MMAX,IP,AT,HTOT,HA,BH,      00025500
      1HE,HC,SAVE,IPUNCH)      00025600
C      00025700
C*****      00025800
C      00025900
ISN 0198      68 ISTEP=1      00026000
ISN 0199      NST=NST+1      00026100
ISN 0200      K=2*NST-1      00026200
ISN 0201      2001 IF(NST.GT.MAXSF) GO TO 501      00026300
C      00026400
C*****      00026500
C      00026600
C      00026700
C      00026800
C      00026900
ISN 0203      CALL OPENBDINST,IMODES,EXTRAL,KWRIT,K,KRT,IMODE1,T1,T2,T4,T5,      00027000
      INTERM,C5,TRIVER,TMHOPE,TSOUND,PI,THR,FHECK,AT,TS,AL,QIN)      00027100
C      00027200
C*****      00027300
C      00027400
C      00027500
C      00027600
ISN 0204      CALL UPNFHT(WX,WY,C6,C1,C2,C4,AT,AG,NIND,F,N1)      00027700
C      00027800
C*****      00027900
C      00028000
C      00028100
C      00028200
ISN 0205      CALL VPMFHT(C2,C6,WX,WY,C4,AT,DOSAL,IMODES,NSOURC,MSOURC,C13,      00028300
      IC10,C7,C8,C9,C14,C1,MIND,F,N1,NST,NPRINT ,IP,TBNB,KRT,NMAX,MMAX,      00028400
      ZIDY,PI,DAY,THR,TMIN,HTOT,HA,BH,HE,HC,SAVE,NS,MS,SS,      00028500
      3QIN,TIN,NZ,NW,UPCON,VARI,DELTAT,NINPUT,ZIG)      00028600
C      00028700
C*****      00028800
C      00028900
ISN 0206      CALL PRINT(ISTEP,NST,NPRINT,K,NMAX,MMAX,IP,AT,HTOT,HA,BH,      00029000
      1HE,HC,SAVE,IPUNCH)      00029100
C      00029200
C*****      00029300
C      00029400

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ISN 0207      CALL OPENBD(INST,IMODES,EXTRAL,KWRIT,K,KRT,IMODE1,T1,T2,T4,T5,      00029500
               INTERM,C5,TRIVER,TMHOPE,TSOUND,PI,THR,FCHECK,AT,TS,AL,QIN)      00029600
C             C*****      00029700
C             C*****      00029800
C             C*****      00029900
ISN 0208      NXT=ILD      00029910
ISN 0209      IF(NXT.FO.O) GO TO 2020      00029920
ISN 0211      2010 IF(NST.LT.90) GO TO 2040      00029930
ISN 0213      GO TO 2020      00029940
ISN 0214      2040 WRITE(6,2030) NXT,CN(5,36),CNP(5,36),QIN,TIN,NS(1),MS(1),NZ,      00029950
               ININPUT,SS(1),Z1A(NXT),Z1B(NXT),Z1C(NXT),Z1E(NXT),Z1D(NXT),      00029955
               2AA(NXT),BB(NXT),SITE,NS(5),MS(5),NST      00029958
ISN 0215      2030 FORMAT(5X,'NST=',14,' CN(5,36) = ',E12.4,' CNP(5,36) = ',      00029960
               1E12.4,' QIN = ',E12.4,' TIN = ',E12.4,' NS = ',14,' MS = ',      00029965
               214,/,5X,' NZ = ',14,' ININPUT = ',14,' SS(1) = ',E12.4,      00029970
               3'Z1A(NST) = ',E12.4,' Z1B(NST) = ',E12.4,' Z1C(NST) = ',E12.4,/,5X,      00029975
               4'Z1E(NST) = ',E12.4,' Z1D(NST) = ',E12.4,' AA(NST) = ',E12.4,      00029980
               5'BB(NST) = ',E12.4,/,5X,' SITE = ',E12.4,' NS(5) = ',14,      00029985
               6'MS(5) = ',14,' NST = ',14)      00029987
ISN 0216      2020 CONTINUE      00029990
C             C*****      00030100
ISN 0217      299 ISTEP=2      00030200
ISN 0218      K=2*NST      00030300
C             C*****      00030400
C             C*****      00030500
C             C*****      00030600
C             C*****      00030700
ISN 0219      CALL VPMSHT(WX,WY,C6,C1,C2,C4,AT,AG,MIND,F,NI)      00030800
