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Improving the Statistical Reliability of Stream Heat Assimilation Prediction

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IMPROVING THE STATISTICAL RELIABILITY OF STREAM HEAT ASSIMILATION PREDICTION

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ABSTRACT

In response to an increased interest in water quality by the public, a large effort has been mounted to develop mathematical models for predicting heat assimilation in bodies of water. The accuracy of these models has recently come under scrutiny due to the need for temperature predictions within 1 ^{o}C of the ambient. This work is an evaluation of existing, one-dimensional stream temperature prediction techniques for accuracy and precision. The approach is through error estimates on a general model that encompasses all of the models presently used. A sensitivity analysis of this general model is used in conjunction with statistical methods to determine the solution errors. Data taken in 1973 at the Vernon, Vermont nuclear plant are used as a data base. These data are used in conjunction with Burlington, Vermont airport weather station data to 1) gain insight into the orders-of-magnitude of the various errors and 2) carry out a detailed data analysis to establish the probabilities of meeting given error requirements. This report contains the model descriptions for the general stream model, the sensitivity analysis model, and the data analysis models; a description of the Vernon, Vermont site; the data for four problems from the Vernon nuclear plant; an order-of-magnitude error study; and the results of the four data analyses. The four appendices contain 1) a description of the input FORMAT specifications, 2) the input data for the four problems, 3) program listings, and 4) the theory of the sensitivity analysis.

This report was submitted in fulfillment of Contract 68-03-0439 by Richard W. McLay, P.E., Essex Junction, Vermont, under the partial sponsorship of the Environmental Protection Agency. Work was completed as of May 1975.

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SECTION I

CONCLUSIONS

1. One-dimensional stream temperature models are effective for predicting average temperatures over a short period of time.

2. Predictions made using site data averaged over a day will be within 2 ^{o}F (1.11 ^{o}C) of the actual average temperature of the following day over 90 percent of the time.

3. The water temperature at the Vernon site is the most important factor in the analysis. The Vernon study indicates that meteorological factors affect the Connecticut river predictions results very little. Travel time thus appears to be a major factor since a knowledge of the initial temperature is essential to accurate predictions.

4. Seasonal effects on prediction accuracy are minor.

SECTION II

RECOMMENDATIONS

The results of this study indicate that, in this case, water temperature at the site is the most important variable in the prediction of the downstream Connecticut river temperature. In order to minimize the errors of prediction, it is recommended that temperatures be monitored upstream of the site and predictions be made over as short a period of time as possible, i.e., average the previous day's data to predict the following day's average temperature. This is motivated by the need to know the initial temperature in the analysis for the entire travel time of water through that portion of the stream being simulated.

These predictions are useful to a plant operator making day-to-day decisions as opposed to a planner predicting conditions to occur several years in the future using an historical weather data base.

This work indicates that for the Vernon plant such predictions will have error within 2 ^{o}F (1.11 ^{o}C) 90 percent of the time. Smaller streams may have greater effects from meteorological parameters, which were not found from the Vernon problems. It is also recommended that similar sensitivity analyses be performed for two-dimensional models used for predicting temperatures in lakes, estuaries, and cooling ponds.

SECTION III

INTRODUCTION

PURPOSE

Stream temperature is an important factor in water quality. The temperature of the stream directly controls the types and amounts of plant and animal life native to it. In recent years there has been an increased interest in water quality by the public. In response to this interest a very large effort has been mounted to develop mathematical models for predicting heat assimilation in bodies of water.

Models have been developed for predicting temperatures in streams, cooling ponds, reservoirs, estuaries, and large lakes (See, for example, the review by Policastro and Tokar [1972]). Usually, a stream model assumes a one-dimensional problem with uniform mixing and with various modes of heat transport at the air-water interface simulated by semi-emperical expressions. In addition, the problem is generally treated as one in a steady-state condition, i.e., the formulation involves a relationship between the flow rate and the position downstream from an initial point, x, allowing the independent variable to be chosen as the variable x while the time variable becomes implicit to the problem. While the development of stream models is straight-forward, their use is subject to a great deal of interpretation and judgement (See, for example, Asbury [1970]).

The purpose of this study is to determine the effects of variations in initial temperature and meteorological data on results of mathematical models for predicting stream temperatures.

SCOPE

Three principal problems inherent in model use to predict heat assimulation are:

1. The extrapolation of weather station meteorological data to the site under study is subject to considerable variance.

2. There is usually a lack of data from which to compute the evaporation and other heat transfer rates for a stream.

3. The temporal variations of the data cause large variations in short-term predictions.

In addition to these, we find that the spatial and temporal variations of temperature in the environment without the addition of a heat load may be greater than either the requirements set by a regulatory agency or the errors inherent in the model, i.e., there is a question as to what the ambient values really are. Local variations in topography and/or tree cover can shade the stream and cause effective incoming and outgoing radiation areas to be reduced. The accuracy of instruments used to measure the various physical quantities is always subject to review. Ground water advection can be an influential transport process, but it is almost impossible to measure. Finally, the large amount of data taken for any site provides a good probability for human error in recording or transposition.

This study considered the three principal problems listed above by using a sensitivity analysis of a general, one-dimensional stream model. This was combined with data analysis techniques to compute the probabilities of meeting given error requirements. Data from the Vernon, Vermont nuclear plant and the Burlington, Vermont weather station were used to form a data base, from which four example problems were obtained and evaluated.

SECTION IV

MODEL DESCRIPTIONS

THE GENERAL STREAM MODEL

The stream model used for the study is one-dimensional with the independent variable being the distance downstream, x . This model is simple enough that a general version of it can be considered that encompasses all one-dimensional models now in existence. A discussion of this concept is given in Appendix D.

All one-dimensional models take a basic form as shown in Figure 1 and are described by the equation:

$$\frac{uA}{\ell}\frac{dT}{dx} = [Q_{Rad} - Q_{Ref} - Q_{Back} - Q_{Evap} - Q_{Conv} + Q_{Mis}] \tag{1}$$

where the variables are as defined in Section VIII, Symbols and Variable Names, and the water is fully mixed at each cross section. Any departure from the form of equation (1) due to direct integration, approximations to the heat fluxes Q , etc., can be shown by a Taylor's expansion to be proportional to some power of the mesh size. (See Appendix D). Put simply, as the number of stations or data points in the models are increased they will all produce results converging toward the same solution, provided that total heat fluxes and the heat transfer coefficients are the same. The fundamental heat flux expressions used in this work are taken from Laevastu [1960], where the processes are linearized in T . Not all authors use linearized expressions (See for example Jaske [1971]). However, numerical experience shows that if the temperature variations are small, i.e., small with respect to absolute temperatures, and of course they always will be, it is justified to linearize the expressions, including the fourth power terms in the back radiation fluxes.

The concept of using a simple, general model was considered essential in this work, since it reduced the study from a huge data handling problem for many models to the study of a single, general model whose error analysis applies equally well to all models in question, provided a convergent mesh size (station length) is specified.

The expressions for the heat fluxes from Laevastu [1960] are:

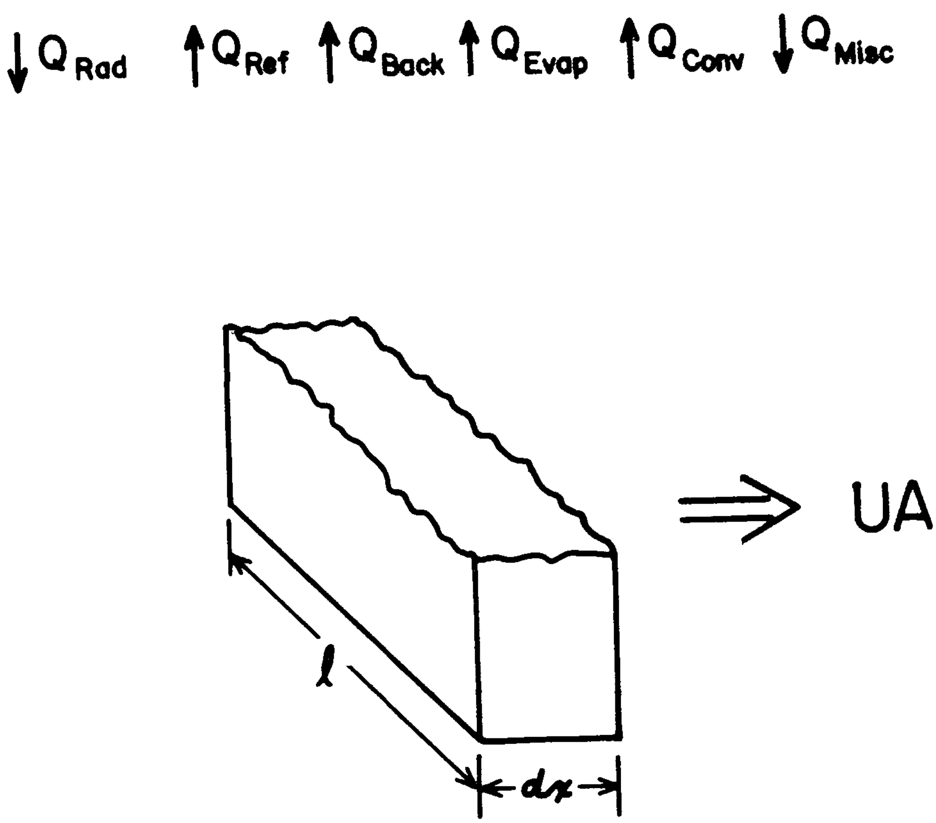

Figure 1. Control volume for stream model

$$Q_{Solar} = 1.9 \sin \bar{\alpha} \; (1 - 0.0006 \; C^3)(0.061) \quad ,$$

$$Q_{Reflected} = \frac{3}{\bar{\alpha}} Q_{Solar} \; (0.061) \quad ,$$

$$Q_{Back} = (1.0 - 0.765 \; C)(14.38 - 0.09 \; (\frac{5}{9} \; (T - 32) - 0.046\phi)(\frac{1}{69.72}) \quad ,$$

$$Q_{Evaporation} = \frac{\rho \; h_{fg}}{240} \; (0.35)(1.0 + 9.8 \times 10^{-3} \; W_2)(e_W - e_a) \quad ,$$

$$Q_{Convection} = 39.0(T - T_a)(0.26 + 0.077 \; W_2) \; \frac{5}{9} \; (0.061) \quad . \tag{2}$$

The definitions are given in Section VIII. It should be noted here that the coefficients from these terms are largely based on empirical data and in many cases will vary considerably. However, as is seen in Section VI, the sensitivity analysis reveals little change in temperature decay rates with considerable change in these flux expressions for the Connecticut River. For smaller streams, this would not be the case.

THE SENSITIVITY ANALYSIS MODEL

In order to study the errors in stream temperature produced by the errors in input data, it is necessary to develop certain error expressions from equation (1). These are developed in view of the two fundamental definitions from Rosko [1972]:

1. Accuracy is defined as conformity of fact.

2. Precision is defined as sharpness of definition.

In the case of this work then, accuracy refers to the convergence of the solution to the actual stream temperature. Similarly, precision refers to the rate of convergence.

The sensitivity, or error, analysis required for the work was developed from equation (1) by making a small change, or variation, in the variables. Equation (1) can be rewritten symbolically as

$$\frac{dT}{dx} = \frac{\ell}{Au} Q \quad . \tag{3}$$

A variation of both sides of this equation yields

$$\frac{d\ \delta T}{dx} = \frac{\ell}{Au}\,\delta Q \quad , \tag{4}$$

where it is assumed that the flow rate and stream width are known and that the process described is linear in its variation. If the error in temperature, $\delta T(o)$, is known at the initial point, it is apparent that, given the errors in the heat fluxes, δQ, the error at any given point downstream can be computed from equation (4) by a direct computation.

It is important to note that, if approximate values of the coefficients in equation (4) are obtained as constants, the equation can be solved in closed-form,

$$\delta T = A \exp[-\alpha x] + \sum_i C_i \quad .$$

Results of an analysis of this type are presented in Section VI.

THE DATA ANALYSIS MODELS

Previous sections have described the mathematical model studied and the sensitivity analysis model. The first of these models, or close variations of it, has been used extensively to predict the mean temperatures of streams. The sensitivity analysis model has the capability of predicting the error in the mean temperature at a point downstream, given the corresponding errors in the mean initial condition for temperature and the mean meteorological conditions. Thus, the mathematical models were available for a study, setting the stage for the data analysis.

The philosophy of the data analysis emerged from the concepts of probability. As has been shown by Hogan et al. [1972], it is unrealistic to establish the error in the estimate of the mean temperature deterministically. Rather, the statement must read to the effect:

> If the errors in the heat fluxes $|\delta Q|$ and the error in initial mean temperature $|\delta T(o)|$ are constrained in size to given values, then the probability that the error in mean stream temperature $|\delta T| \leq 1/n\ ^oC$ will be P_1, $|\delta T| \leq 1\ ^oC$ will be $P_2 (P_2 > P_1)$.

Put simply, for given errors in the initial mean temperature and the meteorological data, it is possible to determine the probability of meeting a given error requirement. This can be done by using the sensitivity analysis model, which appears to be a very realistic approach to assessing the effects of the introduction of a heat load.

The methods employed in the data analysis are best visualized by using Figure 2, where the six primary variables are illustrated. The effect of errors in these variables is shown schematically in the figure, where the initial error δT is seen to decrease with increasing x . By collecting a data base of these variables over a period of several months, it was possible to make use of the sensitivity analysis to compute the error in temperature for a number of trials, based on moving averages. With an increasing number of trials the probability, P , that $|\delta T|$ is less than some given error in temperature can be estimated from:

$$P \doteq \frac{\text{Number of trials with } |\delta T| < \text{given value}}{\text{Total number of trials}} \quad . \quad (5)$$

Figures 3 and 4 illustrate the methods for utilizing the data base to evaluate equation (5). Figure 3 shows schematically the data base at an airport weather station remote to the site, in this case the Burlington, Vermont weather station. These data are collected together with the stream temperatures at the site every three hours, eight points per variable per day. These data are averaged over a specified number of previous days, then compared with the respective averages over the day following to form the errors in the input variables, $\delta\phi$, etc. The sensitivity analysis is then used to predict the errors in temperature downstream. These are then compared with the given temperature error requirement and the components of equation (5) computed. It should be noted here that this model simulates the errors of an observer at the site attempting to predict the temperature several days ahead.

Figure 4 shows schematically the second data analysis model, where the data base includes 1) the remote weather station data, 2) the stream temperatures at the site, and 3) the average daily stream temperature above the site (See Figure 5, station 7). In this case the daily average of the station 7 temperature is compared with the following day's daily average temperature at the site. Meteorological data are averaged in an analogous manner, i.e., daily averages compared for two consecutive days. These form the errors in the input variables. The sensitivity analysis is then used to predict the errors in temperature downstream, these are compared with the given temperature error requirements, and the components of equation (5) computed. This

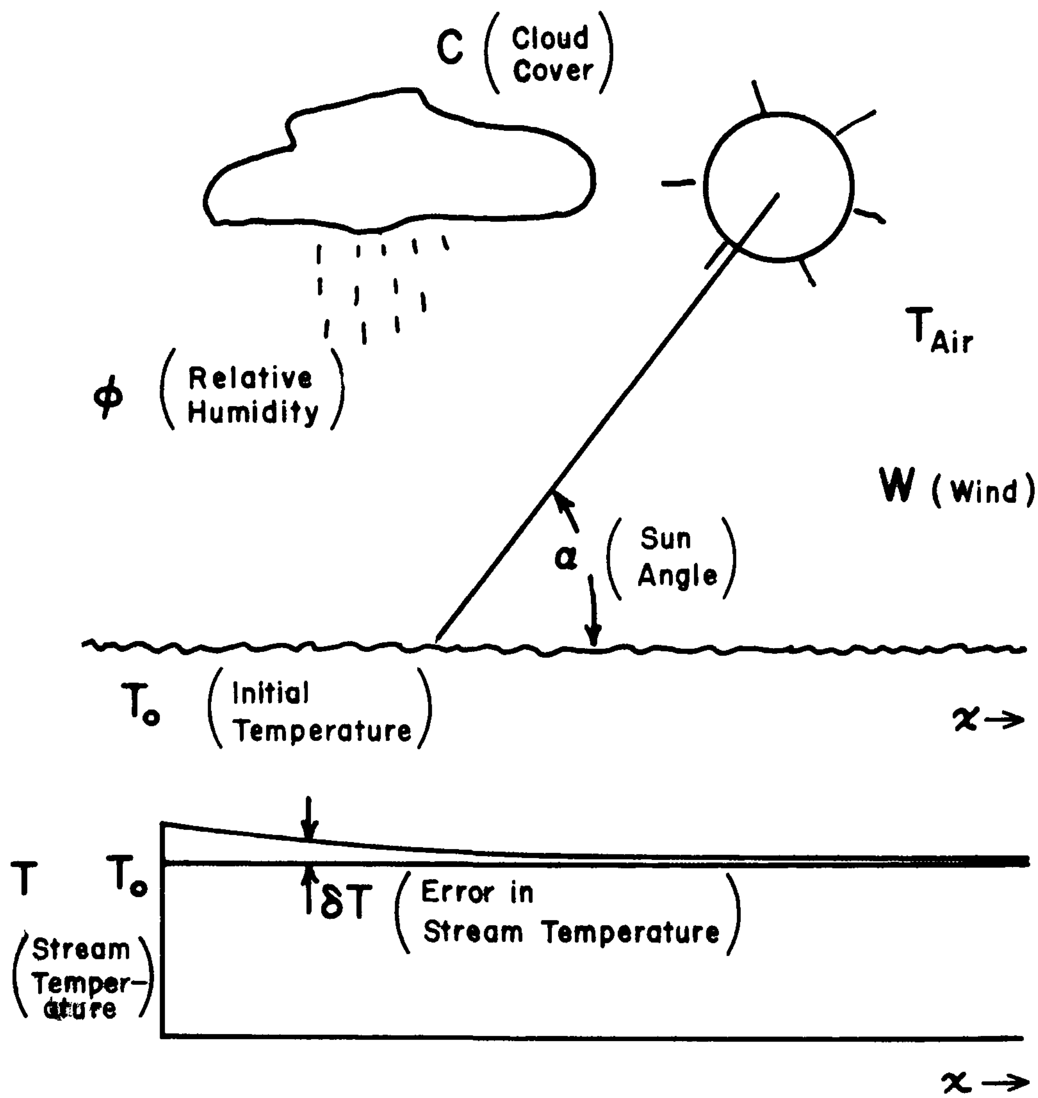

Figure 2. Six primary meteorological and site variables

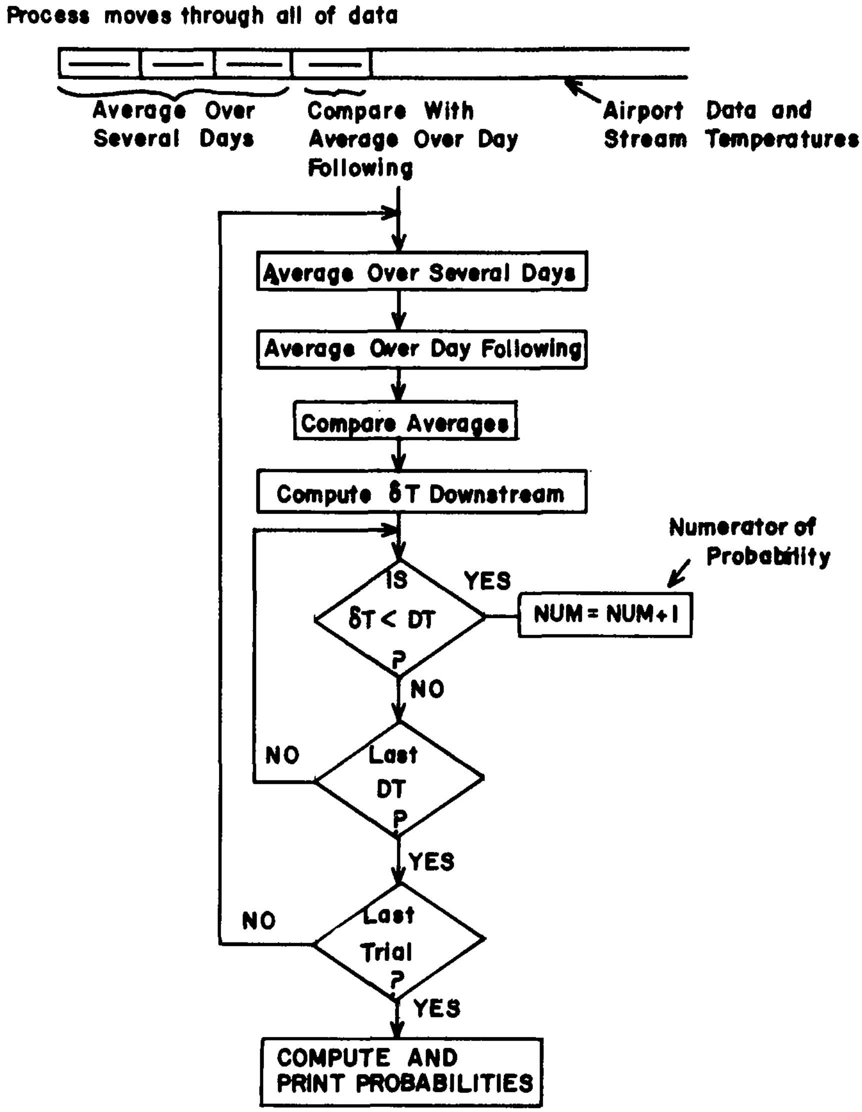

Figure 3. Model using site water temperature data

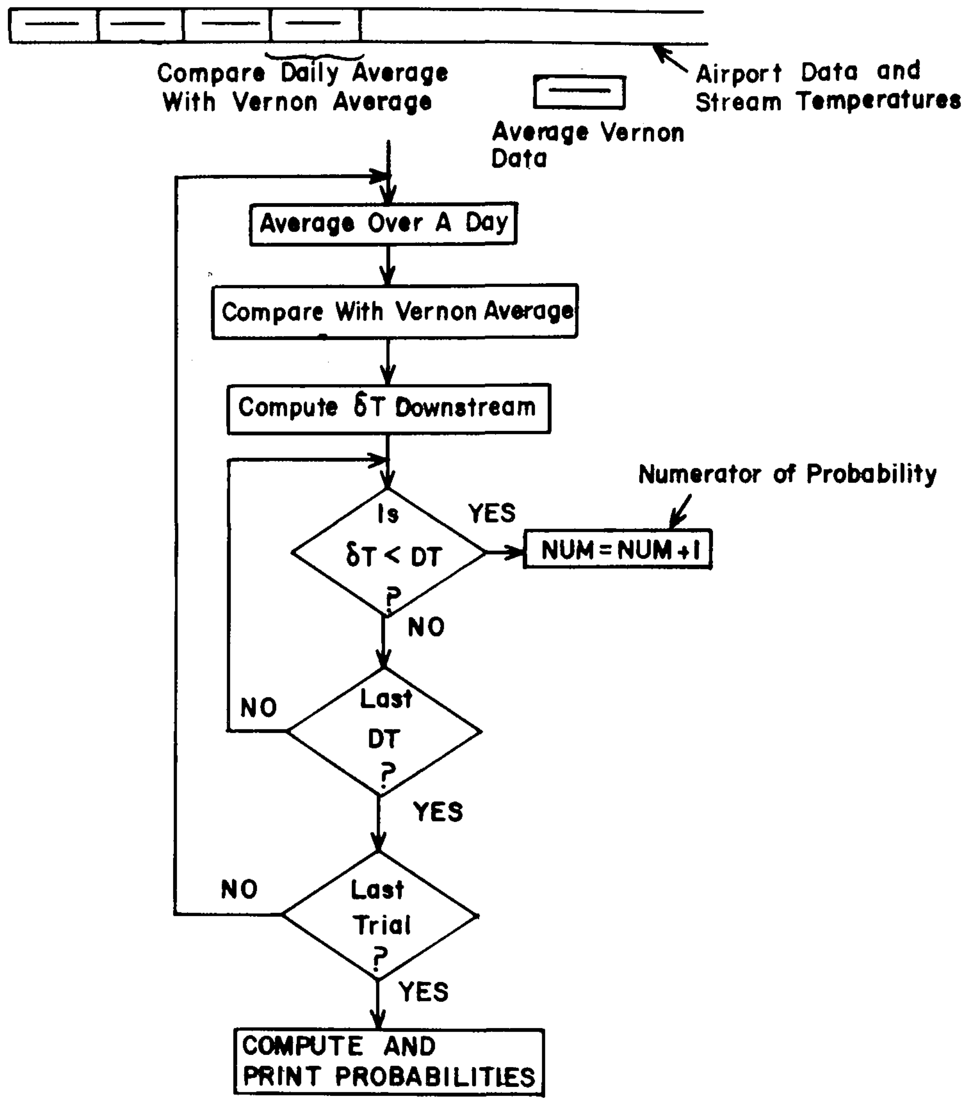

Figure 4. Model using site and station 7 temperature data

model simulates the errors of an observer remote to the site attempting to predict the site stream temperature one day ahead.