C             C*****      00030900
C             C*****      00031000
C             C*****      00031100
ISN 0220      CALL UPNSHT(C2,C6,WX,WY,C4,AT,DOSAL,IMODES,NSOURC,MSOURC,C13,      00031200
               1C10,C7,C8,C9,C14,C1,NIND,F,NI,NST,NPRINT,IP,TBNB,KRT,NMAX,MMAX,      00031300
               2 IDY,PI,DAY,NS,MS,SS,QIN,TIN,NZ,THR,TMIN,HTOT,NW,UPCON,VAR1,      00031400
               3NINPUT)      00031500
C             C*****      00031600
ISN 0221      SUM1=0.      00031700
ISN 0222      GRIDT1 = 0.0      00031800
C             C*****      00031900
ISN 0223      SUM=0.0      00032000
C             C*****      00032100
C             C*****      00032200
C             C*****      00032300
C             C*****      00032400
ISN 0224      NUM=1      00032500
ISN 0225      17 IF(NUM.EQ.NIND) GO TO 36      00032600
ISN 0227      NSRCH=NBD(NUM)/1000000      00032700
ISN 0228      N = NBD(NUM)/10000 -NSRCH*100      00032800
ISN 0229      MF = NBD(NUM)/100-NSRCH*10000-N*100      00032900
ISN 0230      L = NBD(NUM)-NSRCH*1000000-N*10000-MF*100      00033000
ISN 0231      NN=N-1      00033100
ISN 0232      NGRID = L-MF+1      00033200
ISN 0233      GRIDN2=NGRID      00033300
ISN 0234      GRIDT1=GRIDT1+GRIDN2      00033400
ISN 0235      DO 22 M=MF,L      00033500
ISN 0236      MM= M-1      00033600
ISN 0237      SUMTWT =CNP(N,M)*(1.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM)+SEP(N,M)))      00033700
               1*3.0      00033800
ISN 0238      SUM=SUM+SUMTWT

```

ISN 0239	SUM1=SUM1+CNP(N,M)	00033900
ISN 0240	22 CONTINUE	00034000
ISN 0241	NUM=NUM+1	00034100
ISN 0242	GO TO 17	00034200
ISN 0243	36 SUMZIG=SUM1/GRIDT1 + SUMZIG	00034300
	C CONSTAN SHOULD EQUAL (AL**2)*9*DENS*9/5	00034400
ISN 0244	CONSTA=1.00	00034500
ISN 0245	SUMZID=CONSTA*SUM+SUMZID	00034600
ISN 0246	IF(MOD(NST,IPRIND).EQ.0) GO TO 45	00034700
ISN 0248	GO TO 41	00034800
ISN 0249	45 IPRINZ=IPRIND	00034900
ISN 0250	IF(DELTA) GO TO 47	00035000
ISN 0252	IPRINZ=IPRINZ*10**4	00035100
ISN 0253	47 ZID(IID)=SUMZID/IPRINZ	00035200
ISN 0254	ZIG(IID)=SUMZIG/IPRINZ	00035300
ISN 0255	SUMZIG=0.0	00035400
ISN 0256	SUMZID=0.0	00035500
ISN 0257	41 CONTINUE	00035600
ISN 0258	SUM=0.	00035700
ISN 0259	SUM1=0.0	00035800
ISN 0260	NUM=1	00035900
ISN 0261	GRIDT3=0.0	00036000
ISN 0262	NTP(1)= NBD(18)	00036100
ISN 0263	NTP(2)= NBD(11)	00036200
ISN 0264	NTP(3)= NBD(14)	00036300
ISN 0265	NTP(4)= NBD(16)	00036400
ISN 0266	NTP(5)= NBD(17)	00036500
ISN 0267	NTP(6)= NBD(19)	00036600
	C	00036700
	C	00036800
	C	00036900
	POWER PLANT AREA	00037000
ISN 0268	300 IF(NUM.EQ.07) GO TO 310	00037100
ISN 0270	312 NSRCH=NTP(NUM)/1000000	00037200
ISN 0271	N=NTP(NUM)/10000-NSRCH*100	00037300
ISN 0272	MF=NTP(NUM)/100-NSRCH*10000-N*100	00037400
ISN 0273	L=NTP(NUM)-NSRCH*1000000-N*10000-MF*100	00037500
ISN 0274	IF(MF.LT.32) MF=32	00037600
ISN 0276	IF(L.GT.42) L=42	00037700
ISN 0278	NN=N-1	00037800
ISN 0279	NNGD=L-MF+1	00037900
ISN 0280	GRT4=NNGD	00038000
ISN 0281	GRIDT3=GRIDT3+GRT4	00038100
ISN 0282	DO 330 M=MF,L	00038200
ISN 0283	MM=M-1	00038300
ISN 0284	SUMTPT =CNP(N,M)*(1.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM))+SEP(N,M))	00038400
	1*3.0	00038500
ISN 0285	SUM1=SUM1+CNP(N,M)	00038600
ISN 0286	330 SUM=SUM+SUMTPT	00038700
ISN 0287	60 SUMZIF=CONSTA*SUM+SUMZIF	00038800
ISN 0288	SUMZIH=SUM1/GRIDT3 + SUMZIH	00038900
ISN 0289	IF(MOD(NST,IPRIND).EQ.0) GO TO 65	00039000
ISN 0291	GO TO 70	00039100
ISN 0292	65 IPRINZ=IPRIND	00039200
ISN 0293	IF(DELTA) GO TO 67	00039300
ISN 0295	IPRINZ=IPRINZ*10**2	00039400
ISN 0296	67 ZIF(IID)=SUMZIF/IPRINZ	00039500
ISN 0297	ZIH(IID)=SUMZIH/IPRINZ	00039600
ISN 0298	SUMZIF=0.0	


```

ISN 0299      SUMZIH=0.0
ISN 0300      70 CONTINUE
ISN 0301      NUM=NUM+1
ISN 0302      GO TO 300
ISN 0303      310 CONTINUE
C
C      VELOCITY COMPONENTS IN OUTFALL AREA
C
ISN 0304      SUM=0.0
ISN 0305      SUM1=0.0
ISN 0306      316 NZ=1
ISN 0307      INS=NS(NZ)
ISN 0308      IMS=MS(NZ)
C      CHANGE 5 TO NS(2) AND 36 TO MS(1) WHEN YOU RUN POWER PLANT
ISN 0309      SUM=UP(INS,IMS)+SUM
ISN 0310      SUM1=VP(INS,IMS)+SUM1
ISN 0311      375 CONTINUE
ISN 0312      ANZ=NZ
ISN 0313      SUM=SUM/ANZ
ISN 0314      SUM1=SUM1/ANZ
ISN 0315      SUMAA=SUM + SUMAA
ISN 0316      SUMBB=SUM1+SUMBB
ISN 0317      IF(MOD(NST,IPRIND).EQ.0) GO TO 75
ISN 0319      GO TO 80
ISN 0320      75 AA(ILD)=SUMAA/IPRIND
ISN 0321      BB(ILD)=SUMBB/IPRIND
ISN 0322      SUMAA=0.0
ISN 0323      SUMBB=0.0
ISN 0324      IF(MOD(NST,IPRIND).EQ.0) ILD=ILD+1
ISN 0326      NXT=ILD-1
ISN 0327      80 CONTINUE
C
C      WRITE(6,2070) ZID(NXT),ZIG(NXT),ZIF(NXT),ZIH(NXT)
ISN 0328      2070 FORMAT(//,5X,'ZID(NXT) = ',E12.4,'ZIG(NXT) = ',E12.4,
ISN 0329      1,'ZIF(NXT) = ',E12.4,'ZIH(NXT) = ',E12.4)
C      AVERAGE VELOCITY IN WEST PASSAGE
ISN 0330      ZIE(ILD)=(UP(8,47)+UP(9,47))/2.
ISN 0331      CALL DISPLY(NST,MAXST,TBNB,ZIF,ZIG,ZIH,IPRIND)
C
C      IF(NST.LT.MAXST) GO TO 40
ISN 0332      110 CALL PRINT(ISTEST,NST,NPRINT,K,NMAX,MHAX,IP,AT,HTOT,HA,BH,
ISN 0334      1HE,HC,SAVE,IPUNCH)
C
C      *****
C
C
C      END OF MAIN COMPUTATIONAL SCHEME
C
C      *****
C
C      501 CONTINUE
ISN 0335      CALL ANALYZE(MAXST,NTERM,AT,NST,ZIF)
ISN 0336      RETURN
ISN 0337      END
ISN 0338

```


NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.
A		R**	N.R.	B		R**	N.R.	C S	C	R**	005E80	E	C	R**	N.R.
F SFA		R**	000860	H SFA	C	R**	007108	I SF		I**	000654	K SFA		I**	000658
L SF		I**	00065C	M SFA		I**	000660	N SFA		I**	000664	P		R**	N.R.
Q		R**	N.R.	R		R**	N.R.	S		R**	N.R.	U S	C	R**	003F00
V S	C	R**	001F80	W	C	R**	N.R.	Z	C	R**	N.R.	AA SF	C	R**	00E23C
AG SFA		R**	000668	AL SFA		R**	00066C	AT SFA		R**	000670	BB SF	C	R**	00E4F8
BH SFA		R**	000674	CN SF	C	R**	00AF68	C1 SFA		R**	000678	C2 SFA		R**	00067C
C3 S		R**	000680	C4 SFA		R**	000684	C5 SFA		R**	000688	C6 SFA		R**	00068C
C7 SFA		R**	000690	C8 SFA		R**	000694	C9 SFA		R**	000698	E8	C	R**	N.R.
EL	C	R**	N.R.	EP	C	R**	N.R.	FF SF		R**	00069C	F2	C	R**	N.R.
HA SFA		R**	0006A0	HR	C	R**	N.R.	HC SFA		R**	0006A4	HE SFA		R**	0006A8
HL	C	R**	N.R.	HP	C	R**	N.R.	IP SFA		I**	0006AC	MF SF		I**	0006B0
MM SF		I**	0006B4	MS SFA		I**	000920	NA SF		I**	0006B8	NH		I**	N.R.