SECTION V

STUDY AREA AND METHODOLOGY

THE VERNON NUCLEAR PLANT

A program of ecological studies of the Connecticut river in the vicinity of Vernon, Vermont was initiated in 1967, prior to the operation of the Vermont Yankee Nuclear Powerplant. The preoperational studies were enlarged in scope in subsequent years and were continued after the plant became operational in October 1972. The location of the plant is shown in Figure 5, where the positions of short-term and long-term sampling stations are shown. The particulars of these sampling stations are as follows:

Station No.	Location Relative to Vernon Dam	Type
1	6.45 Miles (10.4 Km) South	Short-term
2	4.70 Miles (7.56 Km) South	Short-term
3	0.65 Miles (1.05 KM) South	Long-term
4	0.55 Miles (0.89 Km) North	Short-term
5	1.25 Miles (2.01 Km) North	Short-term
6	4.10 Miles (6.60 Km) North	Short-term
7	4.25 Miles (6.84 Km) North	Long-term
8	8.70 Miles (14.0 Km) North	Short-term

Stations 3 and 7 are permanently emplaced below and above the site respectively. Stations 3 and 7 yielded the water temperature data used in the study while meteorological data were obtained from instruments at the plant and in Keene, New Hampshire.

DATA BASE DESCRIPTION

The data base used in the project was taken from four sources:

1) Measured water temperatures at the site (See Aquatec [1974]),

2) Measured meteorological data at the site (Personal communications) ,

3) Meteorological data from Brattleboro, Vermont and Keene, New Hampshire (U.S. Weather Service),

4) Meteorological data at the Burlington, Vermont weather station (U.S. Weather Service).

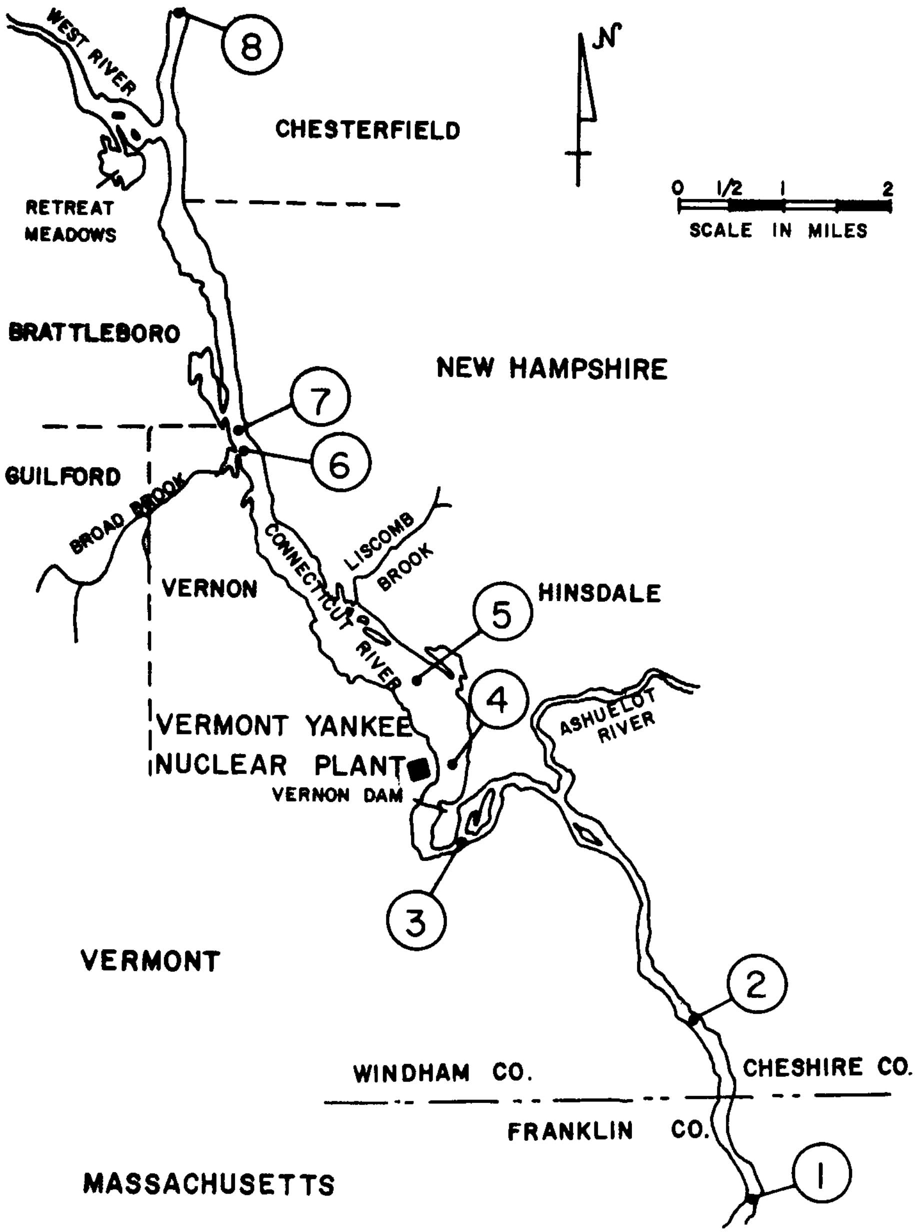

Figure 5. The Vernon nuclear plant-temperature sampling stations

The data base variables and dates for the Vernon plant example problems are as follows:

1. Burlington, Vermont Weather Station data and Vernon, Vermont water temperature data:

   <u>Variables</u>

   Cloud cover, air temperature, relative humidity, wind speed, water temperature from stations 3 and 7.

   <u>Dates of Available Data</u>

   a) May 1, 1973 to June 20, 1973

   b) August 15, 1973 to August 31, 1973 and September 12, 1973 to September 26, 1973.

   c) October 1, 1973 to October 3, 1973, October 17, 1973 to October 24, 1973, and October 27, 1973 to October 29, 1973.

   d) October 17, 1973 to October 24, 1973, October 27, 1973 to October 29, 1973, and November 1, 1973 to November 14, 1973.

2. Vernon, Vermont (and vicinity) site meteorological data:

   <u>Daily Average Variables</u>

   Cloud cover, air temperature, relative humidity, wind speed.

   <u>Dates of Available Data</u>

   June 21, 1973

   September 27, 1973

   October 30, 1973

   November 15, 1973

EXAMPLE PROBLEMS

Four example problems were constructed from the data base previously discussed. They represented spring, summer, fall and winter conditions at the Vernon Nuclear Plant. The days studied were June 21, September 27, October 30, and November 15, 1973. The dates of the data blocks were as labeled a), b), c) and d) above in the previous section "Dates of Available Data." Computations were carried out to a point 25000 feet (7620 meters) downstream from the initial point in the model ($x = 0$).

SECTION VI

DISCUSSION OF RESULTS

In addition to the analyses described in Section IV, the Data Analysis Models, an order-of-magnitude error analysis was carried out using the closed-form solution developed from equation (4).

ORDER-OF-MAGNITUDE ERROR ANALYSIS

In order to gain insight into the solution of equation (4), it was logical to simplify the form of the equation and obtain a closed-form solution

$$\delta T = A e^{-\alpha x} + \sum_i C_i \quad , \qquad (6)$$

where the C_i are the respective particular solutions associated with the errors $\delta\phi$, etc., and the constant A is related directly to the error in water temperature $\delta T(o)$ at the site, $x = 0$. The coefficient α then reveals the rate of decay of the error in temperature with distance. The June 21, 1973 averaged data were taken as an example problem:

$$
\begin{aligned}
uA \text{ (Rate of flow)} &= 13{,}503 \text{ ft}^3/\text{sec} \quad ,\\
El \text{ (River width)} &= 400 \text{ ft} \quad ,\\
C \text{ (Cloud cover)} &= 8 \text{ tenths} \quad ,\\
\bar{\alpha} \text{ (Sun angle)} &= 59^\circ \quad ,\\
\phi \text{ (Relative humidity)} &= 71 \text{ percent} \quad ,\\
W_2 \text{ (Wind speed)} &= 10 \text{ MPH} \quad ,\\
T_{air} \text{ (Air temperature)} &= 75\ ^\circ\text{F} \quad . \qquad (7)
\end{aligned}
$$

These data were compared with the averaged data of May 31, 1973 to obtain the errors in the variables between these two days. This was done arbitrarily to examine the order-of-magnitude of the resulting errors in temperature. The input errors are:

δC (Error in cloud cover) = 2 tenths ,

$\delta \overline{\alpha}$ (Error in sun angle) = 5° ,

$\delta \phi$ (Error in relative humidity) = 29 percent ,

δW_2 (Error in wind speed) = 5.2 MPH ,

δT_{air} (Error in air temperature) = 16 $^{\circ}F$. (8)

Thus, the problem will yield approximate errors for predicting the water temperature on June 21, 1973 given the meteorological data from May 31, 1973. Of interest are the solutions C_i of equation (6), which are due to the respective errors in equation (8). They are found from equation (4) and Appendix D to be

1. δT_{CP} = 10.2 $^{\circ}F$,
2. $\delta T_{\overline{\alpha}P}$ = 1.71 $^{\circ}F$,
3. $\delta T_{\phi P}$ = 0.357 $^{\circ}F$,
4. δT_{w2P} = 1.33 $^{\circ}F$,
5. $\delta T_{T_{airP}}$ = 19.63 $^{\circ}F$. (9)

Similarly, from the same source the coefficient α can be found:

$$\alpha = 0.947 \times 10^6 \quad . \tag{10}$$

The corresponding value of x where the value of δT falls below 5 percent of the original value at $x = 0.$ is

$$x = 3{,}170{,}000 \text{ feet} \quad ,$$

(966,000 meters)

$$\doteq 600 \text{ miles} \quad . \tag{11}$$

(966 kilometers)

This order-of-magnitude study indicates important facts associated with the Vernon site:

1. Modeling the Connecticut river, which has a large flow rate in comparison with its width, produces a solution that will have errors decaying over a very long distance. This means that the error in temperature will remain virtually constant near $x = 0$.

2. The computations are far less sensitive to the environmental factors than thought previously.

3. Since the error in temperature is nearly constant near $x = 0$, the variable of primary concern is the initial error in temperature $\delta T(o)$. Thus, it appears that records of upstream temperatures in the Connecticut river would be useful for projecting average temperatures downstream.

4. Since α is inversely proportional to the volume flow Au it is possible to compute the value of α for the various flow rates, given a known flow-rate A_1U_1 and associated α , α_1 :

$$\alpha = \alpha_1 \frac{A_1U_1}{Au}$$

   This expression will yield the stream flow for which a given decay rate will exist.

RESULTS OF DATA ANALYSES

The results of the four data analyses are presented in the form of probabilities for meeting given error requirements with the variables averaged over a given number of prior days. Tables I, II, and III contain results from all four problems. It should again be emphasized that these results relate to a plant operator making decisions as to the operating conditions of a given plant as opposed to a site planner predicting conditions several years in advance. As indicated on the tables, the river temperatures and the meteorological parameters are averaged over one and two days respectively.

Results in Table I indicate that an observer at the site attempting to predict the average stream temperature the following day at a position 25,000 feet (7,620 meters) downstream by averaging the previous day's meteorological data and stream temperature data would compute an

Table 1. PROBABILITIES OF MEETING GIVEN ERROR REQUIREMENTS BY AN OBSERVER AT THE VERNON SITE AVERAGING ONE DAY AND PREDICTING ONE DAY AHEAD AT A DISTANCE OF 25,000 FEET(7620 METERS) DOWNSTREAM

	Error Requirement $^{\circ}F$ ($^{\circ}C$)			
	$1^{\circ}F$ ($0.56^{\circ}C$)	$2^{\circ}F$ ($1.11^{\circ}C$)	$3^{\circ}F$ ($1.67^{\circ}C$)	$4^{\circ}F$ ($2.22^{\circ}C$)
June 21, 1973	0.6	0.9	0.94	1.0
September 27, 1973	0.613	0.935	0.963	0.968
October 30, 1973	0.769	0.923	0.923	0.923
November 15, 1973	0.75	1.0	1.0	1.0

Table 2. PROBABILITIES OF MEETING GIVEN ERROR REQUIREMENTS BY AN OBSERVER AT THE VERNON SITE AVERAGING TWO DAYS AND PREDICTING ONE DAY AHEAD AT A DISTANCE OF 25,000 FEET (7620 METERS) DOWNSTREAM

	Error Requirement °F (°C)			
	1°F (0.56°C)	2°F (1.11°C)	3°F (1.67°C)	4°F (2.22°C)
June 21, 1973	0.469	0.694	0.898	0.980
September 27, 1973	0.533	0.867	0.933	0.967
October 30, 1973	0.5	0.833	0.833	0.917
November 15, 1973	0.522	0.957	1.0	1.0

Table 3. PROBABILITIES OF MEETING GIVEN ERROR REQUIREMENTS BY AN OBSERVER AT STATION 7 ONE DAY AHEAD AT THE VERNON SITE (SAME POSITION AS STATED FOR TABLE 2)

	Error Requirement °F (°C)			
	1°F (0.56°C)	2°F (1.11°C)	3°F (1.67°C)	4°F (2.22°C)
June 21, 1973	0.520	0.800	0.880	0.960
October 30, 1973	0.846	0.923	0.923	0.923

approximate stream temperature within an error of 2 °F (1.11 °C) between 90 and 100 percent of the time. He would compute an approximate stream temperature within an error of 1 °F (0.56 °C) between 60 and 77 percent of the time.

Table II shows that the same observer at the site making the same prediction of an average temperature as made in Table I but using the average of two prior days' data would compute an approximate stream temperature within an error of 4 °F (2.22 °C) between 92 and 100 percent of the time. He would predict within an error of 3°F (1.67 °C) between 83 and 100 percent of the time. Similarly, a 2 °F (1.11 °C) error would be obtained between 69 and 96 percent of the time. Finally a 1 °F (0.56 °C) error would be obtained between 47 and 53 percent of the time.

Table III shows that an observer using data from station 7 above the Vernon dam, attempting to predict stream temperatures at the Vernon site by averaging a day's station 7 water temperature would compute an approximate stream temperature within an error of 4 °F (2.22 °C) between 92 and 96 percent of the time. He would predict within 3 °F (1.67 °C) between 88 and 92 percent of the time, within 2 °F (1.11 °C) between 80 and 92 percent of the time. Finally, he would predict within 1 °F (0.56 °C) between 52 and 85 percent of the time.

Thus, it is seen that predictions made at the site (with a daily average) a short period of time into the future are accurate over 90 percent of the time for a 2 °F (1.11 °C) allowable error. Averaging data over a two day period of time reduces the probability of meeting the 2 °F (1.11 °C) error to around 80 percent, which appears to be a primary influence of the travel time through this portion of the Connecticut river system, one to two days. These studies indicate that it is important to have good records of upstream temperatures from a site. With these it will be possible to predict an average temperature within 2 °F (1.11 °C). It is important to note, however, that short term fluctuations are not predictable by these methods as used in the project. Finally, the effects of season do not appear to make appreciable differences in predictions.

SECTION VII

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SECTION VIII

SYMBOLS AND VARIABLE NAMES

VARIABLE NAMES

a - General integration limit.

A - Stream cross-sectional area.

A,$\bar{A}$ - Amplitude of exponential decay function.

C - Cloud cover.

C_i - Constants.

c - Specific heat.

DT - Allowable error in stream temperature.

f - Function of several variables.

$\dot{f}$ - Derivative of f($\dot{f}$ = df/dx)/

h - Integration step.

I_1, I_2 - Integrals.

K_i - Kernel function.

ℓ, EL - Stream width.

n - Integer number.

O(-) - Of order(Order of magnitude).

P, P_i - Probability of occurence.

Q - Total heat flux.

Q_i, Q_{ij} - Particular heat fluxes.

Q_{Back} - Back radiation heat flux.

Q_{Conv}, $Q_{Convection}$ - Convective heat flux.

Q_{Evap}, $Q_{Evaporation}$ - Evaporative heat flux.

$Q_{Mis(c)}$ - Miscellaneous heat flux.

Q_{Rad}, Q_{Solar} - Radiative solar heat flux.

Q_{Ref}, $Q_{Reflective}$ - Reflective heat flux.

T - Stream temperature.

T_O - Initial stream temperature.

U,u - Average stream flow velocity.

W, W_2 - Wind speed.

x - Distance downstream.

x_i - Particular position.

$\hat{x}$ - Particular value of x.

x_{max} - Maximum value of x.

y - General function.

$\dot{y}$ - Derivative of general function.

y(0), y_o - Initial value of general function.

y_i - Value of function at x_i.

z - Dummy variable of integration.

GREEK SYMBOLS

α - Decay rate coefficient.

α, $\bar{\alpha}$ - Sun angle.

δC - Error in cloud cover.

δQ - Error in total heat flux.

δT - Error in stream temperature.

$\delta T(0)$ - Initial error in stream temperature.

δT_{air} - Error in air temperature.

δT_{airp} - Particular solution for air temperature error.

δT_{cp} - Particular solution for cloud cover error.

δT_i - Particular solution.

δT_{W2p} - Particular solution for wind speed error.

$\delta T_{\bar{\alpha}p}$ - Particular solution for sun angle error.

$\delta T_{\phi p}$ - Particular solution for relative humidity error.

$\delta W, \delta W_2$ - Error in wind speed.

$\delta\bar{\alpha}$ - Error in sun angle.

$\delta\phi$ - Error in relative humidity.

Δx - Increment in downstream distance.

ϕ - Relative humidity in percent.

ρ - Density.

ξ - Position.

APPENDIX A

FORMAT SPECIFICATIONS

This appendix presents the procedures required for using the three codes developed during the course of the project:

1. The general stream model code, STREAM.

2. The sensitivity analysis code, SENSIT.

3. The data analysis code, MONT.

STREAM

The digital computer code STREAM performs all the necessary computations to predict the stream water temperature at any distance downstream from a given initial station. The principle of conservation of energy is applied to the stream under steady-state, steady-flow conditions. Heat transfer to and from the water in the various heat transfer modes is computed. Numerical integration is used to compute the stream temperature, with a choice of four algorithms available to the user. A listing of the STREAM code is given in APPENDIX C.

INPUT REQUIREMENTS TO STREAM

STREAM accepts the following information:

INTC: (1, 2, 3 or 4) in 6I10 FORMAT. This parameter respectively chooses Euler, Modified Euler, Runge Kutta or Adams-Moulton integration routines.

X, DX, DXPR, XEND: in 6E10.0 FORMAT. These parameters are, respectively, the initial value of the distance downstream in feet (usually 0.), the integration interval in feet, the print interval in feet, and the final value of the distance downstream in feet.

ERRØR, DXMAX: in 6E10.0 FORMAT. These parameters are used by the integration routine only and represent the error in the function in ^{o}F and the maximum integration step size in feet allowed.

TEMP, U, AREA, EL: in 6E10.0 FORMAT. These parameters are, respectively, the initial value of the temperature in ^{o}F, the average velocity of the stream in ft/sec, the cross-sectional area of the stream in ft^2, and the stream width in feet.

RHO, WMPH, TAIR, CLD, RH, ALBAR: in 6E10.0 FORMAT. These are, respectively, the density of the water (62.4 $\#/ft^3$, here), the wind speed in MPH, the air temperature in ^oF, the cloud cover in tenths, the relative humidity in percent, and the average sun angle in degrees.

The final information is read in a loop of 10 sets:

PTBL(I), TTBL(I), HFGTB(I) in 6E10.0 FORMAT. These tables are, respectively, the water saturation pressure table in PSI, the water temperature table in ^oF, and the latent heat of evaporation table in BTU/pound, all corresponding and in order. This information is extracted from standard steam tables for the temperature range 32 to 120 ^oF.

The code then computes the stream temperature downstream from a given point. The output proceeds at each print position with the position X itself, the integration step DX , the stream temperature TEMP, and the derivative of the stream temperature with respect to the position variable DTEMP. Following this, other auxilliary variables are printed out: EW, EVAP, HE, HFG, HØ, EBR, and HC. These are only important for diagnostics, not the solution itself.

SENSIT

The digital computer code SENSIT performs all necessary computations to predict the error in the stream water temperature (due to the difference between the actual and approximate input data) at any distance downstream from a given initial station. The variation in the original equation is coded to examine the effects of errors of the input variables. Numerical integration is used to compute the error in stream temperature, with a choice of four algorithms available to the user. A listing of the SENSIT code is given in APPENDIX C.

INPUT REQUIREMENTS TO SENSIT

SENSIT accepts the following information:

INTC: In 6I10 FORMAT. This variable is the integration routine to be used (See STREAM for description).

X, DX, DXPR, XEND: In 6E10.0 FORMAT (See STREAM for description).

ERROR, DXMAX: In 6E10.0 FORMAT (See STREAM for description).

DT, U, AREA, EL: In 6E10.0 FORMAT. The initial temperature error DT is read in at this point (other variables are described in STREAM).

RHO, WMPH, TAIR, CLD, RH, ALBAR: In 6E10.0 FORMAT (See STREAM for variable description).

PTBL(I), TTBL(I), HFGTB(I): In 6E10.0 FORMAT (See STREAM for variable description).

DALP, DCLD, DRH, DTAIR, DWMPH: In 6E10.0 FORMAT. These variables are the errors in the respective values of the sun angle in degrees, the cloud cover in tenths, the relative humidity in percent, the air temperature in ^{o}F, and the wind velocity in MPH.

NTEMP: In 6I10 FORMAT. This is the number of temperatures given downstream.

STTBL(I), XTBL(I): In 6E10.0 FORMAT. These tables are, respectively, the water temperature and the position downstream in NTEMP sets.

The code then computes the error in the stream temperature downstream from a given point. The output proceeds at each print position with the position X itself, the integration step DX , the stream temperature TEMP, the error in the stream temperature DT, and the derivative of the error in stream temperature DDT .

Following this some auxilliary variables are also printed out: EW, DEW, EVAP, HE, HFG, HØB, HC, HLYMN, and HD, which are important for diagnostics, not for the solution itself,

MONT

The digital computer code MONT performs all the necessary calculations to obtain the probabilities for meeting a given temperature requirement. The code takes prepared data and makes a series of trials, forming data differences, and uses the sensitivity analysis code, SENSIT, to obtain the stream temperature difference at a prescribed distance downstream (in this case 25,000 feet [7620 meters]). The code makes three studies:

1. Computes the probability of meeting given error requirements given in both initial water temperature and meteorological data at the site.

2. Computes the probabilities of meeting given error requirements given errors from water temperature and meteorological time averaged data at the site.

3. Computes the probabilities of meeting given error requirements given errors from water temperature and meteorological data at a remote site, in the case of this study, at station 7 above the nuclear plant. A list of the MONT code is given in APPENDIX C.

INPUT REQUIREMENTS TO MONT

MONT accepts the following information:

NLN, LOG1: In 6I10 FORMAT. The first variable is the number of lines of data (taken every 3 hours, 8 data points per day, each day always complete); the second variable is 0 if no time averaged data appears, not zero if time averaged data appears.

Following these integer variables the major part of the data is read for the remote airport and the site water temperature in a loop of NLN lines as follows:

C(I), TA(I), PHI(I), W(I), TW(I): In 6F10.3 FORMAT. The variables are: 1) the cloud cover in tenths, 2) the air temperature in $^{\circ}F$, 3) the relative humidity in percent, 4) the wind speed in knots, and 5) the site water temperature in $^{\circ}F$.

Next, the average data for the actual site and the particular day are input:

UA, EL, CC, TAIR: In 6F10.3 FORMAT. These variables are 1) the flow volumes of the river in ft^3/sec, 2) the river width in ft, the cloud cover in tenths, and the air temperature in $^{\circ}F$.

TWA, RH, WSP: In 6F10.3 FORMAT. These variables are 1) the water temperature in $^{\circ}F$, 2) the relative humidity in percent and 3) the wind speed in knots.

If LOG1 = 0 the next two sets of data are not necessary. If LOG1 $\neq$ 0 the next two sets of data for the dates of past years prior to the date in question (the time-averaged data).

NTA: In 6I10 FORMAT. This value is the number of lines of time averaged data.

Following this NTA lines of data are read in as follows:

CTA(I), TATA(I), PHITA(I), WTA(I), TWTA(I): In 6F10.3 FORMAT. The variables are 1) the cloud cover in tenths, 2) the air temperature in ^{o}F, 3) the relative humidity in percent, 4) the wind speed in knots, and 5) the water temperature in ^{o}F.

Following this, the data describing the analysis are read in:

NCAS: In 6I10 FORMAT. This is the number of cases of temperature to be used in the trials.

DELT(I), I=1, NCAS: In 6E10.3 FORMAT. These are input in sequence, the first six values of allowed temperature on the first line, the second six on the second line, etc.

NDAS: In 6I10 FORMAT. This is the number of day cases to be tried.

IDAS(I), I=1, NDAS: In 6I10 FORMAT. These are the number of days of data to be averaged in each day case. They are input in sequence, six values per line.

Following this, 10 lines of data are input for the sensitivity analysis program, which is a subroutine in this case.

PTBL(I), TTBL(I), HFGTB(I): In 6E10.3 FORMAT (See STREAM for variables description).

The next data to be input are 1) the number of days since March 21 (the vernal equinox) which is required to estimate the coefficient involved with the sun heating effect, and 2) the latitude of the plant in degrees:

DM21, BETA: In 6E10.0 FORMAT.