NI SFA		I**	0006BC	NN SF		I**	0006C0	NS SFA		I**	000948	NT		I**	N.R.
NW SFA		I**	0006C4	NZ SFA		I**	0006C8	PI SFA		R**	0006CC	RA S		R**	0006D0
SE S	C	R**	000000	SS SFA		R**	000970	TS SFA		R**	0006D4	T1 SFA		R**	0006D8
T2 SFA		R**	0006DC	T4 SFA		R**	0006E0	TS SFA		R**	0006E4	UP SF	C	R**	004EC0
VP SF	C	R**	002F40	WX SFA		R**	0006E8	WY SFA		R**	0006EC	YR SFA		R**	0006F0
ANZ SF		R**	0006F4	ARG SFA		R**	0006F8	ARN	C	R**	N.R.	CNP SF	C	R**	00BF88
C10 SFA		R**	0006FC	C11 S		R**	000700	C12 S		R**	000704	C13 SFA		R**	000708
C14 SFA		R**	00070C	DAY SFA		R**	000710	DEP SFA		R**	000714	HS1 S	C	R**	000F08
HS2	C	R**	N.R.	IDY SFA		I**	000718	ILD SF		I**	00071C	IMS SF		I**	000720
INS SF		I**	000724	KRT SFA		I**	000728	LNL S		I**	00072C	M8D	C	I**	N.R.
NBD F	C	I**	006E40	NST SFA		I**	000730	NTP SF		I**	000998	NUM SF		I**	000734
NXT SF		I**	000738	GIN SFA		R**	00073C	SEP SF	C	R**	000FC0	SUM SF		R**	000740
THR SFA		R**	000744	TIN SFA		R**	000748	ZIA F	C	R**	008528	Z18 F	C	R**	0087E4
ZIC F	C	R**	008AA0	ZID SF	C	R**	00DF80	ZIE SF	C	R**	00ACDC	ZIF SFA		R**	0009C0
ZIG SFA		R**	000C7C	ZIH SFA		R**	000F38	ARGB	C	R**	N.R.	ARGP	C	R**	N.R.
ARHJ S		R**	00074C	CRHJ F		R**	000750	DAVG SFA		R**	0011F4	DIM1 SF		R**	000754
DIVE SF	XF	R**	000C00	FIND SF	XF	R**	000J00	GRT4 SF		R**	000758	HINV F		R**	00075C
HTOT SFA		R**	000760	IRMS S		I**	000764	MIND SFA		I**	000768	MLEF SF		I**	00076C
HMAX SFA		I**	000770	MOBD SF	C	I**	0070E8	MRI8 SF		I**	000774	NROT SF		I**	000778
NIND SFA		I**	00077C	NMAX SFA		I**	000780	NNGD SF		I**	000784	NOBD SF	C	I**	007JF8
NTOP SF		I**	000788	SAVE SFA		R**	00078C	SITE SFA		R**	000790	SUM1 SF		R**	000794
T8NB SFA		R**	000798	TMIN SFA		R**	00079C	UAVG S	C	R**	008D5C	VARI SFA		R**	0007A0
VAVG S	C	R**	009D1C	AMOLD		R**	N.R.	ARCL8	C	R**	N.R.	CDRAG F		R**	0007A4
CHECK SF	XF	R**	000000	CHEZY SF	XF	R**	000J00	CHANN SFA		R**	0007A8	DEPSQ SFA		R**	0007AC
DEPTH SF	XF	R**	000000	DOSAL SFA		L**	0007B0	INVAL SF	XF	I**	000000	ISTEP SFA		I**	0007B4
KUR1H SF	XF	I**	000000	KWRIT SFA		I**	0007B8	MAXST SFA		I**	0007BC	MINDO SFA		I**	0007C0
NGRID SF		I**	0007C4	NINDO SFA		I**	0007C8	NSECT SFA		I**	0007CC	NSRCH SF		I**	0007C4
NTERM SFA		I**	0007D4	PRINT SF	XF	R**	000000	RCCNP SFA		L**	0007D8	SEINV F		R**	0007DC
SUMAA SF		R**	0007E0	SUM88 SF		R**	0007E4	UPCON SFA		R**	0007E8	SQRT	XF	R**	000000
SIN	XF	R**	000000	ACOSMT	C	R**	N.R.	ANGL AT SF		R**	0007EC	ANLYZE SF	XF	R**	000000
ASINMT	C	R**	N.R.	CONSTA SF		R**	0007F0	DELTA SFA		L**	0007F4	DISPLY SF	XF	R**	000000
EXTRAL SFA		R**	0007F8	EXTRA3 S		R**	0007FC	FCHECK SFA		R**	000800	GRIDN1 SFA		R**	000804
GRIDN2 SF		R**	000808	GRIDT1 SF		R**	00080C	GRIDT3 SF		R**	000810	HEATIN SF	XF	R**	000000
IBCOM# F	XF	I**	000000	IFIELD	C	I**	N.R.	IMODES SFA		I**	000814	IMODEL SFA		I**	000818
IPRIND SFA		I**	00081C	IPRINZ SF		I**	000820	IPUNCH SFA		I**	000824	KONVRT		I**	N.R.
MSOURC SFA		I**	000828	NINPOT SFA		I**	00082C	NPRINT SFA		I**	001334	NSOURC SFA		I**	000830
OPEN8D SF	XF	R**	000000	READIN SFA		L**	000834	SALRIS F		R**	000838	SUMTPT SF		R**	00083C
SUMTWT SF		R**	000840	SUMZID SF		R**	000844	SUMZIF F		R**	000848	SUMZIG SF		R**	00084C
SUMZIH SF		R**	000850	TMHOPE SFA		R**	000854	TRIVER SFA		R**	000858	TSOUND SFA		R**	00085C
UPNFHT SF	XF	R**	000000	UPNSHT SF	XF	R**	000000	VPMFHT SF	XF	R**	000000	VPMSHT SF	XF	R**	000000

***** COMMON INFORMATION *****

NAME OF COMMON BLOCK * * SIZE OF BLOCK 00E7B4 HEXADECIMAL BYTES

VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.
SE	R**	000000	SEP	R**	000FC0	V	R**	001F80	VP	R**	002F40
U	R**	003F00	UP	R**	004EC0	C	R**	C05E80	NBD	I**	006E40
MBD	I**	N.R.	MOBD	I**	0070E8	NOBD	I**	0070F8	H	R**	007108
W	R**	N.R.	F2	R**	N.R.	Z	R**	N.R.	E	R**	N.R.
HP	R**	N.R.	EP	R**	N.R.	HB	R**	N.R.	EB	R**	N.R.
ARN	R**	N.R.	ARGP	R**	N.R.	ARGB	R**	N.R.	ARGLB	R**	N.R.
HL	R**	N.R.	EL	R**	N.R.	ZIA	R**	008528	ZIB	R**	0087E4
ZIC	R**	008AA0	UAVG	R**	008D5C	VAVG	R**	009D1C	ZIE	R**	00ACDC
ACOSMT	R**	N.R.	ASINMT	R**	N.R.	CN	R**	00AFC8	CNP	R**	008F88
IFTILD	I**	N.R.	HS1	R**	00DF08	HS2	R**	N.R.	ZID	R**	00DF80
AA	R**	00E23C	BB	R**	00E4F8						

LABEL	ADDR	LABEL	ADDR	LABEL	ADDR	LABEL	ADDR	PAGE 011
2871	001788 NR	2873	001832	2875	001846	87	0018F0 NR	
2080	00191E NR	6	001A88	8	001A98	26	00183E	
61	0018C0	62	0018DE	7	001C20	2	001D96	
3	001DCA	5	001E80	32	001F96	31	001FC2	
33	001FCE	35	0020A2	34	0020C6	40	002114	
88	002126 NR	2001	002144 NR	2010	002190	2040	0021A0	
2020	002278	299	002278 NR	17	0022C2	22	00240A	
36	002442	45	002484	47	0024A2	41	0024F2	
300	00255E	312	00256A	330	0026CA	60	0026E6	
65	002718	67	002734	70	002780	310	00279C	
316	0027A8 NR	375	0027F6 NR	75	002860	80	0028F6	
110	002972	501	00297C					

OPTIONS IN EFFECT NAME= MAIN,OPT=02,LINECNT=60,SIZE=0000K,

OPTIONS IN EFFECT SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,NOIO,NOXREF

STATISTICS SOURCE STATEMENTS = 337 ,PROGRAM SIZE = 10678

STATISTICS NO DIAGNOSTICS GENERATED

***** END OF COMPILATION *****

203K BYTES OF CORE NOT USED

F44-LEVEL LINKAGE EDITOR OPTIONS SPECIFIED LET,LIST,NCAL,XREF
 DEFAULT OPTION(S) USED - SIZE=(122880,16384)

IEW0461 DIVE
 IFW0461 FIND
 IEWC461 CHECK
 IEW0461 CHEZY
 IFW0461 DEPTH
 IEWC461 INVAL
 IEW0461 KURIH
 IEW0461 PRINT
 IEW0461 SORT
 IFW0461 SIN
 IEW0461 ANALYZE
 IEW0461 DISPLY
 IEW0461 HEATIN
 IEW0461 IBCOM#
 IFWC461 OPENBD
 IEW0461 UPNFHT
 IEW0461 UPNSHT
 IEW0461 VPMFHT
 IEW0461 VPMSHT

****MAIN NOW REPLACED IN DATA SET

CROSS REFERENCE TABLE

CONTROL SECTION			ENTRY					
NAME	ORIGIN	LENGTH	NAME	LOCATION	NAME	LOCATION	NAME	LOCATION
MAIN	00	2986						
\$BLANKCCM	2988	E784						