The last data to be input are the daily average of the water temperature at the remote site:

T7(I), I=1, Number of Days in 6E10.3 FORMAT.

The code then computes the errors in the stream temperature downstream from a given point considering the days to be averaged as requested. Three sets of input errors are examined:

1. The airport meteorological data and stream temperature against itself (simulating values at a site).

2. The time-averaged meteorological and stream temperature data against the site data.

3. The airport meteorological data and the remote site water temperature data against the site data water temperatures (simulating predictions from a distance).

These are compared to the requirements on temperature for each case. The number of cases for which the requirements are satisfied are recorded and printed out in the form of probability values.

APPENDIX B

INPUT DATA

This Appendix contains the input for the four example problems.

EXAMPLE PROBLEM INPUT

The input for the four example problems has the following format:

1. The number of lines of data, 8 lines per day (3 hour intevals).

2. The time averaged data logic parameter (1 means time averaged data appears, 0 means no time averaged data appears).

3. The data now appears by line as follows:

   a) Cloud cover in tenths.

   b) Air temperature in ^{o}F.

   c) Relative humidity in percent.

   d) Wind speed in knots.

   e) Water temperature ^{o}F.

4. The average data (over a day) for the plant site then is:

   a) The flow volume, UA, ft^3/sec.

   b) The river width, EL, ft.

   c) The cloud cover at the site in tenths.

   d) The air temperature ^{o}F

   e) The water temperature ^{o}F.

   f) The relative humidity in percent.

   g) The wind speed in knots.

5. If time-averaged data appears the following then is required:

   a) The number of time-averaged data lines.

   b) The lines of data as follows

      1) Cloud cover in tenths.

      2) Air temperature ^{o}F.

      3) Relative humidity in percent.

      4) Wind speed in knots.

      5) The water temperature in ^{o}F.

6. The control data for the data analysis is next.

   a) The number of cases of error in temperature.

   b) The allowed errors in temperature.

   c) The number of cases for days of data to be averaged.

   d) The actual number of days of data to be averaged.

7. The tables of vapor pressure and latent heat (no changes except for very unusual conditions).

8. The days to the date in question past March 21.

9. The latitude of the site in degrees.

10. The daily averages of the water temperatures at the remote site. In this case station 7.

PRINTOUT FOR THE FOUR EXAMPLE PROBLEMS

JUNE 21, 1973

MAY 1 to JUNE 20, 1973

RUN

NUMBER OF DATA LINES= 40RTIME AV. LOGIC= 0

CLD COVER	AIRTEMP	REL HUM	WIND SPD	WATER TEMP
.000	35.000	92.000	4.000	48.000
8.000	33.000	96.000	3.000	48.000
8.000	39.000	93.000	4.000	48.200
9.000	56.000	60.000	5.000	48.500
10.000	56.000	57.000	4.000	48.500
10.000	61.000	52.000	4.000	48.700
10.000	53.000	80.000	4.000	49.000
10.000	54.000	96.000	5.000	49.000
10.000	56.000	90.000	7.000	49.200
10.000	55.000	90.000	8.000	49.200
10.000	56.000	87.000	12.000	49.500
5.000	66.000	68.000	14.000	50.000
10.000	72.000	57.000	14.000	50.500
10.000	73.000	55.000	9.000	51.000
10.000	68.000	68.000	9.000	51.000
10.000	61.000	90.000	4.000	51.000
10.000	64.000	84.000	4.000	51.200
10.000	65.000	78.000	10.000	51.500
8.000	63.000	90.000	11.000	51.700
10.000	70.000	73.000	8.000	52.200
10.000	75.000	54.000	10.000	52.700
10.000	55.000	100.000	7.000	53.000
10.000	50.000	93.000	10.000	52.500
10.000	50.000	80.000	4.000	52.200
10.000	48.000	68.000	5.000	52.000

9.000	46.000	71.000	2.000	52.000
10.000	45.000	80.000	5.000	52.000
10.000	49.000	66.000	6.000	52.200
10.000	50.000	59.000	8.000	52.500
10.000	51.000	52.000	6.000	52.700
10.000	48.000	63.000	4.000	52.500
10.000	46.000	58.000	3.000	52.500
10.000	43.000	76.000	3.000	52.200
10.000	42.000	76.000	2.000	52.000
10.000	42.000	89.000	3.000	52.000
10.000	45.000	77.000	6.000	52.000
10.000	47.000	66.000	7.000	52.000
10.000	45.000	80.000	4.000	52.200
10.000	43.000	89.000	3.000	52.200
10.000	43.000	93.000	3.000	52.000
10.000	43.000	96.000	4.000	51.700
10.000	43.000	93.000	5.000	51.500
10.000	45.000	93.000	9.000	51.500
8.000	53.000	62.000	10.000	51.700
9.000	55.000	51.000	12.000	52.000
9.000	56.000	51.000	11.000	52.500
2.000	53.000	57.000	6.000	52.200
.000	45.000	65.000	4.000	52.000
.000	37.000	89.000	.000	51.500
.000	32.000	96.000	.000	51.200
.000	39.000	93.000	.000	51.000
.000	54.000	53.000	11.000	51.000
.000	58.000	44.000	14.000	51.700
6.000	62.000	34.000	10.000	53.000

2.000	55.000	47.000	4.000	53.200
.000	43.000	83.000	2.000	52.700
1.000	38.000	89.000	.000	52.500
4.000	35.000	92.000	3.000	52.000
5.000	53.000	69.000	14.000	52.000
10.000	63.000	48.000	14.000	52.200
10.000	68.000	41.000	15.000	52.700
10.000	63.000	40.000	16.000	53.500
10.000	57.000	57.000	6.000	53.700
10.000	54.000	69.000	12.000	53.500
10.000	49.000	93.000	9.000	53.500
10.000	50.000	96.000	3.000	53.000
10.000	50.000	96.000	4.000	53.000
10.000	55.000	93.000	7.000	52.700
10.000	56.000	93.000	8.000	52.700
10.000	57.000	83.000	9.000	53.000
10.000	55.000	86.000	5.000	53.200
10.000	53.000	93.000	6.000	53.200
10.000	54.000	90.000	5.000	53.200
10.000	55.000	96.000	7.000	53.000
7.000	58.000	87.000	8.000	52.500
10.000	64.000	75.000	13.000	52.500
10.000	71.000	64.000	12.000	53.000
10.000	75.000	50.000	12.000	54.000
10.000	68.000	63.000	5.000	54.000
10.000	62.000	67.000	18.000	54.000
10.000	57.000	100.000	8.000	54.000
10.000	57.000	93.000	12.000	54.200

10.000	56.000	93.000	11.000	54.500
10.000	57.000	93.000	10.000	54.500
7.000	52.000	83.000	8.000	54.700
8.000	56.000	83.000	5.000	55.000
9.000	56.000	80.000	4.000	55.000
7.000	54.000	72.000	5.000	55.000
10.000	52.000	69.000	9.000	55.200
9.000	46.000	80.000	3.000	55.000
9.000	49.000	80.000	11.000	55.000
10.000	57.000	69.000	13.000	55.500
10.000	55.000	77.000	9.000	56.200
10.000	51.000	100.000	4.000	56.700
7.000	53.000	93.000	5.000	56.500
9.000	49.000	86.000	4.000	56.200
10.000	48.000	89.000	3.000	56.000
10.000	45.000	86.000	5.000	55.700
10.000	46.000	80.000	10.000	55.500
10.000	50.000	69.000	13.000	56.000
10.000	52.000	59.000	13.000	56.200
10.000	51.000	64.000	10.000	56.700
10.000	51.000	57.000	6.000	56.500
8.000	48.000	66.000	5.000	56.000
7.000	45.000	71.000	4.000	56.000
9.000	42.000	83.000	5.000	55.500
10.000	46.000	77.000	3.000	55.200
10.000	50.000	69.000	10.000	55.200
10.000	50.000	69.000	7.000	55.700
10.000	51.000	64.000	8.000	56.000
8.000	49.000	71.000	4.000	56.000

.000	40.000	93.000	2.000	55.500
.000	37.000	96.000	.000	55.000
3.000	33.000	100.000	3.000	54.500
5.000	40.000	96.000	3.000	54.500
9.000	56.000	60.000	3.000	54.500
10.000	55.000	64.000	10.000	54.700
10.000	52.000	83.000	9.000	55.000
10.000	49.000	96.000	5.000	55.000
10.000	48.000	100.000	4.000	55.000
10.000	46.000	100.000	4.000	54.700
10.000	45.000	93.000	9.000	54.700
7.000	47.000	71.000	7.000	54.200
2.000	54.000	49.000	5.000	54.500
4.000	60.000	39.000	13.000	55.000
1.000	62.000	38.000	10.000	55.200
1.000	59.000	42.000	8.000	55.000
1.000	55.000	47.000	7.000	55.000
8.000	54.000	49.000	11.000	55.000
8.000	54.000	55.000	10.000	54.700
5.000	55.000	57.000	10.000	54.500
7.000	64.000	47.000	13.000	54.500
6.000	68.000	39.000	10.000	54.700
10.000	52.000	74.000	14.000	55.000
10.000	45.000	86.000	9.000	54.700
10.000	43.000	93.000	9.000	54.700
10.000	42.000	96.000	5.000	54.700
10.000	42.000	100.000	4.000	54.700
10.000	48.000	83.000	10.000	54.700

10.000	48.000	86.000	4.000	54.700
10.000	49.000	89.000	4.000	54.700
10.000	51.000	77.000	5.000	54.500
10.000	49.000	83.000	5.000	54.000
10.000	42.000	96.000	7.000	53.700
10.000	42.000	100.000	10.000	53.000
10.000	41.000	100.000	10.000	52.500
10.000	42.000	96.000	10.000	52.500
10.000	45.000	93.000	13.000	52.500
10.000	46.000	93.000	10.000	52.500
10.000	46.000	93.000	8.000	52.500
10.000	46.000	93.000	9.000	52.500
10.000	47.000	86.000	7.000	52.500
10.000	49.000	77.000	7.000	51.700
10.000	48.000	80.000	5.000	51.500
6.000	50.000	80.000	3.000	51.200
5.000	60.000	62.000	3.000	51.000
9.000	67.000	49.000	4.000	51.000
10.000	63.000	50.000	10.000	51.000
10.000	60.000	65.000	3.000	51.000
10.000	53.000	90.000	3.000	51.000
10.000	51.000	100.000	5.000	51.000
10.000	51.000	100.000	6.000	51.000
10.000	50.000	100.000	11.000	50.700
10.000	52.000	100.000	13.000	50.500
10.000	51.000	96.000	14.000	50.200
10.000	49.000	96.000	15.000	50.200
10.000	48.000	96.000	14.000	50.200
10.000	47.000	100.000	13.000	50.200

10.000	47.000	100.000	8.000	50.200
10.000	47.000	100.000	7.000	50.200
10.000	47.000	100.000	9.000	50.000
10.000	50.000	86.000	7.000	50.000
10.000	54.000	75.000	8.000	50.200
7.000	58.000	65.000	10.000	50.500
6.000	56.000	62.000	4.000	51.000
.000	43.000	96.000	2.000	51.000
.000	39.000	100.000	3.000	50.500
.000	37.000	100.000	2.000	50.000
.000	45.000	100.000	3.000	50.000
2.000	60.000	70.000	3.000	50.000
8.000	67.000	40.000	6.000	50.500
8.000	68.000	36.000	7.000	51.200
9.000	63.000	43.000	7.000	51.500
9.000	52.000	74.000	4.000	51.700
.000	47.000	89.000	7.000	51.500
.000	42.000	96.000	2.000	51.500
3.000	51.000	90.000	6.000	51.500
4.000	60.000	70.000	8.000	51.700
4.000	67.000	55.000	12.000	52.000
3.000	68.000	51.000	13.000	52.700
3.000	63.000	50.000	6.000	53.500
3.000	52.000	83.000	3.000	53.500
2.000	45.000	96.000	2.000	53.500
10.000	46.000	100.000	5.000	53.700
10.000	47.000	100.000	5.000	53.700
3.000	54.000	86.000	8.000	53.700

1.000	64.000	65.000	8.000	54.000
2.000	66.000	51.000	3.000	54.000
4.000	63.000	65.000	6.000	54.000
6.000	55.000	80.000	7.000	54.000
2.000	50.000	83.000	3.000	54.000
8.000	50.000	86.000	6.000	54.000
7.000	55.000	75.000	7.000	53.700
9.000	58.000	67.000	7.000	53.700
7.000	62.000	58.000	5.000	53.500
2.000	64.000	54.000	4.000	53.500
8.000	61.000	58.000	4.000	53.500
8.000	55.000	80.000	7.000	53.500
6.000	54.000	75.000	10.000	53.500
10.000	51.000	80.000	7.000	53.500
1.000	55.000	75.000	8.000	53.500
5.000	60.000	62.000	15.000	53.700
3.000	65.000	54.000	10.000	54.000
1.000	68.000	49.000	13.000	54.500
9.000	63.000	60.000	6.000	54.700
9.000	57.000	72.000	7.000	54.700
10.000	54.000	80.000	7.000	54.700
10.000	52.000	90.000	10.000	54.700
10.000	51.000	96.000	10.000	55.000
10.000	54.000	100.000	11.000	55.200
10.000	57.000	93.000	9.000	55.500
10.000	58.000	90.000	10.000	55.700
10.000	60.000	93.000	13.000	55.500
10.000	61.000	97.000	10.000	55.200
10.000	63.000	97.000	10.000	55.200

10.000	62.000	97.000	4.000	55.500
10.000	61.000	100.000	8.000	55.500
10.000	62.000	100.000	6.000	55.500
8.000	69.000	73.000	9.000	56.500
7.000	72.000	57.000	8.000	57.200
10.000	60.000	87.000	5.000	57.700
10.000	58.000	93.000	6.000	57.700
10.000	57.000	93.000	.000	57.700
10.000	55.000	100.000	.000	57.700
10.000	56.000	96.000	3.000	57.500
10.000	62.000	75.000	2.000	57.700
9.000	68.000	55.000	5.000	58.000
10.000	64.000	54.000	5.000	58.200
3.000	63.000	65.000	.000	58.200
10.000	58.000	90.000	3.000	58.500
10.000	56.000	96.000	3.000	58.500
10.000	56.000	100.000	4.000	58.500
10.000	56.000	100.000	.000	59.000
10.000	59.000	100.000	4.000	59.000
10.000	60.000	84.000	10.000	59.500
10.000	64.000	73.000	4.000	60.000
10.000	62.000	73.000	4.000	60.000
3.000	58.000	81.000	6.000	60.000
1.000	56.000	80.000	10.000	60.200
.000	54.000	80.000	8.000	60.200
9.000	60.000	70.000	13.000	60.700
9.000	64.000	68.000	14.000	61.500
10.000	62.000	75.000	9.000	62.000

9.000	66.000	65.000	5.000	61.700
10.000	56.000	90.000	8.000	61.500
10.000	53.000	96.000	6.000	61.000
2.000	47.000	83.000	5.000	61.000
6.000	41.000	96.000	4.000	61.000
3.000	47.000	68.000	12.000	60.700
2.000	51.000	46.000	10.000	60.700
1.000	57.000	44.000	12.000	61.500
.00	59.000	44.000	10.000	61.700
.000	56.000	45.000	5.000	61.500
.000	43.000	83.000	3.000	61.200
.000	39.000	93.000	3.000	61.000
.000	36.000	96.000	.000	60.700
.000	47.000	83.000	3.000	60.700
.000	62.000	41.000	10.000	61.000
.000	68.000	33.000	5.000	61.200
4.000	70.000	36.000	8.000	61.500
8.000	65.000	52.000	2.000	61.500
6.000	53.000	86.000	3.000	61.200
6.000	49.000	89.000	3.000	61.000
10.000	53.000	~~86.000~~	~~4.000~~	61.000
10.000	58.000	84.000	9.000	61.000
10.000	57.000	96.000	6.000	61.200
10.000	60.000	100.000	.000	61.500
10.000	64.000	97.000	5.000	62.000
10.000	63.000	100.000	4.000	62.000
10.000	62.000	100.000	3.000	61.500
10.000	60.000	100.000	3.000	61.200
10.000	60.000	100.000	3.000	61.200

8.000	65.000	100.000	3.000	61.000
6.000	77.000	74.000	12.000	61.000
10.000	80.000	65.000	12.000	61.500
10.000	76.000	76.000	4.000	61.700
9.000	76.000	76.000	7.000	61.700
8.000	68.000	87.000	5.000	62.000
8.000	67.000	87.000	8.000	62.000
10.000	71.000	81.000	10.000	62.200
10.000	74.000	76.000	7.000	62.200
7.000	78.000	71.000	13.000	62.700
7.000	85.000	61.000	12.000	63.000
10.000	71.000	90.000	7.000	63.100
7.000	72.000	84.000	5.000	63.500
7.000	72.000	76.000	10.000	63.000
10.000	72.000	82.000	13.000	62.700
8.000	70.000	84.000	16.000	62.700
10.000	70.000	84.000	14.000	62.500
8.000	76.000	66.000	13.000	62.700
7.000	79.000	52.000	8.000	63.000
4.000	80.000	41.000	13.000	64.000
.000	75.000	45.000	8.000	64.500
.000	61.000	75.000	5.000	64.700
.000	56.000	93.000	3.000	64.500
1.000	55.000	93.000	3.000	64.200
8.000	68.000	68.000	10.000	64.000
5.000	77.000	56.000	11.000	64.000
8.000	81.000	51.000	12.000	64.700
7.000	84.000	46.000	10.000	65.200

8.000	79.000	52.000	7.000	65.500
2.000	71.000	64.000	8.000	65.700
3.000	73.000	57.000	12.000	65.700
5.000	71.000	61.000	13.000	65.700
10.000	71.000	66.000	10.000	65.500
10.000	72.000	68.000	11.000	65.500
9.000	79.000	62.000	12.000	66.200
3.000	82.000	43.000	10.000	67.000
7.000	77.000	50.000	8.000	67.500
2.000	72.000	50.000	8.000	67.500
2.000	67.000	53.000	7.000	67.000
2.000	61.000	67.000	5.000	67.000
5.000	64.000	68.000	8.000	66.500
1.000	71.000	49.000	6.000	66.700
8.000	76.000	43.000	8.000	67.500
6.000	79.000	41.000	6.000	68.500
10.000	70.000	71.000	4.000	69.000
7.000	63.000	93.000	3.000	69.000
10.000	64.000	90.000	5.000	68.500
10.000	66.000	78.000	3.000	68.000
10.000	72.000	66.000	8.000	67.500
8.000	73.000	62.000	10.000	67.700
2.000	86.000	55.000	5.000	68.500
6.000	86.000	50.000	8.000	69.700
10.000	78.000	62.000	5.000	60.200
10.000	67.000	90.000	4.000	70.200
2.000	66.000	93.000	3.000	69.700
8.000	66.000	93.000	5.000	69.700
4.000	73.000	82.000	8.000	69.500

5.000	78.000	79.000	11.000	70.200
2.000	85.000	61.000	11.000	71.000
10.000	70.000	93.000	6.000	72.500
10.000	68.000	100.000	6.000	72.200
8.000	66.000	100.000	.000	72.000
5.000	64.000	100.000	3.000	71.700
10.000	64.000	100.000	4.000	71.700
10.000	68.000	93.000	3.000	72.000
10.000	71.000	90.000	5.000	72.000
10.000	66.000	100.000	6.000	72.000
6.000	70.000	76.000	5.000	71.500
4.000	71.000	68.000	5.000	72.000
.000	61.000	90.000	3.000	72.200
8.000	61.000	84.000	5.000	72.000
8.000	57.000	96.000	3.000	72.000
2.000	62.000	87.000	3.000	71.700
3.000	70.000	53.000	7.000	71.700
8.000	73.000	41.000	11.000	71.700
3.000	75.000	34.000	14.000	71.500
5.000	70.000	38.000	13.000	71.500
.000	61.000	39.000	13.000	70.500
.000	53.000	64.000	8.000	70.000
2.000	50.000	71.000	8.000	69.500
9.000	55.000	51.000	12.000	68.700
10.000	55.000	55.000	8.000	68.500
10.000	57.000	60.000	6.000	68.700
10.000	58.000	55.000	7.000	68.500
10.000	55.000	59.000	6.000	68.500

10.000	51.000	80.000	2.000	68.500
10.000	49.000	89.000	4.000	68.000
10.000	48.000	96.000	4.000	67.500
10.000	50.000	96.000	7.000	67.000
10.000	52.000	96.000	7.000	67.000
10.000	52.000	100.000	5.000	67.500
10.000	53.000	100.000	6.000	68.500
10.000	52.000	100.000	11.000	68.500
10.000	52.000	100.000	12.000	68.500
10.000	49.000	100.000	4.000	67.700
5.000	45.000	96.000	5.000	67.500
3.000	51.000	90.000	8.000	67.000
6.000	57.000	72.000	8.000	67.000
4.000	62.000	58.000	11.000	67.200
3.000	65.000	50.000	10.000	67.700
3.000	62.000	54.000	8.000	67.500
5.000	49.000	93.000	3.000	66.500
7.000	45.000	100.000	2.000	65.700
8.000	43.000	100.000	3.000	65.000
10.000	50.000	93.000	4.000	63.500
10.000	61.000	75.000	10.000	62.200
10.000	62.000	73.000	11.000	62.200
8.000	65.000	61.000	12.000	62.700
10.000	59.000	75.000	10.000	62.700
2.000	55.000	90.000	5.000	62.200
.000	55.000	93.000	5.000	61.200
10.000	55.000	96.000	2.000	60.200
10.000	57.000	93.000	3.000	59.500
10.000	65.000	78.000	5.000	59.000

10.000	71.000	66.000	3.000	59.000
10.000	74.000	60.000	6.000	59.000
4.000	72.000	64.000	3.000	59.000
3.000	63.000	84.000	5.000	59.000
7.000	59.000	93.000	3.000	58.700
10.000	64.000	90.000	4.000	58.500
10.000	68.000	87.000	10.000	58.200
2.000	76.000	66.000	12.000	58.500
8.000	83.000	46.000	16.000	59.500
8.000	83.000	51.000	11.000	60.000
3.000	78.000	62.000	8.000	60.200
3.000	73.000	76.000	7.000	60.200

UA= 13503.000R WIDTH= 400.000CLD CØVER= 8.000TEMP AIR= 75.000

TEMP WATER= 62.000REL HUM= 71.000WIND SPEED= 8.700

NUMBER OF CASES= 4

ALLOWED DTS

.1000000E 01

.2000000E 01

.3000000E 01

.4000000E 01

NUMBER OF DAYS AVERAGED= 2

DAYS AVERAGED

1

2

PTBL1 TTBL1 HFGTB1

****

.685E-01	.320E 02	.108E 04
.122E 00	.400E 02	.107E 04
.178E 00	.500E 02	.107E 04
.256E 00	.600E 02	.106E 04
.363E 00	.700E 02	.105E 04
.507E 00	.800E 02	.105E 04
.698E 00	.900E 02	.104E 04
.949E 00	.100E 03	.104E 04
.127E 01	.110E 03	.103E 04
.169E 01	.120E 03	.103E 04

DAYS SINCE MARCH 21= 41.000BETA= 45.000

ADDITIONAL DATA FOR STATION 7 ABOVE THE DAM

TEMPERATURES AT STATION 7, °F, DAILY AVERAGES, MAY 1-JUNE 21

48.9, 50.7, 52.3, 52.4, 52.0, 51.8, 51.9, 52.9,
53.0, 53.1, 54.5, 55.2, 55.0, 54.5, 54.2, 54.2,
53.6, 52.4, 51.4, 50.8, 51.0, 50.6, 52.3, 53.9,
53.7, 54.1, 53.8, 54.3, 55.3, 56.3, 57.9, 59.0,
59.4, 58.8, 58.9, 60.0, 60.9, 62.3, 63.3, 64.6,
65.2, 66.8, 69.2, 69.3, 69.0, 67.3, 66.9, 66.1,
62.4, 59.3, 59.9

SEPTEMBER 27, 1973
AUGUST 15 to 31 and SEPTEMBER 12 to 26

NUMBER OF DATA LINES= 256TIME AV. LOGIC= 0

CLD COVER	AIRTEMP	REL HUM	WIND SPD	WATER TEMP
5.000	66.000	87.000	6.000	78.000
5.000	64.000	90.000	6.000	77.500
10.000	66.000	90.000	7.000	77.200
10.000	70.000	84.000	8.000	77.500
9.000	75.000	69.000	10.000	77.200
10.000	75.000	66.000	10.000	77.000
10.000	71.000	76.000	6.000	77.000
4.000	66.000	87.000	5.000	77.000
.000	62.000	93.000	3.000	76.700
9.000	62.000	97.000	3.000	76.700
10.000	62.000	100.000	4.000	76.000
10.000	67.000	93.000	4.000	75.700
1.000	77.000	62.000	5.000	75.700
1.000	79.000	47.000	9.000	76.500
.000	75.000	58.000	3.000	77.000
.000	65.000	87.000	3.000	76.500
.000	62.000	93.000	3.000	76.200
1.000	59.000	97.000	4.000	76.500
8.000	62.000	97.000	4.000	76.500
8.000	75.000	71.000	5.000	76.500
8.000	82.000	55.000	5.000	76.500
7.000	83.000	51.000	7.000	77.500
9.000	79.000	65.000	4.000	77.700
9.000	68.000	93.000	3.000	77.200
5.000	66.000	93.000	3.000	76.700
5.000	64.000	97.000	3.000	76.700