LOCATION	REFERS TO SYMBOL	IN CONTROL SECTION	LOCATION	REFERS TO SYMBOL	IN CONTROL SECTION
1664			1668		
166C			1670		
1674			1678		
167C			1680		
1684			1688		
168C	DIVE	\$UNRESOLVED	1690	FIND	\$UNRESOLVED
1694	CHECK	\$UNRESOLVED	1698	CHEZY	\$UNRESOLVED
169C	DEPTH	\$UNRESOLVED	16A0	INVAL	\$UNRESOLVED
16A4	KURIH	\$UNRESOLVED	16A8	PRINT	\$UNRESOLVED
16AC	SORT	\$UNRESOLVED	16B0	SIN	\$UNRESOLVED
16B4	ANALYZE	\$UNRESOLVED	16B8	DISPLY	\$UNRESOLVED
16BC	HEATIN	\$UNRESOLVED	16C0	IBCOM#	\$UNRESOLVED
16C4	OPENBD	\$UNRESOLVED	16C8	UPNFHT	\$UNRESOLVED
16CC	UPNSHT	\$UNRESOLVED	16D0	VPNFHT	\$UNRESOLVED
16D4	VPMSHT	\$UNRESOLVED			
ENTRY ADDRESS	00				

F44-LEVEL LINKAGE EDITOR OPTIONS SPECIFIED MAP,LET,LIST,OVLY,XREF
 DEFAULT OPTION(S) USED - SIZE=(122880,16384)

```
IEWCGCO      ENTRY MAIN
IEWOGOO      INCLUDE OBJLIB(MAIN)
IEWCGCO      OVERLAY CNE
IEWOJOO      INCLUDE OBJLIB(KURTH,DIVE,FIND,DEPTH,CHEZY,CHECK,INVAL)
IEWOQOO      INCLUDE OBJLIB(HEATIN)
IEWOQOO      OVERLAY CNE
IEWOQOO      INCLUDE OBJLIB(PRINT)
IEWOQOO      INCLUDE OBJLIB(OPENBD,UPNFHT,VPMFHT,VPMST,UPNST,WATDEP,WATIND)
IEWOQOO      INCLUDE OBJLIB(DISPLY,PLCT)
IEWOQOO      INCLUDE OBJLIB(ANLYZE)
***MAIN      DOES NOT EXIST BUT HAS BEEN ADDED TO DATA SET
```

CROSS REFERENCE TABLE

CONTROL SECTION				ENTRY							
NAME	ORIGIN	LENGTH	SEG. NO.	NAME	LOCATION	NAME	LOCATION	NAME	LOCATION	NAME	LOCATION
\$SECTAB	00	24	1								
MAIN	28	2986	1								
INCSLOG *	29E0	186	1	ALCG10	29E0	ALOG	29F8				
INCSATN2*	2898	108	1	ATAN2	2898	ATAN	28AC				
INCSSCN *	2D68	109	1	COS	2D68	SIN	2D80				
INCSEXP *	2F48	192	1	EXP	2F48						
INCFRXPR*	30E0	183	1	FRXPR#	30E0						
INCECOMH*	3268	F41	1	IBCOM#	3268	FDIOCS#	3324	INTSWTCH	418E		
INCCOMH2*	4180	650	1	SEQDASD	4528						
INCSSQRT*	4810	145	1	SQRT	4810						
INCFCVTH*	4958	1190	1	ADCCN#	4958	FCVAOUTP	4A02	FCVLOUTP	4A92	FCVZOUTP	48E2
				FCVIOUTP	4F90	FCVEQUTP	5492	FCVCOUTP	56AC	INT6SWCH	5993
IPCEFNTH*	5AF8	512	1	ARITH#	5AF8	ADJSWTCH	5E64				
IPCEFIOS*	6010	1378	1	FIOCS#	6010	FIOCSBEP	6016				
INCERRN *	7388	58C	1	ERRMCN	7388	INCERRE	73A0				
IMCUOPT *	7948	300	1								
INCETRCH*	7C48	28E	1	INCTRCH	7C48	ERRTRA	7C50				
INCUATBL*	7ED8	148	1								
\$BLANKCOM	8020	E784	1								
\$ENTAB	167D8	CC	1								

NAME	ORIGIN	LENGTH	SEG. NO.	NAME	LOCATION	NAME	LOCATION	NAME	LOCATION	NAME	LOCATION
168C											
1694											
169C											
16A4											
16AC											
1684	DIVE			DIVE	2	1690		FIND	2	1698	
168C	CHECK			CHECK	2	16A0		CHEZY	2	16A8	
16C4	DEPTH			DEPTH	2	16B0		INVAL	2	16B8	
16CC	KURTH			KURTH	2	16C0		PRINT	3	16C8	
16D4	SQRT			INCSQRT	1	16D8		SIN	1	16E0	
16DC	ANLYZE			ANLYZE	3	16E8		DISPLY	3	16F0	
16E4	HEATIN			HEATIN	2	16F8		IBCOM#	1	2808	