3.000	66.000	97.000	3.000	76.700
8.000	76.000	71.000	6.000	76.700
8.000	85.000	57.000	4.000	77.200
9.000	85.000	51.000	9.000	77.000
10.000	67.000	87.000	11.000	77.000
8.000	66.000	93.000	5.000	76.700
3.000	65.000	93.000	5.000	76.500
8.000	63.000	97.000	6.000	76.500
5.000	63.000	100.000	4.000	75.700
7.000	74.000	84.000	4.000	76.000
5.000	80.000	67.000	4.000	76.700
9.000	69.000	84.000	9.000	77.200
9.000	72.000	84.000	5.000	77.200
4.000	67.000	93.000	5.000	76.500
3.000	63.000	97.000	3.000	76.200
3.000	60.000	97.000	5.000	75.700
.000	63.000	97.000	4.000	75.700
.000	74.000	71.000	10.000	76.000
4.000	79.000	60.000	5.000	76.200
2.000	81.000	54.000	5.000	76.700
1.000	73.000	69.000	6.000	77.200
.000	67.000	84.000	3.000	76.500
.000	63.000	90.000	6.000	76.200
.000	61.000	93.000	7.000	76.200
.000	62.000	97.000	3.000	75.200
4.000	75.000	69.000	11.000	75.500
8.000	80.000	49.000	10.000	76.000
8.000	80.000	56.000	10.000	76.500

10.000	70.000	79.000	6.000	76.700
10.000	68.000	84.000	5.000	76.500
10.000	69.000	76.000	8.000	75.500
10.000	67.000	73.000	13.000	75.200
10.000	66.000	81.000	13.000	75.000
10.000	65.000	84.000	11.000	75.000
10.000	61.000	93.000	10.000	75.200
10.000	61.000	90.000	8.000	76.000
8.000	61.000	75.000	4.000	76.000
1.000	54.000	90.000	4.000	76.000
2.000	51.000	93.000	3.000	75.500
.000	47.000	100.000	3.000	74.500
.000	50.000	100.000	5.000	73.500
.000	64.000	65.000	6.000	73.500
9.000	68.000	55.000	9.000	74.000
7.000	70.000	49.000	5.000	75.000
9.000	67.000	66.000	4.000	75.000
10.000	67.000	61.000	3.000	74.500
10.000	65.000	73.000	8.000	73.700
10.000	64.000	75.000	5.000	73.500
1.000	60.000	81.000	7.000	73.200
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.000	68.000	49.000	6.000	73.500
.000	71.000	48.000	8.000	74.500
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.000	55.000	90.000	5.000	74.500
.000	52.000	93.000	3.000	73.700
.000	49.000	96.000	4.000	73.500
.000	51.000	100.000	5.000	73.200

1.000	69.000	68.000	6.000	73.200
6.000	76.000	48.000	9.000	74.000
9.000	77.000	48.000	8.000	74.000
8.000	69.000	73.000	5.000	73.500
7.000	63.000	90.000	4.000	73.000
10.000	61.000	97.000	4.000	72.700
10.000	62.000	93.000	4.000	72.700
10.000	64.000	90.000	5.000	72.700
10.000	65.000	93.000	5.000	73.000
10.000	75.000	69.000	6.000	74.000
10.000	76.000	66.000	6.000	74.000
10.000	72.000	84.000	4.000	73.700
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10.000	68.000	93.000	5.000	73.500
10.000	66.000	100.000	4.000	73.500
10.000	67.000	97.000	4.000	73.500
.000	79.000	77.000	8.000	74.000
6.000	84.000	65.000	4.000	74.500
6.000	86.000	63.000	4.000	75.000
4.000	81.000	79.000	4.000	75.000
5.000	78.000	88.000	9.000	75.500
10.000	77.000	88.000	9.000	75.500
10.000	68.000	93.000	5.000	75.200
9.000	68.000	100.000	4.000	75.000
4.000	76.000	97.000	4.000	75.500
2.000	83.000	74.000	15.000	76.000
.000	85.000	53.000	9.000	76.500
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.000	64.000	93.000	3.000	76.000
.000	61.000	97.000	3.000	75.700
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2.000	85.000	61.000	11.000	76.000
2.000	87.000	57.000	5.000	77.000
5.000	81.000	79.000	5.000	77.000
3.000	76.000	82.000	5.000	77.000
3.000	72.000	93.000	3.000	76.500
9.000	73.000	87.000	4.000	76.200
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8.000	84.000	67.000	9.000	76.200
9.000	90.000	56.000	9.000	77.000
5.000	91.000	50.000	10.000	77.500
10.000	79.000	69.000	8.000	77.700
4.000	74.000	82.000	4.000	77.200
2.000	70.000	93.000	3.000	76.700
9.000	68.000	100.000	4.000	77.000
5.000	69.000	100.000	5.000	77.000
2.000	83.000	67.000	5.000	77.500
4.000	88.000	61.000	5.000	77.500
10.000	74.000	82.000	12.000	78.500
10.000	74.000	82.000	3.000	79.000
10.000	71.000	90.000	7.000	79.000
10.000	60.000	67.000	7.000	71.200
5.000	56.000	75.000	6.000	70.700
8.000	56.000	75.000	7.000	70.200
7.000	60.000	62.000	9.000	70.500

10.000	62.000	48.000	9.000	70.500
10.000	62.000	50.000	8.000	70.500
10.000	60.000	58.000	6.000	70.500
10.000	56.000	78.000	3.000	70.500
10.000	54.000	83.000	3.000	70.200
4.000	51.000	90.000	3.000	70.000
9.000	51.000	93.000	3.000	69.500
5.000	61.000	58.000	10.000	69.500
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10.000	51.000	86.000	6.000	70.200
10.000	50.000	86.000	4.000	69.700
10.000	51.000	90.000	7.000	69.500
10.000	59.000	70.000	8.000	69.500
10.000	59.000	75.000	5.000	68.500
10.000	55.000	90.000	5.000	68.200
10.000	54.000	93.000	8.000	68.000
10.000	54.000	96.000	4.000	68.000
10.000	54.000	96.000	6.000	68.000
10.000	54.000	96.000	4.000	67.700
10.000	54.000	96.000	6.000	67.500
10.000	55.000	100.000	3.000	67.700
10.000	57.000	96.000	8.000	67.700
8.000	59.000	93.000	5.000	67.700
9.000	57.000	93.000	5.000	67.700
10.000	57.000	96.000	7.000	67.700

10.000	58.000	93.000	11.000	67.500
10.000	58.000	90.000	11.000	67.200
10.000	56.000	83.000	12.000	67.000
9.000	54.000	75.000	13.000	67.000
9.000	54.000	69.000	12.000	67.000
9.000	53.000	72.000	12.000	67.000
6.000	51.000	69.000	9.000	66.700
9.000	51.000	71.000	11.000	66.700
10.000	50.000	71.000	10.000	66.500
.000	42.000	86.000	3.000	66.000
.000	41.000	96.000	4.000	65.500
4.000	52.000	55.000	8.000	66.000
8.000	55.000	53.000	11.000	66.700
6.000	56.000	51.000	5.000	66.700
10.000	50.000	74.000	4.000	66.200
10.000	48.000	93.000	7.000	66.000
10.000	50.000	93.000	10.000	65.700
10.000	50.000	96.000	8.000	65.700
10.000	52.000	96.000	12.000	65.000
10.000	52.000	96.000	4.000	65.000
10.000	54.000	96.000	6.000	65.500
10.000	51.000	96.000	13.000	65.200
10.000	51.000	93.000	13.000	64.700
2.000	47.000	93.000	4.000	64.200
8.000	41.000	96.000	3.000	64.000
4.000	39.000	100.000	3.000	63.500
9.000	40.000	100.000	3.000	63.700
2.000	54.000	90.000	8.000	64.500
.000	61.000	72.000	10.000	64.700

2.000	63.000	60.000	13.000	64.200
1.000	55.000	69.000	7.000	63.700
6.000	55.000	62.000	12.000	63.700
10.000	54.000	64.000	11.000	63.500
10.000	54.000	67.000	13.000	63.500
10.000	54.000	69.000	16.000	63.500
10.000	55.000	75.000	14.000	64.000
10.000	55.000	80.000	8.000	64.200
9.000	51.000	90.000	12.000	64.000
5.000	47.000	74.000	9.000	63.500
.000	43.000	73.000	6.000	63.000
.000	35.000	85.000	4.000	63.000
5.000	33.000	92.000	4.000	62.700
.000	34.000	96.000	4.000	63.000
2.000	48.000	66.000	4.000	63.500
5.000	53.000	45.000	6.000	63.200
4.000	54.000	42.000	7.000	62.700
3.000	44.000	71.000	5.000	62.500
.000	38.000	86.000	5.000	62.200
.000	35.000	89.000	4.000	62.200
.000	34.000	92.000	4.000	62.000
10.000	41.000	86.000	10.000	61.700
10.000	44.000	80.000	7.000	61.500
10.000	48.000	93.000	12.000	61.500
10.000	51.000	93.000	23.000	61.500
10.000	54.000	100.000	17.000	61.000
10.000	57.000	100.000	10.000	61.000
9.000	58.000	100.000	8.000	60.700

7.000	56.000	100.000	3.000	60.700
10.000	53.000	100.000	3.000	61.000
1.000	61.000	97.000	9.000	61.500
10.000	64.000	75.000	6.000	62.000
10.000	57.000	93.000	7.000	61.500
10.000	55.000	96.000	6.000	61.500
10.000	52.000	100.000	8.000	61.200
10.000	50.000	100.000	8.000	61.200
10.000	50.000	100.000	7.000	61.200
10.000	50.000	100.000	6.000	61.000
10.000	50.000	100.000	7.000	60.500
10.000	51.000	100.000	7.000	60.000
10.000	53.000	100.000	4.000	59.500
10.000	53.000	100.000	4.000	59.200
5.000	50.000	93.000	6.000	59.500
7.000	49.000	93.000	4.000	59.500
.000	46.000	89.000	4.000	59.500
1.000	43.000	100.000	3.000	60.000
3.000	56.000	78.000	7.000	60.700
3.000	63.000	65.000	10.000	60.700
7.000	65.000	59.000	10.000	60.000
8.000	54.000	83.000	7.000	59.500
4.000	50.000	89.000	5.000	59.200
.000	47.000	96.000	5.000	59.000
.000	44.000	96.000	3.000	59.000
8.000	45.000	100.000	4.000	58.700
2.000	60.000	87.000	14.000	59.200
7.000	66.000	68.000	12.000	59.500
7.000	68.000	63.000	10.000	59.000

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       .000      61.000      78.000      6.000      59.000

      4.000      61.000      78.000      7.000      58.700

 UA=    7718.000R  WIDTH=     400.000CLD  COVER=      2.000TEMP  AIR=     62.000

 TEMP WATER=     60.000REL  HUM=     72.000WIND   SPEED=      8.700

 NUMBER OF CASES=    4

 ALLOWED DTS

   .1000000E 01

   .2000000E 01

   .3000000E 01

   .4000000E 01

 NUMBER OF DAYS AVERAGED=     2

 DAYS AVERAGED

     1

     2

 PTBL1    TTBL1    HFGTB1

************************************************************
.885E-01  .320E 02  .108E 04
.122E 00  .400E 02  .107E 04
.178E 00  .500E 02  .107E 04
.256E 00  .600E 02  .106E 04
.363E 00  .700E 02  .105E 04
.507E 00  .800E 02  .105E 04
.698E 00  .900E 02  .104E 04
.949E 00  .100E 03  .104E 04
.127E 01  .110E 03  .103E 04
.169E 01  .120E 03  .103E 04

 DAYS SINCE MARCH 21=     75.000BETA=      45.000
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OCTOBER 30 , 1974
OCTOBER 1 to 3 , 17 to 24, and 27 to 29, 1973

NUMBER OF DATA LINES= 112TIME_AV. LOGIC= 0

CLD COVER	AIRTEMP	REL HUM	WIND SPD	WATER TEMP
.000	38.000	96.000	4.000	60.000
.000	37.000	100.000	3.000	60.000
.000	38.000	100.000	3.000	60.000
.000	56.000	72.000	6.000	60.700
3.000	65.000	47.000	8.000	61.000
8.000	66.000	37.000	8.000	60.700
5.000	59.000	56.000	9.000	60.500
5.000	55.000	67.000	5.000	60.500
5.000	54.000	75.000	11.000	60.200
3.000	54.000	75.000	7.000	60.200
10.000	53.000	74.000	9.000	60.200
10.000	58.000	72.000	10.000	60.500
10.000	60.000	84.000	10.000	60.500
10.000	58.000	96.000	9.000	60.700
10.000	58.000	100.000	8.000	60.500
10.000	59.000	97.000	7.000	60.500
10.000	61.000	97.000	8.000	60.500
10.000	60.000	100.000	4.000	60.500
10.000	62.000	100.000	4.000	60.500
10.000	65.000	97.000	6.000	60.700
10.000	64.000	100.000	7.000	61.000
10.000	65.000	100.000	3.000	60.700
10.000	62.000	100.000	5.000	60.500
10.000	58.000	100.000	3.000	60.500
10.000	44.000	65.000	9.000	54.700
10.000	45.000	65.000	6.000	54.700

10.000	45.000	68.000	10.000	54.500
10.000	45.000	77.000	10.000	54.700
10.000	45.000	80.000	14.000	55.000
10.000	47.000	56.000	10.000	55.500
10.000	45.000	58.000	7.000	55.500
10.000	45.000	60.000	7.000	55.500
10.000	43.000	73.000	4.000	55.000
10.000	42.000	76.000	4.000	55.000
9.000	38.000	82.000	5.000	54.700
8.000	46.000	66.000	7.000	54.700
10.000	47.000	61.000	6.000	54.500
10.000	46.000	66.000	6.000	54.500
10.000	45.000	71.000	4.000	54.200
10.000	43.000	73.000	3.000	54.200
1.000	37.000	89.000	3.000	54.000
3.000	32.000	96.000	3.000	54.000
5.000	32.000	100.000	3.000	53.700
1.000	43.000	100.000	.000	53.700
5.000	48.000	63.000	3.000	53.700
10.000	50.000	50.000	5.000	54.200
10.000	44.000	68.000	6.000	54.000
10.000	45.000	58.000	8.000	54.000
10.000	44.000	80.000	11.000	53.700
10.000	44.000	86.000	11.000	53.500
10.000	44.000	86.000	7.000	53.200
10.000	44.000	100.000	3.000	53.000
10.000	46.000	100.000	6.000	53.000
10.000	46.000	100.000	7.000	53.500

10.000	46.000	96.000	10.000	53.200
10.000	44.000	100.000	7.000	53.000
10.000	44.000	100.000	6.000	53.000
9.000	41.000	100.000	7.000	52.700
8.000	39.000	89.000	6.000	52.500
2.000	43.000	71.000	9.000	52.200
.000	47.000	56.000	4.000	52.700
.000	49.000	50.000	4.000	53.200
.000	40.000	86.000	3.000	53.000
.000	37.000	89.000	3.000	52.700
.000	34.000	92.000	5.000	52.500
.000	33.000	96.000	4.000	52.200
4.000	32.000	100.000	3.000	52.000
.000	47.000	93.000	10.000	52.000
3.000	56.000	64.000	6.000	52.000
5.000	58.000	60.000	7.000	52.500
.000	45.000	93.000	5.000	52.500
.000	44.000	86.000	5.000	52.500
.000	40.000	96.000	3.000	52.000
.000	38.000	100.000	3.000	52.000
.000	35.000	100.000	5.000	51.500
4.000	56.000	72.000	11.000	51.700
3.000	62.000	58.000	10.000	52.000
7.000	63.000	54.000	6.000	52.500
8.000	55.000	69.000	5.000	52.500
4.000	50.000	86.000	3.000	52.200
5.000	47.000	93.000	3.000	52.000
5.000	44.000	96.000	3.000	51.500
4.000	39.000	96.000	3.000	51.200

7.000	50.000	96.000	3.000	51.000
4.000	61.000	67.000	6.000	51.500
.000	62.000	67.000	5.000	52.000
.000	52.000	93.000	3.000	52.000
.000	43.000	100.000	3.000	52.000
10.000	54.000	96.000	10.000	52.000
10.000	47.000	96.000	9.000	51.700
10.000	45.000	83.000	10.000	51.500
10.000	44.000	80.000	11.000	51.700
10.000	44.000	74.000	13.000	52.000
10.000	44.000	71.000	9.000	52.000
10.000	40.000	76.000	7.000	51.700
4.000	38.000	67.000	3.000	51.500
2.000	31.000	92.000	3.000	51.000
5.000	30.000	96.000	3.000	51.000
8.000	27.000	96.000	5.000	50.700
8.000	39.000	79.000	4.000	50.500
10.000	42.000	63.000	8.000	50.700
9.000	43.000	63.000	5.000	50.700
10.000	37.000	82.000	3.000	50.500
10.000	41.000	73.000	6.000	50.200
10.000	42.000	71.000	9.000	50.000
8.000	40.000	62.000	12.000	50.000
5.000	36.000	79.000	3.000	50.000
8.000	45.000	68.000	11.000	50.000
10.000	49.000	59.000	12.000	50.000
10.000	49.000	59.000	13.000	50.000
10.000	47.000	74.000	11.000	50.000

10.000 47.000 93.000 8.000 50.000

UA= 6240.000R WIDTH= 400.000CLD COVER= 1.000TEMP AIR= 45.000

TEMP WATER= 50.000REL HUM= 68.000WIND SPEED= .000

NUMBER OF CASES= 4

ALLOWED DTS

.1000000E 01

.2000000E 01

.3000000E 01

.4000000E 01

NUMBER OF DAYS AVERAGED= 2

DAYS AVERAGED

1

2

PTBL1	TTBL1	HFGTB1
.885E-01	.320E 02	.108E 04
.122E 00	.400E 02	.107E 04
.178E 00	.500E 02	.107E 04
.256E 00	.600E 02	.106E 04
.363E 00	.700E 02	.105E 04
.507E 00	.800E 02	.105E 04
.698E 00	.900E 02	.104E 04
.949E 00	.100E 03	.104E 04
.127E 01	.110E 03	.103E 04
.169E 01	.120E 03	.103E 04

DAYS SINCE MARCH 21= 108.000BETA= 45.000

ADDITIONAL DATA FOR STATION 7 ABOVE THE DAM

TEMPERATURES AT STATION 7, ^{o}F, DAILY AVERAGES, OCTOBER 1-3, 17-24, AND 27-29

60.4, 60.0, 59.8, 55.8, 55.0, 54.5, 53.6, 53.4, 53.0, 52.6, 52.9, 52.7, 51.9, 51.0

NOVEMBER 15, 1973
OCTOBER 17 to 24 and 27 to 29, 1973
NOVEMBER 1 to 14, 1973

NUMBER OF DATA LINES= 200TIME AV. LOGIC= 0

CLD COVER	AIRTEMP	REL HUM	WIND SPD	WATER TEMP
10.000	44.000	65.000	9.000	54.700
10.000	45.000	65.000	6.000	54.700
10.000	45.000	68.000	10.000	54.500
10.000	45.000	77.000	10.000	54.700
10.000	45.000	80.000	14.000	55.000
10.000	47.000	56.000	10.000	55.500
10.000	45.000	58.000	7.000	55.500
10.000	45.000	60.000	7.000	55.500
10.000	43.000	73.000	4.000	55.000
10.000	42.000	76.000	4.000	55.000
9.000	38.000	82.000	5.000	54.700
8.000	46.000	66.000	7.000	54.700
10.000	47.000	61.000	6.000	54.500
10.000	46.000	66.000	6.000	54.500
10.000	45.000	71.000	4.000	54.200
10.000	43.000	73.000	3.000	54.200
1.000	37.000	89.000	3.000	54.000
3.000	32.000	96.000	3.000	54.000
5.000	32.000	100.000	3.000	53.700
1.000	43.000	100.000	.000	53.700
5.000	48.000	63.000	3.000	53.700
10.000	50.000	50.000	5.000	54.200
10.000	44.000	68.000	6.000	54.000
10.000	45.000	58.000	8.000	54.000
10.000	44.000	80.000	11.000	53.700
10.000	44.000	86.000	11.000	53.500

10.000	44.000	86.000	7.000	53.200
10.000	44.000	100.000	3.000	53.000
10.000	46.000	100.000	6.000	53.000
10.000	46.000	100.000	7.000	53.500
10.000	46.000	96.000	10.000	53.200
10.000	44.000	100.000	7.000	53.000
10.000	44.000	100.000	6.000	53.000
9.000	41.000	100.000	7.000	52.700
8.000	39.000	89.000	6.000	52.500
2.000	43.000	71.000	9.000	52.200
.000	47.000	56.000	4.000	52.700
.000	49.000	50.000	4.000	53.200
.000	40.000	86.000	3.000	53.000
.000	37.000	89.000	3.000	52.700
.000	34.000	92.000	5.000	52.500
.000	33.000	96.000	4.000	52.200
4.000	32.000	100.000	3.000	52.000
.000	47.000	93.000	10.000	52.000
3.000	56.000	64.000	6.000	52.000
5.000	58.000	60.000	7.000	52.500
.000	45.000	93.000	5.000	52.500
.000	44.000	86.000	5.000	52.500
.000	40.000	96.000	3.000	52.000
.000	38.000	100.000	3.000	52.000
.000	35.000	100.000	5.000	51.500
4.000	56.000	72.000	11.000	51.700
3.000	62.000	58.000	10.000	52.000
7.000	63.000	54.000	6.000	52.500

8.000	55.000	69.000	5.000	52.500
4.000	50.000	86.000	3.000	52.200
5.000	47.000	93.000	3.000	52.000
5.000	44.000	96.000	3.000	51.500
4.000	39.000	96.000	3.000	51.200
7.000	50.000	96.000	3.000	51.000
4.000	61.000	67.000	6.000	51.500
.000	62.000	67.000	5.000	52.000
.000	52.000	93.000	3.000	52.000
.000	43.000	100.000	3.000	52.000
10.000	54.000	96.000	10.000	52.000
10.000	47.000	96.000	9.000	51.700
10.000	45.000	83.000	10.000	51.500
10.000	44.000	80.000	11.000	51.700
10.000	44.000	74.000	13.000	52.000
10.000	44.000	71.000	9.000	52.000
10.000	40.000	76.000	7.000	51.700
4.000	38.000	67.000	3.000	51.500
2.000	31.000	92.000	3.000	51.000
5.000	30.000	96.000	3.000	51.000
8.000	27.000	96.000	5.000	50.700
8.000	39.000	79.000	4.000	50.500
10.000	42.000	63.000	8.000	50.700
9.000	43.000	63.000	5.000	50.700
10.000	37.000	82.000	3.000	50.500
10.000	41.000	73.000	6.000	50.200
10.000	42.000	71.000	9.000	50.000
8.000	40.000	62.000	12.000	50.000
5.000	36.000	79.000	3.000	50.000

8.000	45.000	68.000	11.000	50.000
10.000	49.000	59.000	12.000	50.000
10.000	49.000	59.000	13.000	50.000
10.000	47.000	74.000	11.000	50.000
10.000	47.000	93.000	8.000	50.000
10.000	39.000	93.000	3.000	49.000
10.000	48.000	80.000	5.000	49.000
10.000	46.000	83.000	6.000	49.000
10.000	47.000	93.000	6.000	49.000
10.000	49.000	93.000	9.000	49.200
10.000	50.000	69.000	12.000	50.000
10.000	49.000	63.000	14.000	50.000
10.000	49.000	61.000	20.000	49.200
10.000	49.000	56.000	13.000	49.000
6.000	49.000	50.000	14.000	48.200
4.000	48.000	48.000	16.000	48.200
5.000	49.000	48.000	8.000	48.500
8.000	54.000	43.000	9.000	48.700
10.000	52.000	45.000	9.000	48.700
10.000	50.000	50.000	5.000	48.500
10.000	45.000	74.000	5.000	48.500
10.000	43.000	76.000	6.000	48.700
3.000	42.000	71.000	14.000	48.700
3.000	42.000	60.000	14.000	49.000
3.000	44.000	47.000	15.000	49.000
9.000	44.000	40.000	17.000	49.200
9.000	42.000	41.000	12.000	49.000
4.000	41.000	40.000	15.000	49.000

9.000	40.000	39.000	14.000	48.500
9.000	39.000	38.000	18.000	48.500
6.000	37.000	39.000	12.000	48.500
8.000	36.000	40.000	14.000	48.200
9.000	36.000	40.000	17.000	48.200
9.000	38.000	37.000	11.000	48.200
6.000	39.000	36.000	11.000	48.200
9.000	37.000	41.000	8.000	47.500
1.000	33.000	44.000	8.000	47.000
2.000	31.000	47.000	6.000	47.000
2.000	32.000	43.000	7.000	46.700
3.000	31.000	43.000	7.000	46.700
5.000	34.000	42.000	12.000	47.000
9.000	35.000	37.000	9.000	47.000
6.000	38.000	31.000	10.000	46.700
5.000	35.000	32.000	11.000	46.500
8.000	34.000	37.000	7.000	45.700
10.000	32.000	33.000	11.000	45.500
10.000	31.000	36.000	10.000	45.200
10.000	30.000	41.000	12.000	45.000
7.000	28.000	53.000	14.000	45.000
9.000	31.000	40.000	10.000	45.000
10.000	32.000	38.000	17.000	45.000
10.000	29.000	58.000	8.000	44.700
10.000	28.000	61.000	12.000	44.500
7.000	27.000	55.000	7.000	44.500
7.000	25.000	60.000	9.000	44.500
8.000	27.000	61.000	5.000	44.500
8.000	30.000	58.000	4.000	44.500