16FC	OPENBD			OPENBD	3	2C08		UPNFHT	3	2E98	
16F4	UPNSHT			UPNSHT	3	3050		VPNFHT	3	31F0	
16FC	VPMSHT			VPMSHT	3	31E8		IBCOM#	1	3324	
2B44	INCERRM			INCERRM	1	4090		IBCOM#	1	40BC	
2D24	INCERRM			INCERRM	1	40A0		IBCOM#	1	40A8	
2E0C	INCERRM			INCERRM	1	40B0		IBCOM#	1	4044	
304C	INCERRM			INCERRM	1	4074		IBCOM#	1	407C	
31F4	INCERRM			INCERRM	1	404C		IBCOM#	1	4054	
31EC	EXP			INCSEXP	1	4450		IBCOM#	1	41F4	
4098	ADCON#			INCFCVTH	1	4670		IBCOM#	1	48E0	
409C	ARITH#			INCFNTH	1	5954		IBCOM#	1	5E84	
40B8	INCUIOPT			INCUIOPT	1	5E60		IBCOM#	1	5E0C	
40A4	FCVLOUTP			INCFCVTH	1	5F2C		IBCOM#	1	6F8C	
40AC	FCVLOUTP			INCFCVTH	1	7934		IBCOM#	1	793C	
40B4	FCVLOUTP			INCFCVTH	1	708C		IBCOM#	1	70C4	
4070	IHCCOMH2			IHCCOMH2	1			IBCOM#	1		
4048	IHCCOMH2			IHCCOMH2	1			IBCOM#	1		
4050	IHCCOMH2			IHCCOMH2	1			IBCOM#	1		
444D	IHCECOMH			IHCECOMH	1			IBCOM#	1		
41F8	INCERRM			INCERRM	1			IBCOM#	1		
466D	INCERRM			INCERRM	1			IBCOM#	1		
468D	INCERRM			INCERRM	1			IBCOM#	1		
4908	INCERRM			INCERRM	1			IBCOM#	1		
5950	INCERRM			INCERRM	1			IBCOM#	1		
5E88	INTSWTCH			INCECCMH	1			IBCOM#	1		
5E5C	INCUIOPT			INCUIOPT	1			IBCOM#	1		
5EBC	FIDCS#			INCEFIOS	1			IBCOM#	1		
6170	INCERRM			INCERRM	1			IBCOM#	1		
6FC0	IBCOM#			IHCECOMH	1			IBCOM#	1		
7938	IBCOM#			IHCECOMH	1			IBCOM#	1		
7940	FIDCSBEP			INCEFIOS	1			IBCOM#	1		
7DC0	ADCON#			INCFCVTH	1			IBCOM#	1		

CONTROL SECTION				ENTRY			
NAME	ORIGIN	LENGTH	SEG. NO.	NAME	LOCATION	NAME	LOCATION
KURIM	168A8	204C	2				
DIVE	188F8	30C	2				
FINC	18CD8	9EC	2				
DEPTH	196C8	33A	2				
CPEZY	19A08	3CA	2				
CHECK	19DD8	432	2				
INVAL	1A210	C84	2				
HEATIN	1AE98	430	2				

LOCATION	REFERS TO SYMBOL	IN CONTROL SECTION	SEG. NO.	LOCATION	REFERS TO SYMBOL	IN CONTROL SECTION	SEG. NO.
17478			1	1747C			1
1748C			1	17484			1
17488			1	1748C			1
17490			1	17494			1
17498			1	1749C			1
174A0	SIN	IMCSCN	1	174A4	ATAN	IMCSATNZ	1
174A8	SQRT	IMCSSQRT	1	174AC	COS	IMCSCN	1
174B0	IBCOM#	IMCECOMH	1	18A90			1
18A94			1	18A98			1
18A9C			1	18AA0			1
18AA4			1	18AA8			1
18AAC			1	18AB0			1
18AB4			1	18AB8	IBCOM#	IMCECOMH	1
18E38			1	18E3C			1
18E40			1	18E44			1
18E48			1	18E4C			1
18E50			1	18E54			1
18E58			1	18E5C			1
18E60	IBCOM#	IMCECOMH	1	197E8			1
197EC			1	197F0			1
197F4			1	197F8			1
197FC			1	19800			1
19804			1	19808			1
1980C			1	19810	IBCOM#	IMCECOMH	1
19810			1	19814			1
19818			1	1981C			1
19820			1	19824			1
19828			1	1982C			1
19830			1	19834			1
19838	EXP	IMCSEXP	1	1983C	ALOG	IMCSLOG	1
19840	IBCOM#	IMCECOMH	1	1A050			1
1A054			1	1A058			1
1A05C			1	1A060			1
1A064			1	1A068			1
1A06C			1	1A070			1

LOCATION	REFERS TO SYMBOL	IN CONTROL SECTION	SEG. NO.	LOCATION	REFERS TO SYMBOL	IN CONTROL SECTION	SEG. NO.
1A074			1	1A078	IBCOM#	IHCECOMH	1
1A520			1	1A524			1
1A528			1	1A52C			1
1A530			1	1A534			1
1A538			1	1A53C			1
1A540			1	1A544			1
1A550	IBCOM#	IHCECOMH	1	1AF98			1
1AF9C			1	1AFA0			1
1AFA4			1	1AFA8			1
1AFAC			1	1AF80			1
1AFB4			1	1AF88			1
1AFBC			1				

CONTROL SECTION				ENTRY			
NAME	ORIGIN	LENGTH	SEG. NO.	NAME	LOCATION	NAME	LOCATION
PRINT	168A8	D20	3				
OPENBD	175C8	790	3				
UPNFHT	17D58	1EC2	3				
VPMFHT	19C20	330C	3				
VPMSHT	1CF30	1ECC	3				
UPNSHT	1EE00	2A24	3				
WATCEP	21828	586	3				
WATIND	21DE0	830	3				
DISPLY	22610	3F48	3				
PLOT	26558	98E	3				
ANLYZE	26F18	CBA	3				

LOCATION	REFERS TO SYMBOL	IN CONTROL SECTION	SEG. NO.	LOCATION	REFERS TO SYMBOL	IN CONTROL SECTION	SEG. NO.
16CA8			1	16CAC			1
16C80			1	16CB4			1
16C88			1	16CB8			1
16CC0			1	16CC4			1
16CC8			1	16CCC			1
16CD0	IBCOM#	IHCECOMH	1	17780			1
17784			1	17788			1
1778C			1	177C0			1
177C4			1	177C8			1
177CC			1	177D0			1
177D4			1	177D8	COS	IHCSSCN	1
18EE4			1	18EE8			1
18EEC			1	18EFO			1
18EF4			1	18EF8			1
18EFC			1	18FO0			1
18F04			1	18F08			1
18F14	SQRT	IHCSSQRT	1	181D4			1
18108			1	181DC			1
181E0			1	181E4			1

LOCATION	REFERS TO SYMBOL	IN CONTROL SECTION	SEG. NO.	LOCATION	REFERS TO SYMBOL	IN CONTROL SECTION	SEG. NO.
181E8			1	181E8			1
181F0			1	181F4			1
181F8			1	18224	FRXPR#	IHCFRXPR	1
18228	COS	IHCSSCN	1	1822C	SQRT	IHCSSQRT	1
18230	IBCOM#	IHCCEOMH	1	1823C	WATDEP	WATDEP	3
18240	WATIND	WATIND	3	1E08C			1
1E0C0			1	1E0C4			1
1E0C8			1	1E0CC			1
1E0D0			1	1E0D4			1
1E0D8			1	1E0DC			1
1E0E0			1	1E0EC	SQRT	IHCSSQRT	1
200B4			1	2C0B8			1
2C0B8			1	200C0			1
200C4			1	200C8			1
200CC			1	200D0			1
200D4			1	200C8			1
200FC	SQRT	IHCSSQRT	1	21980			1
219B4			1	21988			1
219BC			1	219C0			1
219C4			1	219C8			1
219CC			1	219F0			1
219D4			1	219E0	FRXPR#	IHCFRXPR	1
219E4	SIN	IHCSSCN	1	219E8	COS	IHCSSCN	1
22050			1	22054			1
22058			1	2205C			1
22060			1	22064			1
22068			1	2206C			1
22070			1	22074			1
22078	FRXPR#	IHCFRXPR	1	2207C	SIN	IHCSSCN	1
22080	COS	IHCSSCN	1	22084	EXP	IHCSEXP	1
22088	IBCOM#	IHCCEOMH	1	25E70			1
25E74			1	25E78			1
25E7C			1	25E80			1
25E84			1	25E88			1
25E8C			1	25E90			1
25E94			1	25E80	PLOT	PLOT	3
25E84	IBCOM#	IHCCEOMH	1	26950			1
26954			1	26958			1
2695C			1	26960			1
26964			1	26968			1
2696C			1	26970			1
26974			1	26980	IBCOM#	IHCCEOMH	1
27468			1	2746C			1
27470			1	27474			1
27478			1	2747C			1
27480			1	27484			1
27488			1	2748C			1
27498	COS	IHCSSCN	1	2749C	IBCOM#	IHCCEOMH	1

ENTRY ADDRESS 28
TOTAL LENGTH 27808

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