7.000	36.000	52.000	6.000	44.700
9.000	38.000	46.000	12.000	44.700
9.000	38.000	46.000	10.000	44.200
10.000	38.000	53.000	7.000	44.000
10.000	36.000	57.000	8.000	44.000
10.000	36.000	62.000	7.000	44.000
10.000	36.000	62.000	10.000	43.500
10.000	36.000	57.000	15.000	43.500
10.000	38.000	50.000	15.000	43.500
9.000	40.000	45.000	14.000	43.500
10.000	41.000	45.000	13.000	43.500
7.000	38.000	57.000	8.000	43.500
9.000	36.000	42.000	12.000	43.200
9.000	35.000	42.000	7.000	43.000
6.000	32.000	45.000	7.000	43.000
7.000	32.000	43.000	12.000	43.000
7.000	34.000	38.000	12.000	43.000
9.000	33.000	45.000	12.000	43.000
9.000	31.000	43.000	15.000	42.500
10.000	29.000	45.000	13.000	42.200
9.000	26.000	46.000	14.000	42.000
10.000	25.000	46.000	12.000	41.700
10.000	25.000	53.000	12.000	41.500
10.000	25.000	66.000	10.000	41.500
8.000	30.000	56.000	9.000	41.500
7.000	33.000	42.000	9.000	41.200
5.000	31.000	43.000	10.000	41.200
10.000	31.000	45.000	11.000	41.000

10.000	29.000	51.000	6.000	41.000
10.000	27.000	55.000	6.000	41.000
9.000	27.000	53.000	6.000	41.000
8.000	29.000	49.000	9.000	41.000
8.000	33.000	48.000	4.000	42.000
10.000	36.000	42.000	7.000	42.000
10.000	34.000	44.000	6.000	41.500
10.000	33.000	50.000	.000	41.200
10.000	34.000	52.000	7.000	41.200
10.000	34.000	64.000	7.000	41.200
10.000	35.000	59.000	10.000	41.200
10.000	37.000	59.000	12.000	41.500
10.000	39.000	53.000	14.000	41.500
10.000	39.000	51.000	15.000	41.500
10.000	39.000	48.000	14.000	41.500
10.000	41.000	43.000	14.000	41.500
10.000	41.000	43.000	13.000	41.500
10.000	41.000	43.000	13.000	41.500
10.000	41.000	45.000	10.000	41.500
10.000	43.000	47.000	13.000	41.500
10.000	45.000	49.000	10.000	41.500
10.000	46.000	50.000	8.000	41.500
10.000	46.000	52.000	5.000	41.500
10.000	46.000	52.000	8.000	41.500
10.000	48.000	48.000	13.000	41.500
10.000	51.000	48.000	14.000	41.500
10.000	54.000	51.000	14.000	41.500
10.000	55.000	57.000	10.000	41.500
8.000	61.000	46.000	13.000	42.000

```
     8.000      57.000      42.000      12.000      42.000

     6.000      48.000      63.000       4.000      42.000

     8.000      45.000      71.000       4.000      42.000

UA=   7640.000R  WIDTH=    400.000CLD  COVER=      1.000TEMP  AIR=     50.000

TEMP WATER=     41.700REL  HUM=     68.000WIND   SPEED=      4.400

NUMBER OF CASES=    4

ALLOWED DTS

  .1000000E 01

  .2000000E 01

  .3000000E 01

  .4000000E 01

NUMBER OF DAYS AVERAGED=     2

DAYS AVERAGED

    1

    2

PTBL1    TTBL1    HFGTB1

*************************************************************
.885E-01  .320E 02  .108E 04
.122E 00  .400E 02  .107E 04
.178E 00  .500E 02  .107E 04
.256E 00  .600E 02  .106E 04
.363E 00  .700E 02  .105E 04
.507E 00  .800E 02  .105E 04
.698E 00  .900E 02  .104E 04
.949E 00  .100E 03  .104E 04
.127E 01  .110E 03  .103E 04
.169E 01  .120E 03  .103E 04
```

APPENDIX C

PROGRAM LISTINGS

This appendix presents complete program listings for the STREAM, SENSIT, and MONT codes.

```
C
C
C        STREAM
C
C
C        STREAM THERMAL MØDEL
C
C
         CØMMØN DTEMP,TEMP,XPR,XEND,DXPR,X,DX, INT,INTC,IN,IØ,EL,AREA,U
         CØMMØN ERRØR,DXMAX
         CØMMØNRHØ, WMD,HD,TAIR,CLD,RH,ALBAR,TWS,TA, EW,EA,HØS,HS
         CØMMØN HSR,HØB,EBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CØNST
         CØMMØN  HFG,CLD1,HFGTB(10),CØNS1
         IN=5
         IØ=6
         CALL INPUT
         IF(INTC - 4) 4,105,105
4        XPR = DXPR
5        CØNTINUE
         DØ 100 JE= 1,INT
         CALL DIFFQ
         GØ TØ (10,10,20), INTC
10       CALL EULER(DTEMP,TEMP,DX,1,JE,X)
         GØ TØ 100
20       CALL RK4(DTEMP,TEMP,DX,1,JE,X)
100      CØNTINUE
         IF(X - XPR )       5,250,250
250      CALL ØUPT
```

```
      XPR = XPR + DXPR
      IF(X - XEND) 5,300,300
105   CØNTINUE
      JUMP = -1
110   CØNTINUE
      XPR = X + DXPR
120   CØNTINUE
      CALLNØRD(DTEMP,X,XPR,TEMP,ERRØR,1,DX,DXMAX,JUMP,KSTP,KC,1.E-6,IØ)
      IF(JUMP)130,140,150
130   WRITE(IØ,131) X
131   FØRMAT(//'    X ='E14.5'  INTEGRATIØN FAILURE')
      CALL EXIT
140   CØNTINUE
      CALL DIFFQ
      GØ TØ 120
150   CALL ØUPT
      IF(X - XEND) 110,300,300
300   CALL EXIT
      END
      SUBRØUTINE INPUT
      CØMMØN DTEMP,TEMP,  XPR,XEND,DXPR,X,DX, INT,INTC,
     1 IN,IØ,EL,AREA,U,ERRØR,DXMAX
      CØMMØNRHØ, WMD,HD,TAIR,CLD,RH,ALBAR,TWS,TA, EW,EA,HØS,HS
      CØMMØN HSR,HØB,EBR,EVAP,HE,HC,HLYMN,PTBL(10) ,TTBL(10) ,WMS,CØNST
      CØMMØN  HFG,CLD1,HFGTB(10),CØNS1
10    FØRMAT(6F10.0)
20    FØRMAT(6I10)
C     CHØICE ØF INTEGRATIØN SUBRØUTINE
```

```
      READ(IN,20)     INTC
      IF(INTC - 3) 30,40,50
   30 INT = INTC
      GØ TØ 60
   40 INT = 4
      GØ TØ 60
   50 CØNTINUE
   60 CØNTINUE
      GØ TØ (110,120,130,140), INTC
  110 WRITE(IØ,115)
  115 FØRMAT('1     ****   EULER INTEGRATIØN    *****'//)
      GØ TØ 150
  120 CØNTINUE
      WRITE(IØ,125)
  125 FØRMAT('1      *****  MØD. EULER INTEGRATIØN  *****'//)
       GØ TØ 150
  130 WRITE(IØ,135)
  135 FØRMAT('1      *****  4 TH ØRDER  RUNGE-KUTTA   ******'//)
       GØ TØ 150
  140 WRITE(IØ,145)
  145 FØRMAT('1     *****   ADAMS MØULTØN INTEG.  *******'//)
  150 CØNTINUE
C
C     INTEGRATIØN CØNTRØL PARAMETERS
      READ(IN,10) X,DX,DXPR,XEND
      WRITE(IØ,160)X,DX,DXPR,XEND
  160 FØRMAT('  X ='F6.2'    DX ='E10.3'     DXPR ='E10.3
     1 '   XEND ='E10.3,/)
      READ(IN,10) ERRØR,DXMAX
```

```
      WRITE(IØ,180) ERRØR,DXMAX
180   FØRMAT('   ERRØR ='E10.3'   DXMAX ='E10.3,/)
      READ(IN,10) TEMP,U,AREA,EL
      READ(IN,10) RHØ,WMPH,TAIR,CLD,RH,ALBAR
      DØ 185 I=1,10
185   READ(IN,10) PTBL(I), TTBL(I), HFGTB(I)
      TA = (TAIR - 32.)*5./9.
      W = WMPH*22./15.
      WMS = W * .3048
      WMD = WMPH * 24.
      CØNST = EL/(RHØ*U*AREA)
      CØNS1 = (RHØ*0.00328)/(24.*3600.*0.0614)
      SINA = SIN(ALBAR*3.14159/180.)
      CLD1 = 1. - .0765*CLD
C     INCIDENT SØLAR RADIATIØN
      HØS = 1.9*SINA
      HS = HØS*(1. - .0006*CLD**3)
C     REFLECTED SØLAR RADIATIØN
      HSR = HS*3./ALBAR
      EA = RH*(1013./1470.)*SI(TTBL,PTBL,TAIR,10)
      WRITE(IØ,200) TEMP
200   FØRMAT('  INITIAL STREAM TEMPERATURE ='F6.2'  DEG F'/)
      WRITE(IØ,210) U,AREA,EL
210   FØRMAT('  STREAM VELØCITY ='F6.3' FT/SEC   CR. SEC. AREA ='
     1F10.2'  SQ. FT.     SURFACE WIDTH ='F6.1'  FT'/)
      WRITE(IØ,220) RHØ,CLD,RH,ALBAR
220   FØRMAT('  RHØ='F5.2'  LB/CU.FT.      CLD='F4.1'  TENTHS',
     1'    RH='F5.1'  PCT'/'  ALBAR ='F4.1'  DEGREES'/)
```

```
      WRITE(IO,230) TAIR,TA,CONST, CONS1
230   FORMAT('  AIR TEMP. ='F5.1'  DFG F'F8.1'  DFG C',
     1'    CONST ='E10.3'     CONS1 ='E10.3'/)
      WRITE(IO,240) W,WMPH,WMS,WMD
240   FORMAT('  WIND VELOCITY ='F6.2' FT/SEC'F8.2'MPH'F8.2' METERS',
     1'/SEC'F8.2'  MILES/DAY'/)
      WRITE(IO,260)
260   FORMAT(/,T20'TTBL'T40'PTBL'T60'HFGTB'/)
      DO 270 I =1,10
270   WRITE(IO,280) TTBL(I), PTBL(I), HFGTB(I)
280   FORMAT(10X,3F20.5)
      WRITE(IO,300) EA,HOS,HS,HSR
300   FORMAT(//'  FA ='E12.4'    HOS ='E12.4'   HS ='E12.4,
     1 '   HSR ='E12.4'  LY/MIN')
      WRITE(IO,310)
310   FORMAT('1')
      RETURN
      END
      SUBROUTINE OUPT
      COMMON DTEMP, TFMP,       XPR,XFND,DXPR,X,DX, INT,INTC,
     1 IN,IO,EI,ARFA,U,ERROR,DXMAX
      COMMONRHO, WMD,HD,TAIR,CLD,RH,ALBAR,TWS,TA, EW,EA,HOS,HS
      COMMON HSR,HOB,FBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CONST
      COMMON  HFG,CLD1,HFGTB(10),CONS1
      WRITE(IO,10) X,DX
10    FORMAT('   X ='F7.1' FT      DX ='F6.1' /)
      WRITE(IO,20) TEMP,DTEMP
20    FORMAT('  STREAM TEMP ='F6.2' DFG F        DTEMP ='E10.3'
     1'  DEG F/FT'/)
```

```
      WRITE(IØ,30) EW, EVAP,HE,HFG
   30 FØRMAT('  EW ='E12.5'                    EVAP,MMPD ='E12.5' HE ='
     1E12.5'  LY/MIN    HFG ='E12.5,/)
      WRITE(IØ,50) HØB,EBR,HC
   50 FØRMAT('  HØB ='E12.5'  EBR='E12.5'   HC  ='E12.5'  LY/MIN'/)
      WRITE(IØ,60) HLYMN,HD
   60 FØRMAT('  TØTAL HEAT TRANSFER ='E12.5'  LY/MIN'E15.5,
     1'   BTU/SEC-FT2'/)
      WRITE(IØ,70)
   70 FØRMAT(////)
      RETURN
      END
      SUBRØUTINE DIFEQ
      CØMMØNDTEMP,  TEMP,       XPR,XEND,DXPR,X,DX,  INT,INTC,
     1 IN,IØ,FI ,AREA,U,ERRØR,DXMAX
      CØMMØNRHØ, WMD,HD,TAIR,CLD,RH,ALBAR,TWS,TA,  EW,EA,HØS,HS
      CØMMØN HSR,HØB,EBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CØNST
      CØMMØN  HFG,CLD1,HFGTB(10),CØNS1
C     THERMAL EXCHANGE WITH ENVIRØNMENT.
      TWS= (TEMP-32.)*5./9.
      EW=(1013./14.7)*SI(TTBL,PTBL,TEMP,10)
C     EFFECTIVE BACK RADIATIØN.
      HØB= (14.38-.09*TWS-.046*RH)/69.72
      EBR = HØB * CLD1
C     EVAPØRATIØN HEAT TRANSFER.
      EVAP = .35* (EW-EA)*(1. + .0098* WMD)
      HFG = SI(TTBL,HFGTB,TEMP,10)
      HE = EVAP*HFG*CØNS1
```

```
C     CONVECTION HEAT TRANSFER
      HC = 39.*(.26 + .077*WMS)*(TWS - TA )/1440.
C     TOTAL HEAT TRANSFER TO WATER, LY/MIN
      HLYMN = HS - (EBR + HSR + HC + HE)
C     TOTAL HEAT TRANSFER, BTU/SEC-FT2
      HD = HLYMN * .0614
C     DERIVATIVE CALCULATION
      DTEMP = CONST*HD
      RETURN
      END
CCCCC
CCCCC
CCCCC
CCCCC
      FUNCTION SI(XTBL,YTBL,X,N)
C     LINEAR INTERPOLATION OR EXTRAPOLATION OF SINGLE VARIABLE FUNCTION
C     XTBL = INDEPENDENT VARIABLE TABLE
C     YTBL = DEPENDENT VARIABLE TABLE
C     IND = INDICATOR OF EXTRAPOLATION
C     0=NO EXTRAPOLATION, 1=LOWER EXTRAPOLATION, 2=4PPER E73RAPOLATION
      DIMENSION XTBL(40),YTBL(40)
C     CHECK TO SEE IF EXTRAPOLATION IS NEEDED.
      IF(X-XTBL(1)) 120,130,150
  120 IND = 1
  130 II = 2
      GO TO 254
  150 IF(XTBL(N)-X) 160,180,210
 160   IND = 2
 180   II = N
```

```
      GO TO 254
C     FIND X IN TABLE.S IN TABLE
  210 DO 220 IK=2,N
      II = IK
      IF(XTBL(IK)-X) 220,254,254
  220 CONTINUE
  254 X1 = XTBL(II-1)
      X2 = XTBL(II)
      Y1 = YTBL(II-1)
      Y2 = YTBL(II)
      SI = Y1+(Y2-Y1)*(X-X1)/(X2-X1)
      RETURN
      END
CCCCC
CCCCC
C     EULER AND MODIFIED EULER INTEGRATION
CCCCC
CCCCC
CCCCC
      SUBROUTINE EULER(YP,Y,DT,NE,J,T)
      DIMENSION YP(20),Y(20), SY(20),SYP(20)
      GO TO(10,20),J
   10 CONTINUE
      DO 100 I=1,NE
      SY(I)= Y(I)
      SYP(I)= YP(I)
      Y(I)= Y(I)+DT*YP(I)
  100 CONTINUE
```

```
      T=T+DT
      RETURN
   20 CØNTINUE
      DØ 200 I=1,NE
      Y(I)= SY(I)+(YP(I)+SYP(I))*DT/2.
  200 CØNTINUE
      RETURN
      END
CCCCC
CCCCC
CCCCC
C     FØURTH ØRDER RUNGE-KUTTA INTEGRATIØN
CCCCC
CCCCC
CCCCC
      SUBRØUTINE RK4(YP,Y,DT,NE,J,T)
      DIMENSIØN YP(5),Y(5),AK(5,4),SY(5)
      GØ TØ(10,20,30,40),J
10    CØNTINUE
      DØ 100 I=1,NE
      SY(I) = Y(I)
      AK(I,1) = DT*YP(I)
      Y(I) = Y(I) +AK(I,1)*.5
100   CØNTINUE
      ST = T
      T = T + DT*.5
      RETURN
20    CØNTINUE
      DØ 200 I=1,NE
```

```
          AK(I,2) = DT*YP(I)
          Y(I) = SY(I) + AK(I,2)*.5
200       CONTINUE
          RETURN
30        CONTINUE
          DO 300 I = 1,NE
          AK(I,3) = DT*YP(I)
          Y(I) = SY (I) + AK(I,3)
300       CONTINUE
          T = ST + DT
          RETURN
40        CONTINUE
          DO 400 I = 1,NE
          AK(I,4) = DT *YP(I)
          Y(I)=SY(I)+(AK(I,1)+AK(I,4)+2.*(AK(I,2)+AK(I,3)))/6.
400       CONTINUE
          RETURN
          END
CCCCC
CCCCC
CCCCC
C         ADAMS-MOULTON INTEGRATION
CCCCC
CCCCC
CCCCC
          SUBROUTINENORD(F,T,TLIM,Y,ERROR,NF,H,HMAX,JUMP,KSTP,KCON,CLIF,IO)
          DIMENSION STARY(5),Y(5),SY(5),SAVEY(5),F(5),FP(5),DELTA(5),DALTA(5
         1),A(5),B(5),C(5),D(5),AA(5),BB(5),CC(5),DD(5),SF(5)
```

```
      IF(KSTP-32767)993,991,991
  991 KSTP=28
C     TEST FOR TYPE OF ENTRY
 993  IF(JUMP)1,998,999
  998 GO TO (1000,11,21,802,803),IA
C     JUMP POS.    RESTORE VALUES
  999 T=SAVET
 992  JUMP=0
      DO 901 I=1,NF
      F(I)=SF(I)
 901  Y(I)=SAVEY(I)
      GO TO 102
C     JUMP NEG.     INITIALIZE
    1 DO 5 I=1,NE
      STARY(I)=Y(I)
      A(I)=0.001
      B(I)=0.001
      C(I)=0.001
    5 D(I)=0.001
      KSTP=0
      KDELY=0
      KCON=0
      XT=95./(288.*64.)
      U=863./(12.*5040.)
      V=95.0/288.0
      P=25.0/24.0
      Q=35.0/72.0
      R=5.0/48.0
      S=1.0/120.0
```

```
      IA=1
      JUMP=0
      GO TO 1101
C     BEGIN INTEGRATION STEP
 1000 DO 1111 I=1,NE
      SF(I)=F(I)
 1111 SAVEY(I)=Y(I)
C     H TOO SMALL  RETURN WITH JUMP NEG.
  600 IF(ABS(T+H)-ABS(T))605,601,605
  601 JUMP=-1
      GO TO 1101
  605 T=T+H
      DO 10 I=1,NE
      Y(I)=Y(I)+H*(F(I)+A(I)+B(I)+C(I)+D(I))
   10 FP(I)=F(I)+2.0*A(I)+3.0*B(I)+4.0*C(I)+5.0*D(I)
      IA=2
      GO TO 1101
   11 DO 12 I=1,NE
   12 SY(I)=Y(I)
      DO 20 I=1,NE
      DELTA  (I)=F(I)-FP(I)
   20 Y(I)=Y(I)+V*DELTA  (I)*H
      IA=3
      KCON=1
      GO TO 1101
   21 KCON=0
      DO 30 I=1,NE
      DALTA  (I)=F(I)-FP(I)
```

```
   29 Y(I)=SY(I)+V*DALTA  (I)*H
   30 CØNTINUE
C     TEST FØR STARTING SEQUENCE
   31 IF(KSTP-28)35,40,40
C     APPLY TEST 2 ØN ZERØTH STEP
   35 IF(KSTP)50,50,60
C     HALVING TESTS
   40 DØ 45 I=1,NE
      IF(ABS(DALTA  (I))-ERRØR/ABS(H))45,45,55
   45 CØNTINUE
   50 IF(V*H*CLIF-0.125)60,60,55
   55 T=T-H
C     FAIL TESTS, HALVE H
  223 H=H/2.0
      KDELY=0
      DØ 56 I=1,NE
      A(I)=A(I)/2.0
      B(I)=B(I)/4.0
      C(I)=C(I)/8.0
      F(I)=SF(I)
      Y(I)=SAVFY(I)
   56 D(I)=D(I)/16.0
      GØ TØ 1000
C     PASS TESTS, CØRRECT A,B,C,D
   60 KSTP=KSTP+1
      DØ 65 I=1,NE
      A(I)=A(I)+3.0*B(I)+6.0*C(I)+10.0*D(I)+P*DALTA  (I)
   62 B(I)=B(I)+4.0*C(I)+10.0*D(I)+Q*DALTA(I)
   64 C(I)=C(I)+5.0*D(I)+R*DALTA(I)
```

```
   67 D(I)=D(I)+S*DALTA(I)
   65 CONTINUE
C     IF IN STARTING SEQUENCE, BRANCH
      IF(KSTP-24)70,90,100
   70 GO TO (1000,1000,1000,74,1000,1000,1000,78,1000,1000,1000,74,1000,
     11000,1000,86,1000,1000,1000,74,1000,1000,1000),KSTP
C     4TH, 12TH, 20TH STEP, GO BACK
   74 H=-H
      DO 75 I=1,NE
      A(I)=-A(I)
   75 C(I)=-C(I)
      GO TO 1000
C     8TH STEP  GO FOWARD
   78 H=-H
      DO 79 I=1,NE
      Y(I)=STARY(I)
      A(I)=-A(I)
   79 C(I)=-C(I)
      GO TO 1000
C     16TH STEP, HALVE H, APPLY TEST 1
   86 H=H/2.0
      DO 87 I=1,NE
      A(I)=A(I)/2.0
      B(I)=B(I)/4.0
      C(I)=C(I)/8.0
   87 D(I)=D(I)/16.0
      DO 88 I=1,NE
      IF(ABS(DALTA  (I))-ERROR/ABS(H))88,88,89
```

```
   88 C0NTINUE
C     PASS TEST   G0 F0WARD WITH HALVFD H
      G0 T0 78
C     FAIL TEST   BEGIN AGAIN WITH HALVFD H
   89 H=-H
      D0 92 I=1,NE
   92 Y(I)=STARY(I)
      G0 T0 1
C     24TH STEP, D0UBLE H, STARTING SFQUENCE ENDS
   90 H=H*2.0
      D0 91 I=1,NE
      A(I)=A(I)*2.0
      B(I)=B(I)*4.0
      C(I)=C(I)*8.0
   91 D(I)=D(I)*16.0
      G0 T0 78
  100 KDELY=KDFLY+1
C     WILL NEXT STFP M0VE PAST TLIM
  102 IF(ABS(TLIM-T)-ABS(H))103,103,110
C     YES..........SAVF T AND Y, INTEGRATE T0 TLIM,RETURN.
  103 ENDH=TLIM-T
      D0 105 I=1,NF
      AA(I)=ENDH*A(I)/H
      BB(I)=ENDH**2*B(I)/H**2
      CC(I)=ENDH**3*C(I)/H**3
  105 DD(I)=ENDH**4*D(I)/H**4
      SAVFT=T
      D0 800 I=1,NF
      SF(I)=F(I)
```

```
  800 SAVEY(I)=Y(I)
  806 T=TLIM
      D0 106 I=1,NF
      Y(I)=Y(I)+ENDH*(F(I)+AA(I)+BB(I)+CC(I)+DD(I))
  106 FP(I)=F(I)+2.0*AA(I)+3.0*BB(I)+4.0*CC(I)+5.0*DD(I)
      IA=4
      G0 T0 1101
  802 D0 805 I=1,NF
  805 SY(I)=Y(I)
      D0 107 I=1,NF
      DELTA  (I)=F(I)-FP(I)
  107 Y(I)=Y(I)+V*DELTA  (I)*ENDH
      IA=5
      G0 T0 1101
  803 D0 108 I=1,NF
      DALTA  (I)=F(I)-FP(I)
  108 Y(I)=SY(I)+V*DALTA  (I)*ENDH
      JUMP=1
      G0 T0 1101
C     N0........TEST F0R D0UBLING. IF 0K, BEGIN NEST STE- AFTER D0UBLING
  110 IF(ABS(TLIM-T)-ABS(2.0*H))1000,1000,111
  111 IF(KDELY-4)1000,120,120
  120 IF(ABS(2.0*H)-ABS(HMAX))121,121,1000
  121 D0 125 I=1,NF
      IF(ABS(DALTA  (I))-ERR0R/(128.0*ABS(H)))125,125,1000
  125 C0NTINUE
      IF(V*H*CLIF-0.0625)130,1000,1000
  130 C0NTINUE
```

```
  335 H=2.0*H
      DØ 135 I=1,NF
      A(I)=2.0*A(I)
      B(I)=4.0*B(I)
      C(I)=8.0*C(I)
  135 D(I)=16.0*D(I)
      KDELY=0
      GØ TØ 1000
 1101 CØNTINUE
 1150 FØRMAT(/,2X,'HH =',2X,F10.6,14X,'KSTP =',2X,I3,10X,'DAL3A(I)',/)
 1151 FØRMAT(5(2X,I2,1X,E14.7))
      RETURN
      END
```

```
C
C
C     SENSIT
C
C
C     SENSITIVITY ANALYSIS
C
C
C
      COMMONDDT,DT,XPR,XEND,DXPR,X,DX,INT,INTC,IN,IO,EL,AREA,U
      COMMON ERROR,DXMAX,TEMP,HFGTB(10),CONS1
      COMMONRHO,WMD,HD,TAIR,CLD,RH,AI BAR,TWS,TA,EW,EA,HOS,HS
      COMMON HSR,HOB,EBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CONST
      COMMON HFG,HOC,CLD1,CLD2,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
     1DTA,DW,DWMS,DWMD,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
      IN=5
      IO=6
      CALL INPUT
      IF(INTC - 4) 4,105,105
4     XPR = DXPR
5     CONTINUE
      DO 100 JE= 1,INT
      CALL DIFFQ
      GO TO (10,10,20), INTC
10    CALL EULER(DDT,DT,DX,1,JE,X)
      GO TO 100
20    CALL RK4(DDT,DT,DX,1,JE,X)
100   CONTINUE
      IF(X - XPR )        5,250,250
250   CALL OUPT
      XPR = XPR + DXPR
      IF(X - XEND) 5,300,300
105   CONTINUE
      JUMP = -1
110   CONTINUE
      XPR = X + DXPR
```

```
120   CØNTINUE
      CALLNØRD(DDT,X,XPR,DT,ERRØR,1,DX,DXMAX,JUMP,KS,KC,1.E-6,IØ)
      IF(JUMP)130,140,150
130   WRITE(IØ,131) X
131   FØRMAT(//'    X ='E14.5'   INTEGRATIØN FAILURE')
      CALL EXIT
140   CØNTINUE
      CALL DIFFQ
      GØ TØ 120
150   CALL ØUPT
      IF(X - XEND) 110,300,300
300   CALL EXIT
      END
      SUBRØUTINE INPUT
      CØMMØN DDT,   DT,   XPR,XEND,DXPR,X,DX,INT,INTC,
     1 IN,IØ,EL,AREA,U,ERRØR,DXMAX,TEMP,HFGTB(10),CØNS1
      CØMMØNRHØ,WMD,HD,TAIR,CLD,RH,ALBAR,TWS,TA,EW,EA,HØS,HS
      CØMMØN HSR,HØB,EBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CØNST
      CØMMØN HFG,HØC,CLD1,CLD2,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
     1DTA,DW,DWMS,DWMD,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
10    FØRMAT(6F10.0)
20    FØRMAT(6I10)
      RATIØ = 3.14159/180.
C     CHØICE ØF INTEGRATIØN SUBRØUTINE
      READ(IN,20)  INTC
      IF(INTC - 3) 30,40,50
30    INT = INTC
      GØ TØ 60
```

```
 40     INT = 4
        GØ TØ 60
 50     CØNTINUE
 60     CØNTINUE
        GØ TØ (110,120,130,140), INTC
 110    WRITE(IØ,115)
 115    FØRMAT('1     ****    EULER INTEGRATIØN    *****'//)
        GØ TØ 150
 120    CØNTINUE
        WRITE(IØ,125)
 125    FØRMAT('1      *****  MØD. EULER INTEGRATIØN  *****'//)
         GØ TØ 150
 130    WRITE(IØ,135)
 135    FØRMAT('1      *****  4 TH ØRDER  RUNGE-KUTTA   ******'//)
         GØ TØ 150
 140    WRITE(IØ,145)
 145    FØRMAT('1     *****    ADAMS MØULTØN INTEG.  *******'//)
 150    CØNTINUE
C
C       INTEGRATIØN CØNTRØL PARAMETERS
        READ(IN,10) X,DX,DXPR,XEND
        WRITE(IØ,160)X,DX,DXPR,XEND
 160    FØRMAT('  X ='F6.2'    DX ='E10.3'     DXPR ='E10.3
       1 '     XEND ='E10.3,/)
        READ(IN,10) ERRØR,DXMAX
        WRITE(IØ,180) ERRØR,DXMAX
 180    FØRMAT('   ERRØR ='E10.3'   DXMAX ='E10.3,/)
        READ(IN,10)  DT,U,AREA,EL
        READ(IN,10) RHØ,WMPH,TAIR,CLD,RH,ALBAR
```

```
      DØ 185 I=1,10
  185 READ(IN,10) PTBL(I), TTBL(I), HFGTB(I)
      TA = (TAIR - 32.)*5./9.
      W = WMPH*22./15.
      WMS = W * .3048
      WMD = WMPH * 24.
      CØNST = FL/(RHØ*U*AREA)
      CØNS1 = (RHØ*0.00328)/(24.*3600.*0.0614)
      READ(IN,10) DALP,DCLD,DRH,DTAIR,DWMPH
      DTA = DTAIR*5./9.
      HØS = 1.9*SIN(ALBAR*RATIØ)
      HØC = 1.9*CØS(ALBAR*RATIØ)
      CLD1 = 1. - .0765*CLD
      CLD2 = -.0018*CLD**2
      CLD3 = 1. - .0006*CLD**3
      DALPR = DALP * RATIØ
      DW = DWMPH*22./15.
      DWMS = DW * .3048
      DWMD = DWMPH*24.
C     INCIDENT SØLAR RADIATIØN
      HS = HØS * CLD3
C     REFLECTED SØLAR RADIATIØN
      HSR = HS * 3./ALBAR
      FTA = SI(TTBL,PTBL,TAIR,10)
      EA = RH*(1013./1470.)*FTA
      TAIRP = TAIR+DTAIR
      FTAP = SI(TTBL,PTBL,TAIRP,10)
      DEA = (1013./1470.)*(DRH*FTA + RH*(FTAP - FTA))
      WRITE(IØ,200) DT
```

```
200   FØRMAT('  INITIAL DT ='E12.4            '       DEG F'/)
      WRITE(IØ,210) U,AREA,EL
210   FØRMAT('  STREAM VELØCITY ='F6.3' FT/SEC   CR. SEC. AREA ='
     1F10.2'  SQ. FT.     SURFACE WIDTH ='F6.1'  FT'/)
      WRITE(IØ,220) RHØ,CLD,RH,ALBAR
220   FØRMAT('  RHØ='F5.2'  LB/CU.FT.      CLD='F4.1'  TENTHS',
     1'     RH='F5.1'  PCT'/'  ALBAR ='F4.1'  DEGREES'/)
      WRITE(IØ,230) TAIR,TA,CØNST,CØNS1
230   FØRMAT('  AIR TEMP. ='F5.1'  DEG F'F8.1'  DEG C',
     1'     CØNST ='E10.3'     CØNS1 ='F10.3,/)
      WRITE(IØ,240) W,WMPH,WMS,WMD
240   FØRMAT('  WIND VELØCITY ='F6.2' FT/SEC'F8.2'MPH'F8.2' METERS',
     1'/SEC'F8.2'  MILES/DAY'/)
      WRITE(IØ,260)
260   FØRMAT(/,T20'TTBL'T40'PTBL'T60'HFGTB'/)
      DØ 270 I =1,10
270   WRITE(IØ,280) TTBL(I), PTBL(I), HFGTB(I)
280   FØRMAT(10X,3F20.5)
      WRITE(IØ,300)DCLD,DRH,DTAIR
300   FØRMAT(/'  DCLD ='F6.3'  DRH ='F5.3'  DTAIR ='F6.2)
      WRITE(IØ,310) DALP,DWMPH
310   FØRMAT(/'  DALP ='F6.2'  DWMPH ='F6.2)
      WRITE(IØ,320) HØS,HØC,HS,HSR
320   FØRMAT(/'  HØS='E12.4'  HØC='E12.4'  HS='E12.4'  HSR='E12.4' LY/MIN')
     1N')
      WRITE(IØ,330) EA,DEA
330   FØRMAT(/'  EA ='E12.4'  DEA ='E12.4)
      WRITE(IØ,340)
```

```
340  FØRMAT(/,T20'STTBL'T40'XTBL'/)
     READ(IN,20) NTEMP
     DØ 350 I =1,NTEMP
     READ(IN,10)   STTBL(I),XTBL(I)
     WRITE(IØ,280) STTBL(I),XTBL(I)
350  CØNTINUE
     WRITE(IØ,360)
360  FØRMAT('1')
     RETURN
     END
     SUBRØUTINE ØUPT
     CØMMØN  DDT,        DT,XPR,XEND,DXPR,X,DX,INT,
    1INTC, IN,IØ,FL,AREA,U,ERRØR,DXMAX,TEMP,HFGTB(10),CØNS1
     CØMMØNRHØ,WND,HD,TAIR,CLD,RH,ALBAR,TWS,TA,EW,EA,HØS,HS
     CØMMØN HSR,HØB,EBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CØNST
     CØMMØN HFG,HØC,CLD1,CLD2,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
    1DTA,DW,DWMS,DWMD,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
     WRITE(IØ,10) X,DX
 10  FØRMAT('    X ='F7.1' FT    DX ='F6.1        ,/)
     WRITE(IØ,20) TEMP
20   FØRMAT('  STREAM TEMP ='E12.4' DEG F'/)
     WRITE(IØ,70) DT,DDT
     WRITE(IØ,30) EW,DEW,EVAP,HE,HFG
30   FØRMAT('  EW ='F12.5'   DEW ='F12.5'  EVAP ='E12.5'   HE ='
    1E12.5' LY/MIN    HFG ='E12.5,/)
     WRITE(IØ,50) HØB,EBR,HC
50   FØRMAT('  HØB ='E12.5'   EBR='F12.5'   HC  ='E12.5'  LY/MIN'/)
     WRITE(IØ,60) HLYMN,HD
60   FØRMAT('  TØTAL HEAT TRANSFER ='E12.5'  LY/MIN'E15.5,
```

```
     1'   BTU/SEC-FT2'/)
70    FORMAT('  DT ='E12.5'    DDT ='F12.5,/)
      WRITE(IO,80) DLYMN,DBTUS
80    FORMAT('  DLYMN ='E12.5'    DBTUS ='E12.5,/)
      WRITE(IO,90)
90    FORMAT(1X,60('*'),//)
      RETURN
      END
      SUBROUTINE DIFEQ
      COMMON  DDT,DT,              XPR,XFND,DXPR,X,DX,
     1INT,INTC, IN,IO,EL,AREA,U,ERROR,DXMAX,TEMP,HFGTB(10),CONS1
      COMMONRHO,WMD,HD,TAIR,C,RH,ALBAR,TWS,TA,EW,FA,HOS,HS
      COMMON HSR,HOB,EBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CONST
      COMMON HFG,HOC,CLD1,CLD2,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
     1DTA,DW,DWMS,DWMD,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
C     THERMAL FXCHANGF WITH ENVIRONMFNT.
      TEMP = SI(XTBL,STTBL,X,NTEMP)
      TWS= (TEMP-32.)*5./9.
      DTWS = DT*5./9.
      FTA = SI(TTBL,PTBL,TEMP,10)
      TTW = TEMP + DT
      FTB = SI(TTBL,PTBL,TTW,10)
      EW = (1013./14.7)*FTA
      DEW = (1013./14.7)*(FTB - FTA)
C     EFFECTIVF BACK RADIATION.
      HOB= (14.38-.09*TWS-.046*RH)/69.72
      EBR = HOB*CLD1
C     EVAPORATION HEAT TRANSFER.
```

```
      EVAP = .35* (EW-EA)*(1. + .0098* WMD)
      HFG = SI(TTBL,HFGTB,TEMP,10)
      HE = EVAP*HFG*CØNS1
C     CØNVECTIØN HEAT TRANSFER
      HC = 39.*(.26 + .077*WMS)*(TWS - TA )/1440.
C     TØTAL HEAT TRANSFER TØ WATER, LY/MIN
      HLYMN = HS - (EBR + HSR + HC + HE)
C     TØTAL HEAT TRANSFER, BTU/SEC-FT2
      HD = HLYMN * .0614
      F1 = CLD2*DCLD*HØS
      F2 = CLD3*HØC*DALPR
      F3 = .0765*DCLD*HØB
      F4 = -CLD1*(-.09*DTWS - .046*DRH)/69.72
      F5 = -(F1+F2)*3./ALBAR
      F6 = HS*3.*DALP/ALBAR**2
      F7 = -(.35*HFG/14400.)*((1. + .0098*WMD)*(DEW - DEA) +
     1 .0098*DWMD*(EW - EA))
      F8 = -(39./1440.)*((.26 + .077*WMS)*(DTWS - DTA) +
     1 .077*DWMS*(TWS - TA))
      DLYMN = F1 + F2 + F3 + F4 + F5 + F6 + F7 + F8
      DBTUS = DLYMN*.0614
      DDT = CØNST*DBTUS
      RETURN
      END
CCCCC
CCCCC
CCCCC
CCCCC
```

```
      FUNCTIØN SI(XTBL,YTBL,X,N)
C     LINEAR INTERPØLATIØN ØR EXTRAPØLATIØN ØF SINGLE VARIABLE FUNCTIØN
C     XTBL = INDEPENDENT VARIABLE TABLE
C     YTBL = DEPENDENT VARIABLE TABLF
C     IND = INDICATØR ØF EXTRAPØLATIØN
C     Ø=NØ EXTRAPØLATIØN, 1=LØWER EXTRAPØLATIØN, 2=4PPER E73RAPØLATIØN
      DIMENSIØN XTBL(40),YTBL(40)
C     CHECK TØ SEE IF EXTRAPØLATIØN IS NEEDED.
      IF(X-XTBL(1)) 120,130,150
  120 IND = 1
  130 II = 2
      GØ TØ 254
  150 IF(XTBL(N)-X) 160,180,210
 160   IND = 2
 180   II = N
      GØ TØ 254
C     FIND X IN TABLE.S IN TABLE
  210 DØ 220 IK=2,N
      II = IK
      IF(XTBL(IK)-X) 220,254,254
  220 CØNTINUE
  254 X1 = XTBL(II-1)
      X2 = XTBI(II)
      Y1 = YTBI(II-1)
      Y2 = YTBL(II)
      SI = Y1+(Y2-Y1)*(X-X1)/(X2-X1)
      RETURN
      END
CCCCC
```

```
CCCCC
C     EULER AND MODIFIED EULER INTEGRATION
CCCCC
CCCCC
CCCCC
      SUBROUTINE EULER(YP,Y,DT,NE,J,T)
      DIMENSION YP(20),Y(20), SY(20),SYP(20)
      GO TO(10,20),J
   10 CONTINUE
      DO 100 I=1,NE
      SY(I)= Y(I)
      SYP(I)= YP(I)
      Y(I)= Y(I)+DT*YP(I)
  100 CONTINUE
      T=T+DT
      RETURN
   20 CONTINUE
      DO 200 I=1,NE
      Y(I)= SY(I)+(YP(I)+SYP(I))*DT/2.
  200 CONTINUE
      RETURN
      END
CCCCC
CCCCC
CCCCC
C     FOURTH ORDER RUNGE-KUTTA INTEGRATION
CCCCC
CCCCC
CCCCC
```

```
      SUBRØUTINE RK4(YP,Y,DT,NE,J,T)
      DIMENSIØN YP(5),Y(5),AK(5,4),SY(5)
      GØ TØ(10,20,30,40),J
10    CØNTINUE
      DØ 100 I=1,NE
      SY(I) = Y(I)
      AK(I,1) = DT*YP(I)
      Y(I) = Y(I) +AK(I,1)*.5
100   CØNTINUE
      ST = T
      T = T + DT*.5
      RETURN
20    CØNTINUE
      DØ 200 I=1,NE
      AK(I,2) = DT*YP(I)
      Y(I) = SY(I) + AK(I,2)*.5
200   CØNTINUE
      RETURN
30    CØNTINUE
      DØ 300 I = 1,NE
      AK(I,3) = DT*YP(I)
      Y(I) = SY (I) + AK(I,3)
300   CØNTINUE
      T = ST + DT
      RETURN
40    CØNTINUE
      DØ 400 I = 1,NE
      AK(I,4) = DT *YP(I)
```

```
      Y(I)=SY(I)+(AK(I,1)+AK(I,4)+2.*(AK(I,2)+AK(I,3)))/6.
  400 CONTINUE
      RETURN
      END
CCCCC
CCCCC
CCCCC
C     ADAMS-MOULTON INTEGRATION
CCCCC
CCCCC
CCCCC
      SUBROUTINENORD(F,T,TLIM,Y,ERROR,NF,H,HMAX,JUMP,KSTP,KCON,CLIF,IO)
      DIMENSION STARY(5),Y(5),SY(5),SAVEY(5),F(5),FP(5),DELTA(5),DALTA(5
     1),A(5),B(5),C(5),D(5),AA(5),BB(5),CC(5),DD(5),SF(5)
      IF(KSTP-32767)993,991,991
  991 KSTP=28
C     TEST FOR TYPE OF ENTRY
 993  IF(JUMP)1,998,999
  998 GO TO (1000,11,21,802,803),IA
C     JUMP POS.    RESTORE VALUES
  999 T=SAVET
 992  JUMP=0
      DO 901 I=1,NE
      F(I)=SF(I)
 901  Y(I)=SAVEY(I)
      GO TO 102
C     JUMP NEG.    INITIALIZE
    1 DO 5 I=1,NE
      STARY(I)=Y(I)
```

```
      A(I)=0.001
      B(I)=0.001
      C(I)=0.001
    5 D(I)=0.001
      KSTP=0
      KDELY=0
      KC0N=0
      XT=95./(288.*64.)
      U=863./(12.*5040.)
      V=95.0/288.0
      P=25.0/24.0
      Q=35.0/72.0
      R=5.0/48.0
      S=1.0/120.0
      IA=1
      JUMP=0
      G0 T0 1101
C     BEGIN INTEGRATI0N STEP
 1000 D0 1111 I=1,NE
      SF(I)=F(I)
 1111 SAVEY(I)=Y(I)
C     H T00 SMALL  RETURN WITH JUMP NEG.
  600 IF(ABS(T+H)-ABS(T))605,601,605
  601 JUMP=-1
      G0 T0 1101
  605 T=T+H
      D0 10 I=1,NE
      Y(I)=Y(I)+H*(F(I)+A(I)+B(I)+C(I)+D(I))
```

```
   10 FP(I)=F(I)+2.0*A(I)+3.0*B(I)+4.0*C(I)+5.0*D(I)
      IA=2
      GØ TØ 1101
   11 DØ 12 I=1,NE
   12 SY(I)=Y(I)
      DØ 20 I=1,NE
      DELTA(I)=F(I)-FP(I)
   20 Y(I)=Y(I)+V*DELTA(I)*H
      IA=3
      KCØN=1
      GØ TØ 1101
   21 KCØN=0
      DØ 30 I=1,NE
      DALTA(I)=F(I)-FP(I)
   29 Y(I)=SY(I)+V*DALTA(I)*H
   30 CØNTINUE
C     TEST FØR STARTING SEQUENCE
   31 IF(KSTP-28)35,40,40
C     APPLY TEST 2 ØN ZERØTH STEP
   35 IF(KSTP)50,50,60
C     HALVING TESTS
   40 DØ 45 I=1,NE
      IF(ABS(DALTA(I))-ERRØR/ABS(H))45,45,55
   45 CØNTINUE
   50 IF(V*H*CLIF-0.125)60,60,55
   55 T=T-H
C     FAIL TESTS, HALVE H
  223 H=H/2.0
      KDELY=0
```

```
      DO 56 I=1,NE
      A(I)=A(I)/2.0
      B(I)=B(I)/4.0
      C(I)=C(I)/8.0
      F(I)=SF(I)
      Y(I)=SAVFY(I)
   56 D(I)=D(I)/16.0
      GO TO 1000
C     PASS TESTS, CORRECT A,B,C,D
   60 KSTP=KSTP+1
      DO 65 I=1,NE
      A(I)=A(I)+3.0*B(I)+6.0*C(I)+10.0*D(I)+P*DALTA   (I)
   62 B(I)=B(I)+4.0*C(I)+10.0*D(I)+Q*DALTA(I)
   64 C(I)=C(I)+5.0*D(I)+R*DALTA(I)
   67 D(I)=D(I)+S*DALTA(I)
   65 CONTINUE
C     IF IN STARTING SEQUENCE, BRANCH
      IF(KSTP-24)70,90,100
   70 GO TO (1000,1000,1000,74,1000,1000,1000,78,1000,1000,1000,74,1000,
     11000,1000,86,1000,1000,1000,74,1000,1000,1000),KSTP
C     4TH, 12TH, 20TH STEP, GO BACK
   74 H=-H
      DO 75 I=1,NE
      A(I)=-A(I)
   75 C(I)=-C(I)
      GO TO 1000
C     8TH STEP  GO FOWARD
   78 H=-H
```

```
      DO 79 I=1,NE
      Y(I)=STARY(I)
      A(I)=-A(I)
   79 C(I)=-C(I)
      GO TO 1000
C     16TH STEP, HALVE H, APPLY TEST 1
   86 H=H/2.0
      DO 87 I=1,NE
      A(I)=A(I)/2.0
      B(I)=B(I)/4.0
      C(I)=C(I)/8.0
   87 D(I)=D(I)/16.0
      DO 88 I=1,NE
      IF(ABS(DALTA  (I))-ERROR/ABS(H))88,88,89
   88 CONTINUE
C     PASS TEST   GO FOWARD WITH HALVED H
      GO TO 78
C     FAIL TEST   BEGIN AGAIN WITH HALVED H
   89 H=-H
      DO 92 I=1,NE
   92 Y(I)=STARY(I)
      GO TO 1
C     24TH STEP, DOUBLE H, STARTING SEQUENCE ENDS
   90 H=H*2.0
      DO 91 I=1,NE
      A(I)=A(I)*2.0
      B(I)=B(I)*4.0
      C(I)=C(I)*8.0
   91 D(I)=D(I)*16.0
```

```
      GØ TØ 78
  100 KDELY=KDELY+1
C     WILL NEXT STEP MØVE PAST TLIM
  102 IF(ABS(TLIM-T)-ABS(H))103,103,110
C     YES..........SAVE T AND Y, INTEGRATE TØ TLIM,RETURN.
  103 ENDH=TLIM-T
      DØ 105 I=1,NF
      AA(I)=ENDH*A(I)/H
      BB(I)=ENDH**2*B(I)/H**2
      CC(I)=ENDH**3*C(I)/H**3
  105 DD(I)=ENDH**4*D(I)/H**4
      SAVET=T
      DØ 800 I=1,NF
      SF(I)=F(I)
  800 SAVEY(I)=Y(I)
  806 T=TLIM
      DØ 106 I=1,NF
      Y(I)=Y(I)+ENDH*(F(I)+AA(I)+BB(I)+CC(I)+DD(I))
  106 FP(I)=F(I)+2.0*AA(I)+3.0*BB(I)+4.0*CC(I)+5.0*DD(I)
      IA=4
      GØ TØ 1101
  802 DØ 805 I=1,NF
  805 SY(I)=Y(I)
      DØ 107 I=1,NF
      DELTA  (I)=F(I)-FP(I)
  107 Y(I)=Y(I)+V*DELTA  (I)*ENDH
      IA=5
      GØ TØ 1101
```

```
CCCCC C(1000)=CLØUD CØVER
CCCCC TA(1000)=AIR TEMP.
C     PHI(1000)= REL HUMIDITY
C     W(1000)= WIND SPEED
C     TW(1000)= WATER TEMP
C     NCAS= NØ. ØF CASES
C     NDA= NØ. ØF DAYS TØ BE TRIED
C     DELT(50)= ERRØR CRITERIØR TØ BE SATISFIED
C     IDAS(50)= NØ. ØF DAYS IN TRIAL
C     NLN= NØ. ØF LINES
C     DT= ERRØR CRITERIØR FØR THE SPECIFIC CASE
C     NTA= NØ. ØF TIME AVERAGED DATA PØINTS
C     UA,EL,CC,.....,WSP= ACTUAL DATA AT VERNØN
C     INT2,INT3= DATA PØINT NUMBERS
C     DC,DTA,....,DTW= ERRØR IN VARIABLES
      CØMMØN YP1(5),Y1(5),XPR1,XEND1,DXPR1,X1,DX1,NE1,INT1,INTC1,IN1,IØ1
     1,EL1,AREA1,U1
      CØMMØN ERRØR1,DXMAX1,TEMP1,HFGTB1(10),CØNS11
      CØMMØN RHØ1,W1,WMD1,HD1,TAIR1,CLD1,RH1,ALBAR1,TWS1,TA1,TWSA1,EW1,
     1EA1,HØS1,HS1
      CØMMØN HSR1,HØB1,EBR1,EVAP1,HE1,HC1,HLYMN1,PTBL1(10),TTBL1(10),
     1WMS1,CØNST1
      CØMMØN CLIF1,HFG1,HØC1,CLD11,CLD21,CLD31,DALP1,DALPR1,DCLD1,DRH1,
     1DTAIR1,DTA1,DW1,DWMS1,DWMD1,DEA1,DEW1,DLYMN1,DBTUS1,NTEMP1,
     2STTBL1(10),XTBL1(10)
      CØMMØN C(1000),TA(1000),PHI(1000),W(1000),TW(1000)
      CØMMØN NCAS, NDA, DELT(50), IDAS(50)
      CØMMØN NLN,IN,IØU,DT,NTA,IDA
      CØMMØN CTA(50),TATA(50),PHITA(50),WTA(50),TWTA(50)
```

```
      CØMMØN UA,EL,CC,TAIR,TWA,RH,WSP
      CØMMØN INT2,INT3,DC,DTA,DPHI,DW,DTW,INVS,IFLAG
      CØMMØN DM21,BETA
      CØMMØN LAG1,NDAS
      CØMMØN ICAS,PRP(50,10)
CCCCC
CCCCC
CCCCC
CCCCC
      CALL RFEAD
      DT=1.
      DØ 20 IDA=1,NDAS
      CALL PRØB
   20 CØNTINUE
      CALL PRØU
      CALL VERNØN
      CALL EXIT
      END
C     SUBRØUTINE FØR READING IN DATA
CCCCC
CCCCC
CCCCC
CCCCC
CCCCC
      SUBRØUTINE RFEAD
      CØMMØN YP1(5),Y1(5),XPR1,XEND1,DXPR1,X1,DX1,NE1,INT1,INTC1,IN1,IØ1
     1,EL1,AREA1,U1
```

```
      CØMMØN ERRØR1,DXMAX1,TEMP1,HFGTB1(10),CØNS11
      CØMMØN RHØ1,W1,WMD1,HD1,TAIR1,CLD1,RH1,ALBAR1,TWS1,TA1,TWSA1,EW1,
     1EA1,HØS1,HS1
      CØMMØN HSR1,HØB1,EBR1,EVAP1,HE1,HC1,HLYMN1,PTBL1(10),TTBL1(10),
     1WMS1,CØNST1
      CØMMØN CLIF1,HFG1,HØC1,CLD11,CLD21,CLD31,DALP1,DALPR1,DCLD1,DRH1,
     1DTAIR1,DTA1,DW1,DWMS1,DWMD1,DEA1,DEW1,DLYMN1,DBTUS1,NTEMP1,
     2STTBL1(10),XTBL1(10)
      CØMMØN C(1000),TA(1000),PHI(1000),W(1000),TW(1000)
      CØMMØN NCAS, NDA, DELT(50), IDAS(50)
      CØMMØN NLN,IN,IØU,DT,NTA,IDA
      CØMMØN CTA(50),TATA(50),PHITA(50),WTA(50),TWTA(50)
      CØMMØN UA,EL,CC,TAIR,TWA,RH,WSP
      CØMMØN INT2,INT3,DC,DTA,DPHI,DW,DTW,INVS,IFLAG
      CØMMØN DM21,BETA
      CØMMØN LØG1,NDAS
      CØMMØN ICAS,PRP(50,10)
      IN=101
      IØU=102
 1000 FØRMAT(6F10.3)
 1001 FØRMAT(6I10)
      READ (IN,1001) NLN,LØG1
      WRITE(IØU,2000)NLN,LØG1
 2000 FØRMAT(1H0,2X,'NUMBER ØF DATA LINES=',I5,'TIME AV. LØGIC=',I5)
      WRITE(IØU,2001)
 2001 FØRMAT(1H0,2X,'CLD CØVER  AIRTEMP  REL HUM  WIND SPD  WATER TEMP')
      DØ 10 I= 1,NLN
      READ(IN,1000) C(I),TA(I),PHI(I),W(I),TW(I)
      WRITE(IØU,2002)C(I),TA(I),PHI(I),W(I),TW(I)
```

```
2002 FØRMAT(1H0,2X,5(F10.3,1X))
  10 CØNTINUE
C       PLANT DATA
C       UA=VØL, FL=RIVER WIDTH, CL=CLØUD CØVER, TAIR=ØBVIØUS
C       TWA=WATER TEMP, RH=REL HUMIDITY, WSP=WIND SPEED(KNØTS)
        READ(IN,1000)UA,EL,CC,TAIR
        WRITE (IØU,2003)UA,EL,CC,TAIR
2003 FØRMAT(1H0,2X,'UA=',1X,F10.3,'R  WIDTH=',1X,F10.3,'CLD  CØVER=',
     11X,F10.3,'TEMP  AIR=',1X,F10.3)
        READ(IN,1000)TWA,RH,WSP
        WRITE(IØU,2004)TWA,RH,WSP
2004 FØRMAT('0',2X,'TEMP WATER=',1X,F10.3,'REL  HUM=',1X,F10.3,'WIND
     1SPEED=',1X,F10.3)
        IF(LØG1)15,16,15
  15 CØNTINUE
        READ(IN,1001)NTA
        WRITE(IØU,2005)NTA
2005 FØRMAT(1H0,2X,'NUMBER ØF TIME AV. DATA PØINTS=',1X,I5)
        WRITE(IØU,2006)
2006 FØRMAT('0',2X,'CLD CØVER TA   AIR TEMP TA   REL HUM TA   WIND TA
     1   TEMP WATER TA')
        DØ 20 I=1,NTA
        READ(IN,1000) CTA(I),TATA(I),PHITA(I),WTA(I),TWTA(I)
        WRITE(IØU,2007)CTA(I),TATA(I),PHITA(I),WTA(I),TWTA(I)
2007 FØRMAT(1H0,2X,5(F10.3,1X))
  20 CØNTINUE
  16 CØNTINUE
        READ(IN,1001)NCAS
```

```
      WRITE(IØU,2008)NCAS
 2008 FØRMAT(1H0,2X,'NUMBER ØF CASES=',1X,I4)
      READ(IN,3000)(DELT(I), I=1,NCAS)
 3000 FØRMAT(6F10.3)
      WRITE(IØU,3010)
 3010 FØRMAT(1H0,2X,'ALLØWED DTS')
      WRITE(IØU,2009)(DELT(I),I=1,NCAS)
 2009 FØRMAT(1H0,2X,E14.7)
      READ(IN,1001)NDAS
      WRITE(IØU,2010)NDAS
 2010 FØRMAT('0',2X,'NUMBER ØF DAYS AVERAGED=',2X,I4)
      READ(IN,1001)(IDAS(I), I=1,NDAS)
      WRITE(IØU,3011)
 3011 FØRMAT(1H0,2X,'DAYS AVERAGED')
      WRITE(IØU,2050)(IDAS(I),I=1,NDAS)
 2050 FØRMAT(1H0,2X,I5)
      WRITE(IØU,2011)
 2011 FØRMAT(1H0,2X,'PTBL1     TTBL1     HFGTB1',//,2X,60('*'))
      DØ 185 I=1,10
      READ(IN,1002) PTBL1(I),TTBL1(I),HFGTB1(I)
      WRITE(IØU,2012)PTBL1(I),TTBL1(I),HFGTB1(I)
 2012 FØRMAT(6F10.3)
 1002 FØRMAT(6F10.3)
  185 CØNTINUE
      READ(IN,1000) DM21,BETA
      WRITE(IØU,2013)DM21,BETA
      BETA=BETA/57.296
 2013 FØRMAT(1H0,2X,'DAYS SINCE MARCH 21=',2X,F10.3,'BETA=',2X,F10.3)
      DØ 30 IDA=1,NDAS
```

```
      DO 40 ICAS=1,NCAS
      PRP(IDA,ICAS)=0.
   40 CONTINUE
   30 CONTINUE
      RETURN
      END
CCCCC
CCCCC
CCCCC
CCCCC
CCCCC
      SUBROUTINE PROB
      COMMON YP1(5),Y1(5),XPR1,XEND1,DXPR1,X1,DX1,NE1,INT1,INTC1,IN1,IO1
     1,EL1,AREA1,U1
      COMMON ERROR1,DXMAX1,TEMP1,HFGTB1(10),CONS11
      COMMON RHO1,W1,WMD1,HD1,TAIR1,CLD1,RH1,ALBAR1,TWS1,TA1,TWSA1,EW1,
     1EA1,HOS1,HS1
      COMMON HSR1,HOB1,ERR1,EVAP1,HE1,HC1,HLYMN1,PTBL1(10),TTBL1(10),
     1WMS1,CONST1
      COMMON CDIF1,HFG1,HOC1,CLD11,CLD21,CLD31,DALP1,DALPR1,DCLD1,DRH1,
     1DTAIR1,DTA1,DW1,DWMS1,DWMD1,DEA1,DEW1,DLYMN1,DBTUS1,NTEMP1,
     2STTBL1(10),XTBL1(10)
      COMMON C(1000),TA(1000),PHI(1000),W(1000),TW(1000)
      COMMON NCAS, NDA, DELT(50), IDAS(50)
      COMMON NIN,IN,IOU,DT,NTA,IDA
      COMMON CTA(50),TATA(50),PHITA(50),WTA(50),TWTA(50)
      COMMON UA,EL,CC,TAIR,TWA,RH,WSP
      COMMON INT2,INT3,DC,DTA,DPHI,DW,DTW,INVS,IFLAG
```

```
      CØMMØN DM21,BETA
      CØMMØN LØG1,NDAS
      CØMMØN ICAS,PRP(50,10)
      DIMENSIØN PR(10)
C     NDA= NUMBER ØF DAYS IN THE CASE
      ID=IDA
      NDA=IDAS(ID)
      NC1=NLN/8
      FNDA=NDA*8
      FNDA=1/FNDA
      IF(NDA-NC1) 10,999,999
   10 CØNTINUE
      NDIF=NC1-NDA
      ENUM=0.
      DEN=0.
      DENP=0.
      DØ 20 I20=1,NDIF
      CS=0.
      TAS=0.
      PHIS=0.
      WS=0.
      TWS=0.
      DØ 30 I=1,NDA
      DØ 40 J=1,8
      INT=8*(I20+I-1)+J-8
      CS=CS + C(INT)
      TAS=TAS + TA(INT)
      PHIS=PHIS + PHI(INT)
```

```
      WS=WS + W(INT)
      TWS= TWS + TW(INT)
   40 CØNTINUE
   30 CØNTINUE
      CS= CS*FNDA
      TAS= TAS*FNDA
      PHIS=PHIS*FNDA
      WS= WS*FNDA
      TWS= TWS*FNDA
C     INT2= FØLLØWING DAY
      INT2= I20+NDA
      C1S=0.
      TA1S=0.
      PHI1S=0.
      W1S=0.
      TW1S=0.
      DØ 50 I=1,8
C     INT3= THE ACTUAL PØSITIØN IN THE DAY
      INT3=INT2*8-8+I
      C1S=C1S+C(INT3)
      TA1S=TA1S+TA(INT3)
      PHI1S=PHI1S+PHI(INT3)
      W1S=W1S+W(INT3)
      TW1S=TW1S+TW(INT3)
   50 CØNTINUE
      C1S=C1S*.125
      TA1S=TA1S*.125
      PHI1S=PHI1S*.125
      W1S=W1S*.125
```

```
      TW1S=TW1S*.125
      DC=C1S-CS
      DTA=TA1S-TAS
      DPHI=PHI1S-PHIS
      DW=W1S-WS
      DTW=TW1S-TWS
      STTBL1(1)=TW1S
      STTBL1(2)=TW1S
      XTBL1(1)=0.
      XTBL1(2)=25000.
      NTEMP1=2
      INVS=INT2*8-4
      CALL CØMP(ENUM,DEN)
      DØ 60 ICAS=1,NCAS
      IF(ABS(Y1(1))-DELT(ICAS)) 65,65,70
 65   CØNTINUE
      PRP(IDA,ICAS)=PRP(IDA,ICAS)+1.
 70   CØNTINUE
 60   CØNTINUE
 20   CØNTINUE
      DENP=NDIF
      DØ 75 ICAS=1,NCAS
      PRP(IDA,ICAS)=PRP(IDA,ICAS)/DENP
 75   CØNTINUE
      IF(LØG1)200,201,200
 200  CØNTINUE
      ENUM=0.
      DEN=0.
      DENP=0.
```

```
      C(1000)=CC
      TA(1000)=TAIR
      PHI(1000)=RH
      W(1000)=WSP
      TW(1000)=TWA
      DØ 205 ICAS=1,NCAS
      PR(ICAS)=0.
  205 CØNTINUE
      DØ 210 I=1,NTA
      DC=CTA(I)-CC
      DTA=TATA(I)-TAIR
      DPHI=PHITA(I)-RH
      DW=WTA(I)-WSP
      DTW=TWTA(I)-TWA
      STTBL1(1)=TW(1000)
      STTBL1(2)=TW(1000)
      XTBL1(1)=0.
      XTBL1(2)=25000.
      NTEMP1=2.
      INVS=1000
      CALL CØMP(ENUM,DEN)
      DØ 80 ICAS=1,NCAS
      IF(ABS(Y1(1))-DELT(ICAS))85,85,80
   85 CØNTINUE
      PR(ICAS)=PR(ICAS)+1.
   80 CØNTINUE
  210 CØNTINUE
      FNTA=NTA
```

```
      DØ 90 ICAS=1,NCAS
      PR(ICAS)=PR(ICAS)/ENTA
      CALL ØUTT(IØU,PR(ICAS),IDA)
   90 CØNTINUE
  201 CØNTINUE
      RETURN
  999 CØNTINUE
      WRITE(IØU,4000)
 4000 FØRMAT(1H0,2X,'TØØ SMALL')
      CALL EXIT
      END
CCCCC
CCCCC
CCCCC
CCCCC
CCCCC
      SUBRØUTINE ØUTT(IØU,P,I)
      WRITE(IØU,2000)I,P
 2000 FØRMAT(1H0,2X,'CASE',I4,2X,'PRØBABILITY',E14.7)
      RETURN
      END
CCCCC
CCCCC
CCCCC
CCCCC
      SUBRØUTINE  CØMP(ENUM,DEN)
      CØMMØN YP1(5),Y1(5),XPR1,XEND1,DXPR1,X1,DX1,NE1,INT1,INTC1,IN1,IØ1
     1,EL1,AREA1,U1
      CØMMØN ERRØR1,DXMAX1,TEMP1,HFGTB1(10),CØNS11
```

```
      CØMMØN RHØ1,W1,WMD1,HD1,TAIR1,CLD1,RH1,ALBAR1,TWS1,TA1,TWSA1,EW1,
     1EA1,HØS1,HS1
      CØMMØN HSR1,HØB1,EBR1,EVAP1,HE1,HC1,HLYMN1,PTBL1(10),TTBL1(10),
     1WMS1,CØNST1
      CØMMØN CLIF1,HFG1,HØC1,CLD11,CLD21,CLD31,DALP1,DALPR1,DCLD1,DRH1,
     1DTAIR1,DTA1,DW1,DWMS1,DWMD1,DEA1,DEW1,DLYMN1,DBTUS1,NTEMP1,
     2STTBL1(10),XTBL1(10)
      CØMMØN C(1000),TA(1000),PHI(1000),W(1000),TW(1000)
      CØMMØN NCAS, NDA, DELT(50), IDAS(50)
      CØMMØN NIN,IN,IØU,DT,NTA,IDA
      CØMMØN CTA(50),TATA(50),PHITA(50),WTA(50),TWTA(50)
      CØMMØN UA,EL,CC,TAIR,TWA,RH,WSP
      CØMMØN INT2,INT3,DC,DTA,DPHI,DW,DTW,INVS,IFLAG
      CØMMØN DM21,BETA
      CØMMØN LAG1,NDAS
      CØMMØN ICAS,PRP(50,10)
      RHØ1=62.4
      X1=0.
      Y1(1)=DTW
      XEND1=25000.
      DXPR1=XEND1
      DX1=1000.
      NE1=1
      IN1=IN
      IØ1=IØU
      EL1=EL
      AREA1=UA
      U1=1.
```

```
      ERR0R1=.01
      DXMAX1=25000.
      TEMP1=TW(INVS)
      W1=W(INVS)*6080./3600.
      WMS1=W1*.3048
      WMD1=W1*3600.*24./5280.
      WMPH1=WMD1/24.
      TAIR1=TA(INVS)
      CLD1=C(INVS)
      RH1=PHI(INVS)
      ALBAR1=ALNAP(DMP1,BETA)
      ALBAR1=ALBAR1*57.296
      TWS1=5.*(TEMP1-32.)/9.
      TA1=5.*(TAIR1-32.)/9.
      DALP1=5.
      DALPR1=DALP1/57.296
      DCLD1=DC
      DRH1=DPHI
      DTAIR1=DTA
      DW1=DW*6080./3600.
      DWMS1=DW1*.3048
      DWMD1=DW1*3600.*24./5280.
CCCCC
CCCCC
CCCCC
CCCCC
      CALL HUNDL
CCCCC
CCCCC
```

```
CCCCC
      IFLAG=0
      IF(ABS(Y1(1))-DT)10,10,20
   10 CØNTINUE
      ENUM=ENUM+1.
      IFLAG=1
   20 CØNTINUE
      DEN=DEN+1.
      RETURN
      END
CCCCC
CCCCC
CCCCC
CCCCC
      FUNCTIØN ALNAP(DM21,BETA)
      SN1=SIN(BETA)
      TH1= 6.28*DM21/ 365.
      DEL= ASIN(SIN((23.45/57.296))*SIN(TH1))
      PHY=ACØS(TAN(DEL)*TAN(BETA))
      T0=24.*PHY/6.28
      T1=24.-T0
      AV=(T1-T0)*SIN(DEL)*SN1/24.
      AV=AV-CØS(DEL)*CØS(BETA)*(SIN(6.28*T1/24.)-SIN(6.28*T0/24.))/6.28
      ALNAP=ASIN(AV)
      RETURN
      END
CCCCC
CCCCC
```

```
CCCCC
CCCCC
CCCCC
      SUBROUTINE HUNDL
C     STREAM THERMAL MODEL      ****    SENSITIVITY ANALYSIS    ****
      COMMON YP(5),Y(5),XPR,XEND,DXPR,X,DX,NE,INT,INTC,IN,IO,EL,AREA,U
      COMMON ERROR,DXMAX,TEMP,HFGTB(10),CONS1
      COMMONRHA,W,WMD,HD,TAIR,CLD,RH,ALBAR,TWS,TA,TWSA,EW,EA,HOS,HS
      COMMON HSR,HAB,FBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CONST
      COMMON CLIF,HFG,HPC,CLD1,CLD2,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
     1DTA,DW,DWMS,DWMD,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
      CLIF = 1.E-6
      CALL INPUT
      IF(INTC - 4) 4,105,105
4     XPR = DXPR
5     CONTINUE
      DO 100 JF= 1,INT
      CALL DIFFO
      GO TO (10,10,20), INTC
10    CALL EULER(YP,Y,DX,NE,JE,X)
      GO TO 100
20    CALL RK4(YP,Y,DX,NE,JE,X)
100   CONTINUE
      IF(X - XPR+ DX/4.) 5,250,250
 250  CONTINUE
      XPR = XPR + DXPR
      IF(X - XEND) 5,300,300
105   CONTINUE
      JUMP = -1
```

```
 110  CØNTINUE
      XPR = X + DXPR
 120  CØNTINUE
      CALLNØRD(YP,X,XPR,Y,ERRØR,NE,DX,DXMAX,JUMP,KSTP,KCØN,CLIF,IØ)
      IF(JUMP)130,140,150
 130  WRITE(IØ,131) X
 131  FØRMAT(//'    X ='E14.5'   INTEGRATIØN FAILURE')
      RETURN
 140  CØNTINUE
      CALL DIFFQ
      GØ TØ 120
  150 CØNTINUE
      IF(X - XFND) 110,300,300
  300 CØNTINUE
      RETURN
      END
CCCCC
CCCCC
CCCCC
CCCCC
      SUBRØUTINE INPUT
      DIMENSIØN PTBL(10),TTBL(10)
      CØMMØN YP(5), DT,      DUM(4),XPR,XFND,DXPR,X,DX,NE,INT,INTC,
     1 IN,IØ,EI ,AREA,U,ERRØR,DXMAX,TEMP,HFGTB(10),CØNS1
      CØMMØNRHØ,W,WMD,HD,TAIR,CLD,RH,ALBAR,TWS,TA,TWSA,EW,EA,HØS,HS
      CØMMØN HSR,HØR,EBR,EVAP,HE,HC,HLYMN,PTBL ,TTBL ,WMS,CØNST
      CØMMØN CLIF,HFG,HØC,CLD1,CLD2,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
     1DTA,DW,DWMS,DWMD,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
```

```
 10     FØRMAT(6F10.0)
 20     FØRMAT(6I10)
        RATIØ = 3.14159/180.
 C      NUMBER ØF EQUATIØNS AND CHØICE ØF INTEGRATIØN SUBRØUTINE
        NE=1
        INTC=1
        IF(INTC - 3) 30,40,50
 30     INT = INTC
        GØ TØ 60
 40     INT = 4
        GØ TØ 60
 50     CØNTINUE
 60     CØNTINUE
        JFLA=1
        IF(JFLA-1)65,150,65
     65 CØNTINUE
        GØ TØ (110,120,130,140), INTC
 110    WRITE(IØ,115)
 115    FØRMAT('1     ****   EULER INTEGRATIØN     *****'//)
        GØ TØ 150
 120    CØNTINUE
        WRITE(IØ,125)
 125    FØRMAT('1      *****  MØD. EULER INTEGRATIØN  *****'//)
         GØ TØ 150
 130    WRITE(IØ,135)
 135    FØRMAT('1      *****  4 TH ØRDER  RUNGE-KUTTA  '******'//)
         GØ TØ 150
 140    WRITE(IØ,145)
 145    FØRMAT('1     *****   ADAMS MØULTØN INTEG.  *******'//)
```

```
150   CONTINUE
C
C     INTEGRATION CONTROL PARAMETERS
      CONST = FL/(RHO*U*AREA)
      CONS1 = (RHO*0.00328)/(24.*3600.*0.0614)
      DTA = DTAIR*5./9.
      HOS = 1.9*SIN(ALBAR*RATIO)
      HOC = 1.9*COS(ALBAR*RATIO)
      CLD1 = 1. - .0765*CLD
      CLD2 = -.0018*CLD**2
      CLD3 = 1. - .0006*CLD**3
      DALPR = DALP * RATIO
      DW = DWMPH*22./15.
      DWMS = DW * .3048
      DWMD = DWMPH*24.
C     INCIDENT SOLAR RADIATION
      HS = HOS * CLD3
C     REFLECTED SOLAR RADIATION
      HSR = HS * 3./ALBAR
      FTA = SI(TTBL,PTBL,TAIR,10)
      EA = RH*(1013./1470.)*FTA
      TAIRP = TAIR+DTAIR
      FTAP = SI(TTBL,PTBL,TAIRP,10)
      DEA = (1013./1470.)*(DRH*FTA + RH*(FTAP - FTA))
      IFLA=1
      IF(IFLA-1) 198,199,198
 198  CONTINUE
      WRITE(IO,200) DT
```

```
200   FØRMAT('  INITIAL DT ='F12.4            '       DEG F'/)
      WRITE(I8,210) U,AREA,EL
210   FØRMAT('  STREAM VELØCITY ='F6.3' FT/SEC   CR. SEC. AREA ='
     1F10.2'  SQ. FT.     SURFACE WIDTH ='F6.1'  FT'/)
      WRITE(I8,220) RHØ,CLD,RH,ALBAR
220   FØRMAT('  RHØ='F5.2'  LB/CU.FT.      CLD='F4.1'  TENTHS',
     1'    RH='F5.1'  PCT'/'  ALBAR ='F4.1'  DEGREES'/)
      WRITE(I8,230) TAIR,TA,CØNST,CØNS1
230   FØRMAT('  AIR TEMP. ='F5.1'  DEG F'F8.1'  DEG C',
     1'    CØNST ='E10.3'    CØNS1 ='F10.3,/)
      WRITE(I8,240) W,WMPH,WMS,WMD
240   FØRMAT('  WIND VELØCITY ='F6.2' FT/SEC'F8.2'MPH'F8.2' METERS',
     1'/SEC'F8.2'  MILES/DAY'/)
      WRITE(I8,260)
260   FØRMAT(/,T20'TTBL'T40'PTBL'T60'HFGTB'/)
      DØ 270 I =1,10
270   WRITE(I8,280) TTBL(I), PTBL(I), HFGTB(I)
280   FØRMAT(10X,3F20.5)
      WRITE(I8,300)DCLD,DRH,DTAIR
300   FØRMAT(/'  DCLD ='F6.3'  DRH ='F5.3'  DTAIR ='F6.2)
      WRITE(I8,310) DALP,DWMPH
310   FØRMAT(/'  DALP ='F6.2'  DWMPH ='F6.2)
      WRITE(I8,320) HØS,HØC,HS,HSR
320   FØRMAT(/'  HØS='E12.4'  HØC='E12.4'  HS='E12.4'  HSR='E12.4' LY/MIN')
     1N')
      WRITE(I8,330) EA,DEA
330   FØRMAT(/'  EA ='E12.4'  DEA ='F12.4)
      WRITE(I8,340)
340   FØRMAT(/,T20'STTBL'T40'XTBL'/)
```

```
 199  C9NTINUE
      RETURN
      END
CCCCC
CCCCC
CCCCC
CCCCC
      SUBR8UTINE 8UPT
      C8MM8N  DDT,YP(4), DT,DUM(4),XPR,XEND,DXPR,X,DX,NE,INT,
     1INTC, IN,I8,FL,AREA,U,ERR8R,DXMAX,TEMP,HFGTB(10),C8NS1
      C8MM8NRH8,W,WMD,HD,TAIR,CLD,RH,ALPAR,TWS,TA,TWSA,EW,EA,H8S,HS
      C8MM8N HSR,H8S,EBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,C8NST
      C8MM8N CLIF,HFG,H8C,CLD1,CLD2,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
     1DTA,DW,DWMS,DWMD,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
      WRITE(I8,10) X,DX
  10  F8RMAT('      X ='F7.1' FT     DX ='F6.1        ,/)
      WRITE(I8,20) TEMP
 20   F8RMAT('  STREAM TEMP ='E12.4' DEG F'/)
      WRITE(I8,70) DT,DDT
      WRITE(I8,30) EW,DEW,EVAP,HE,HFG
 30   F8RMAT('  EW ='E12.5'    DEW ='E12.5'  EVAP ='E12.5'    HE ='
     1E12.5'  LY/MIN    HFG ='E12.5,/)
      WRITE(I8,50) H8R,EBR,HC
 50   F8RMAT('  H8R ='E12.5'   EBR='E12.5'   HC   ='E12.5'  LY/MIN'/)
      WRITE(I8,60) HLYMN,HD
 60   F8RMAT('  T8TAL HEAT TRANSFER ='E12.5'  LY/MIN'E15.5,
     1'   BTU/SEC-FT2'/)
 70   F8RMAT('  DT ='E12.5'     DDT ='E12.5,/)
```

```
      WRITE(IØ,80) DLYMN,DØTUS
   80 FØRMAT('  DLYMN ='E12.5'     DØTUS ='E12.5,/)
      WRITE(IØ,90)
   90 FØRMAT(1X,60('*'),//)
      RETURN
      END
CCCCC
CCCCC
CCCCC
CCCCC
      SUBRØUTINE DIFEQ
      CØMMØN  DDT,YP(4), DT,           DUM(4),XPR,XEND,DXPR,X,DX,NE,
     1INT,INTC, IN,IØ,EL,AREA,U,ERRØR,DXMAX,TEMP,HFGTB(10),CØNS1
      CØMMØNRHØ,W,WMD,HD,TAIR,C,RH,ALBAR,TWS,TA,TWSA,EW,EA,HØS,HS
      CØMMØN HSR,HØB,EØR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CØNST
      CØMMØN CLIF,HFG,HØC,CLD1,CLD2,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
     1DTA,DW,DWMS,DWMD,DEA,DEW,DLYMN,DØTUS,NTEMP,STTBL(10),XTBL(10)
C     THERMAL EXCHANGE WITH ENVIRØNMENT.
      TEMP = SI(XTBL,STTBL,X,NTEMP)
      TWS= (TEMP-32.)*5./9.
      TWSA = TWS + 273.
      DTWS = DT*5./9.
      FTA = SI(TTBL,PTBL,TEMP,10)
      TTW = TEMP + DT
      FTB = SI(TTBL,PTBL,TTW,10)
      EW = (1013./14.7)*FTA
      DEW = (1013./14.7)*(FTB - FTA)
C     EFFECTIVE BACK RADIATIØN.
      HØB= (14.38-.09*TWS-.046*RH)/69.72
```

```
      EBR = HBR*CLD1
C     EVAPØRATIØN HEAT TRANSFER.
      EVAP = .35* (EW-EA)*(1. + .0098* WMD)
      HFG = SI(TTBL,HFGTB,TEMP,10)
      HE = EVAP*HFG*CØNS1
C     CØNVECTIØN HEAT TRANSFER
      HC = 39.*(.26 + .077*WMS)*(TWS - TA )/1440.
C     TØTAL HEAT TRANSFER TØ WATER, LY/MIN
      HLYMN = HS - (EBR + HSR + HC + HE)
C     TØTAL HEAT TRANSFER, BTU/SEC-FT2
      HD = HLYMN * .0614
      F1 = CLD2*DCLD*HBS
      F2 = CLD3*HBC*DALPR
      F3 = .0765*DCLD*HBR
      F4 = -CLD1*(-.09*DTWS - .046*DRH)/69.72
      F5 = -(F1+F2)*3./ALBAR
      F6 = HS*3.*DALP/ALBAR**2
      F7 = -(.35*HFG/14400.)*((1. + .0098*WMD)*(DEW - DEA) +
     1 .0098*DWMD*(EW - EA))
      F8 = -(39./1440.)*((.26 + .077*WMS)*(DTWS - DTA) +
     1 .077*DWMS*(TWS - TA))
      DLYMN = F1 + F2 + F3 + F4 + F5 + F6 + F7 + F8
      DBTUS = DLYMN*.0614
      DDT = CØNST*DBTUS
      RETURN
      END
CCCCC
CCCCC
```

```
      CCCCC
      CCCCC
            FUNCTIØN SI(XTBL,YTBL,X,N)
      C     LINEAR INTERPØLATIØN ØR EXTRAPØLATIØN ØF SINGLE VARIABLE FUNCTIØN
      C     XTBL = INDEPENDENT VARIABLE TABLE
      C     YTBL = DEPENDENT VARIABLE TABLE
      C     IND = INDICATØR ØF EXTRAPØLATIØN
      C     Ø=NØ EXTRAPØLATIØN, 1=LØWER EXTRAPØLATIØN, 2=4PPER E73RAPØLATIØN
            DIMENSIØN XTBL(40),YTBL(40)
      C     CHECK TØ SEE IF EXTRAPØLATIØN IS NEEDED.
            IF(X-XTBI(1)) 120,130,150
        120 IND = 1
        130 II = 2
            GØ TØ 254
        150 IF(XTBL(N)-X) 160,180,210
       160   IND = 2
       180   II = N
            GØ TØ 254
      C     FIND X IN TABLE*S IN TABLE
        210 DØ 220 IK=2,N
            II = IK
            IF(XTBL(IK)-X) 220,254,254
        220 CØNTINUE
        254 X1 = XTBI(II-1)
            X2 = XTBI(II)
            Y1 = YTBI(II-1)
            Y2 = YTBI(II)
            SI = Y1+(Y2-Y1)*(X-X1)/(X2-X1)
            RETURN
```

```
      END
CCCCC
CCCCC
CCCCC
CCCCC
      SUBRØUTINE EULER(YP,Y,DT,NE,J,T)
      DIMENSIØN YP(20),Y(20), SY(20),SYP(20)
      GØ TØ(10,20),J
   10 CØNTINUE
      DØ 100 I=1,NE
      SY(I)= Y(I)
      SYP(I)= YP(I)
      Y(I)= Y(I)+DT*YP(I)
  100 CØNTINUE
      T=T+DT
      RETURN
   20 CØNTINUE
      DØ 200 I=1,NE
      Y(I)= SY(I)+(YP(I)+SYP(I))*DT/2.
  200 CØNTINUE
      RETURN
      END
CCCCC
CCCCC
CCCCC
CCCCC
      SUBRØUTINE RK4(YP,Y,DT,NE,J,T)
      DIMENSIØN YP(5),Y(5),AK(5,4),SY(5)
```

```
      GØ TØ(10,20,30,40),J
   10 CØNTINUE
      DØ 100 I=1,NF
      SY(I) = Y(I)
      AK(I,1) = DT*YP(I)
      Y(I) = Y(I) +AK(I,1)*.5
  100 CØNTINUE
      ST = T
      T = T + DT*.5
      RETURN
   20 CØNTINUE
      DØ 200 I=1,NF
      AK(I,2) = DT*YP(I)
      Y(I) = SY(I) + AK(I,2)*.5
  200 CØNTINUE
      RETURN
   30 CØNTINUE
      DØ 300 I = 1,NE
      AK(I,3) = DT*YP(I)
      Y(I) = SY (I) + AK(I,3)
  300 CØNTINUE
      T = ST + DT
      RETURN
   40 CØNTINUE
      DØ 400 I = 1,NE
      AK(I,4) = DT *YP(I)
      Y(I)=SY(I)+(AK(I,1)+AK(I,4)+2.*(AK(I,2)+AK(I,3)))/6.
  400 CØNTINUE
      RETURN
```

```
      END
CCCCC
CCCCC
CCCCC
CCCCC
      SUBROUTINENENORD(F,T,TLIM,Y,ERROR,NF,H,HMAX,JUMP,KSTP,KCON,CLIF,IO)
      DIMENSION STARY(5),Y(5),SY(5),SAVFY(5),F(5),FP(5),DELTA(5),DALTA(5
     1),A(5),B(5),C(5),D(5),AA(5),BB(5),CC(5),DD(5),SF(5)
      IF(KSTP-32767)993,991,991
  991 KSTP=28
C     TEST FOR TYPE OF ENTRY
 993  IF(JUMP)1,998,999
  998 GO TO (1000,11,21,802,803),IA
C     JUMP POS.    RESTORE VALUES
  999 T=SAVET
 992  JUMP=0
      DO 901 I=1,NE
      F(I)=SF(I)
 901  Y(I)=SAVFY(I)
      GO TO 102
C     JUMP NEG.    INITIALIZE
    1 DO 5 I=1,NE
      STARY(I)=Y(I)
      A(I)=0.001
      B(I)=0.001
      C(I)=0.001
    5 D(I)=0.001
      KSTP=0
```

```
      KDELY=0
      KC8N=0
      XT=95./(288.*64.)
      U=863./(12.*5040.)
      V=95.0/288.0
      P=25.0/24.0
      G=35.0/72.0
      R=5.0/48.0
      S=1.0/120.0
      IA=1
      JUMP=0
      G9 T8 1101
C     BEGIN INTEGRATI8N STEP
 1000 D9 1111 I=1,NE
      SF(I)=F(I)
 1111 SAVEY(I)=Y(I)
C     H T88 SMALL  RETURN WITH JUMP NEG.
  600 IF(ABS(T+H)-ABS(T))605,601,605
  601 JUMP=-1
      G9 T8 1101
  605 T=T+H
      D8 10 I=1,NE
      Y(I)=Y(I)+H*(F(I)+A(I)+B(I)+C(I)+D(I))
   10 FP(I)=F(I)+2.0*A(I)+3.0*B(I)+4.0*C(I)+5.0*D(I)
      IA=2
      G9 T8 1101
   11 D9 12 I=1,NE
   12 SY(I)=Y(I)
      D8 20 I=1,NE
```

```
      DELTA  (I)=F(I)-FP(I)
   20 Y(I)=Y(I)+V*DELTA  (I)*H
      IA=3
      KCØN=1
      GØ TØ 1101
   21 KCØN=0
      DØ 30 I=1,NE
      DALTA  (I)=F(I)-FP(I)
   29 Y(I)=SY(I)+V*DALTA  (I)*H
   30 CØNTINUE
C     TEST FØR STARTING SEQUENCE
   31 IF(KSTP-28)35,40,40
C     APPLY TEST 2 ØN ZERØTH STEP
   35 IF(KSTP)50,50,60
C     HALVING TESTS
   40 DØ 45 I=1,NE
      IF(ABS(DALTA  (I))-ERRØR/ABS(H))45,45,55
   45 CØNTINUE
   50 IF(V*H*CLIF-0.125)60,60,55
   55 T=T-H
C     FAIL TESTS, HALVE H
  223 H=H/2.0
      KDELY=0
      DØ 56 I=1,NE
      A(I)=A(I)/2.0
      B(I)=B(I)/4.0
      C(I)=C(I)/8.0
      F(I)=SF(I)
```

```
      Y(I)=SAVFY(I)
   56 D(I)=D(I)/16.0
      GØ TØ 1000
C     PASS TESTS, CØRRECT A,B,C,D
   60 KSTP=KSTP+1
      DØ 65 I=1,NE
      A(I)=A(I)+3.0*B(I)+6.0*C(I)+10.0*D(I)+P*DALTA  (I)
   62 B(I)=B(I)+4.0*C(I)+10.0*D(I)+Q*DALTA(I)
   64 C(I)=C(I)+5.0*D(I)+R*DALTA(I)
   67 D(I)=D(I)+S*DALTA(I)
   65 CØNTINUE
C     IF IN STARTING SEQUENCE, BRANCH
      IF(KSTP-24)70,90,100
   70 GØ TØ (1000,1000,1000,74,1000,1000,1000,78,1000,1000,1000,74,1000,
     11000,1000,86,1000,1000,1000,74,1000,1000,1000),KSTP
C     4TH, 12TH, 20TH STEP, GØ BACK
   74 H=-H
      DØ 75 I=1,NE
      A(I)=-A(I)
   75 C(I)=-C(I)
      GØ TØ 1000
C     8TH STEP  GØ FØWARD
   78 H=-H
      DØ 79 I=1,NE
      Y(I)=STARY(I)
      A(I)=-A(I)
   79 C(I)=-C(I)
      GØ TØ 1000
C     16TH STEP, HALVE H, APPLY TEST 1
```

```
      86 H=H/2.0
         DØ 87 I=1,NE
         A(I)=A(I)/2.0
         B(I)=B(I)/4.0
         C(I)=C(I)/8.0
      87 D(I)=D(I)/16.0
         DØ 88 I=1,NE
         IF(ABS(DALTA  (I))-ERRØR/ABS(H))88,88,89
      88 CØNTINUE
C        PASS TEST   GØ FØWARD WITH HALVED H
         GØ TØ 78
C        FAIL TEST   BEGIN AGAIN WITH HALVED H
      89 H=-H
         DØ 92 I=1,NE
      92 Y(I)=STARY(I)
         GØ TØ 1
C        24TH STEP, DØUBLE H, STARTING SEQUENCE ENDS
      90 H=H*2.0
         DØ 91 I=1,NE
         A(I)=A(I)*2.0
         B(I)=B(I)*4.0
         C(I)=C(I)*8.0
      91 D(I)=D(I)*16.0
         GØ TØ 78
     100 KDELY=KDELY+1
C        WILL NEXT STEP MØVE PAST TLIM
     102 IF(ABS(TLIM-T)-ABS(H))103,103,110
C        YES..........SAVE T AND Y, INTEGRATE TØ TLIM,RETURN.
```

```
  103 ENDH=TLIM-T
      DO 105 I=1,NF
      AA(I)=ENDH*A(I)/H
      BB(I)=ENDH**2*B(I)/H**2
      CC(I)=ENDH**3*C(I)/H**3
  105 DD(I)=ENDH**4*D(I)/H**4
      SAVET=T
      DO 800 I=1,NF
      SF(I)=F(I)
  800 SAVEY(I)=Y(I)
  806 T=TLIM
      DO 106 I=1,NF
      Y(I)=Y(I)+ENDH*(F(I)+AA(I)+BB(I)+CC(I)+DD(I))
  106 FP(I)=F(I)+2.0*AA(I)+3.0*BB(I)+4.0*CC(I)+5.0*DD(I)
      IA=4
      GO TO 1101
  802 DO 805 I=1,NF
  805 SY(I)=Y(I)
      DO 107 I=1,NF
      DELTA  (I)=F(I)-FP(I)
  107 Y(I)=Y(I)+V*DELTA  (I)*ENDH
      IA=5
      GO TO 1101
  803 DO 108 I=1,NF
      DALTA  (I)=F(I)-FP(I)
  108 Y(I)=SY(I)+V*DALTA  (I)*ENDH
      JUMP=1
      GO TO 1101
C     NO.......TEST FOR DOUBLING. IF OK, BEGIN NEST STE- AFTER DOUBLING
```

```
      110 IF(ABS(TLIM-T)-ABS(2.0*H))1000,1000,111
      111 IF(KDELY-4)1000,120,120
      120 IF(ABS(2.0*H)-ABS(HMAX))121,121,1000
      121 DØ 125 I=1,NF
          IF(ABS(DALTA  (I))-ERRØR/(128.0*ABS(H)))125,125,1000
      125 CØNTINUE
          IF(V*H*CLIF-0.0625)130,1000,1000
      130 CØNTINUE
      335 H=2.0*H
          DØ 135 I=1,NF
          A(I)=2.0*A(I)
          B(I)=4.0*B(I)
          C(I)=8.0*C(I)
      135 D(I)=16.0*D(I)
          KDELY=0
          GØ TØ 1000
     1101 CØNTINUE
     1150 FØRMAT(/,2X,'HH =',2X,F10.6,14X,'KSTP =',2X,I3,10X,'DAL3A(I)',/)
     1151 FØRMAT(5(2X,I2,1X,E14.7))
          RETURN
          END
CCCCC
CCCCC
CCCCC
CCCCC
CCCCC
          SUBRØUTINE DEBUG(A,N)
          IØU=102
```

```
      WRITE(IOU,1000)A,N
 1000 FORMAT(1H0,2X,'A=',E14.7,1X,'N=',I4)
      RETURN
      END
      SUBROUTINE PROU
      COMMON YP1(5),Y1(5),XPR1,XEND1,DXPR1,X1,DX1,NE1,INT1,INTC1,IN1,IO1
     1,EL1,AREA1,U1
      COMMON ERROR1,DXMAX1,TEMP1,HFGTB1(10),CONS11
      COMMON RHO1,W1,WMD1,HD1,TAIR1,CLD1,RH1,ALBAR1,TWS1,TA1,TWSA1,EW1,
     1EA1,HOS1,HS1
      COMMON HSR1,HOB1,EBR1,EVAP1,HE1,HC1,HLYMN1,PTBL1(10),TTBL1(10),
     1WMS1,CONST1
      COMMON CLIF1,HFB1,HOC1,CLD11,CLD21,CLD31,DALP1,DALPR1,DCLD1,DRH1,
     1DTAIR1,DTA1,DW1,DWMS1,DWMD1,DEA1,DEW1,DLYMN1,DBTUS1,NTEMP1,
     2STTBL1(10),XTBL1(10)
      COMMON C(1000),TA(1000),PHI(1000),W(1000),TW(1000)
      COMMON NCAS, NDA, DELT(50), IDAS(50)
      COMMON NLN,IN,IOU,DT,NTA,IDA
      COMMON CTA(50),TATA(50),PHITA(50),WTA(50),TWTA(50)
      COMMON UA,EL,CC,TAIR,TWA,RH,WSP
      COMMON INT2,INT3,DC,DTA,DPHI,DW,DTW,INVS,IFLAG
      COMMON DM21,BETA
      COMMON LAG1,NDAS
      COMMON ICAS,PRP(50,10)
      WRITE(IOU,2000)
 2000 FORMAT(1H0,2X,'PROBABILITY CHART'/,2X,60('*'))
      WRITE(IOU,2001)(DELT(I),I=1,NCAS)
 2001 FORMAT(1H0,10X,10(E10.3,1X))
      DO 10 I=1,NDAS
```

```
      WRITE(IØU,2002)IDAS(I),(PRP(I,J),J=1,NCAS)
 2002 FØRMAT(1H0,2X,I5,1X,5(E10.3,1X))
   10 CØNTINUE
      RETURN
      END
      SUBRØUTINE VERNØN
      CØMMØN YP1(5),Y1(5),XPR1,XEND1,DXPR1,X1,DX1,NE1,INT1,INTC1,IN1,IØ1
     1,EL1,AREA1,U1
      CØMMØN ERRØR1,DXMAX1,TEMP1,HFGTB1(10),CØNS11
      CØMMØN RHØ1,W1,WMD1,HD1,TAIR1,CLD1,RH1,ALBAR1,TWS1,TA1,TWSA1,EW1,
     1EA1,HØS1,HS1
      CØMMØN HSR1,HØB1,ERR1,EVAP1,HE1,HC1,HLYMN1,PTBL1(10),TTBL1(10),
     1WMS1,CØNST1
      CØMMØN CDIF1,HFG1,HØC1,CLD11,CLD21,CLD31,DALP1,DALPR1,DCLD1,DRH1,
     1DTAIR1,DTA1,DW1,DWMS1,DWMD1,DEA1,DEW1,DLYMN1,DBTUS1,NTEMP1,
     2STTBL1(10),XTBL1(10)
      CØMMØN C(1000),TA(1000),PHI(1000),W(1000),TW(1000)
      CØMMØN NCAS, NDA, DELT(50), IDAS(50)
      CØMMØN NIN,IN,IØU,DT,NTA,IDA
      CØMMØN CTA(50),TATA(50),PHITA(50),WTA(50),TWTA(50)
      CØMMØN UA,EL,CC,TAIR,TWA,RH,WSP
      CØMMØN INT2,INT3,DC,DTA,DPHI,DW,DTW,INVS,IFLAG
      CØMMØN DM21,BETA
      CØMMØN LAG1,NDAS
      CØMMØN ICAS,PRP(50,10)
      DIMENSIØN PR(10),T7(100)
      DØ 3 I=1,NCAS
      PR(I)=0.
```

```
    3 CØNTINUE
C     NDA= NUMBER ØF DAYS IN THE CASE
      NDA=1
      NC1=NLN/8
      FNDA=NDA*8
      FNDA=1./FNDA
      READ(IN,1020)(T7(I),I=1,NC1)
 1020 FØRMAT(6F10.3)
      DØ 5 I=1,NC1
      WRITE(IØU,2001)T7(I)
 2001 FØRMAT(/,2X,F14.7)
    5 CØNTINUE
      IF(NDA-NC1) 10,999,999
   10 CØNTINUE
      NDIF=NC1-NDA
      ENUM=0.
      DEN=0.
      DENP=0.
      DØ 20 I20=1,NDIF
      CS=0.
      TAS=0.
      PHIS=0.
      WS=0.
      TWS=0.
      DØ 30 I=1,NDA
      DØ 40 J=1,8
      INT=8*(I20+I-1)+J-8
      CS=CS + C(INT)
      TAS=TAS + TA(INT)
```

```
      PHIS=PHIS + PHI(INT)
      WS=WS + W(INT)
   40 CØNTINUE
   30 CØNTINUE
      CS= CS*FNDA
      TAS= TAS*FNDA
      PHIS=PHIS*FNDA
      WS= WS*FNDA
      TWS=T7(I20)
C     INT2= FØLLØWING DAY
      INT2= I20+NDA
      C1S=0.
      TA1S=0.
      PHI1S=0.
      W1S=0.
      TW1S=0.
      DØ 50 I=1,8
C     INT3= THE ACTUAL PØSITIØN IN THE DAY
      INT3=INT2*8-8+I
      C1S=C1S+C(INT3)
      TA1S=TA1S+TA(INT3)
      PHI1S=PHI1S+PHI(INT3)
      W1S=W1S+W(INT3)
      TW1S=TW1S+TW(INT3)
   50 CØNTINUE
      C1S=C1S*.125
      TA1S=TA1S*.125
      PHI1S=PHI1S*.125
```

```
      W1S=W1S*.125
      TW1S=TW1S*.125
      DC=C1S-CS
      DTA=TA1S-TAS
      DPHI=PHI1S-PHIS
      DW=W1S-WS
      DTW=TW1S-TWS
      STTBL1(1)=TW1S
      STTBL1(2)=TW1S
      XTBL1(1)=0.
      XTBL1(2)=25000.
      NTEMP1=2
      INVS=INT2*8-4
      CALL CØMP(ENUM,DEN)
      DØ 60 ICAS=1,NCAS
      IF(ABS(Y1(1))-DELT(ICAS)) 65,65,70
   65 CØNTINUE
      PR(ICAS)=PR(ICAS)+1.
   70 CØNTINUE
   60 CØNTINUE
   20 CØNTINUE
      DENP=NDIF
      DØ 75 ICAS=1,NCAS
      PR(ICAS)=PR(ICAS)/DENP
   75 CØNTINUE
      WRITE(IØU,2000)(PR(I),I=1,NCAS)
 2000 FØRMAT(/,2X,'STATIØN 7 RESULTS',10(F6.3,1X))
      RETURN
  999 CØNTINUE
      WRITE(IØU,4000)
 4000 FØRMAT(/,2X,'TØØ SMALL')
      CALL EXIT
      RETURN
      END
```

APPENDIX D

THEORY OF THE SENSITIVITY ANALYSIS

In this appendix the development of the equation (1) is discussed together with the problems of convergence and averaging of the data. The sensitivity analysis is further discussed with the exact solution being developed for the constant coefficient equation.

THE GENERAL STREAM MODEL

The equation (1) is developed from the energy equation heat fluxes shown in Figure 1. The development of this equation is based on a Taylor's expansion of the dependent variable, T , about the position, x , downstream:

$$T(x + dx) = T(x) + \frac{dT}{dx}(x)\, dx \quad . \tag{D-1}$$

Use of this Taylor's expansion together with the conservation of energy for the control volume in Figure 1 yields:

$$uA\, T(x) - uA\left[T(x) + \frac{dT}{dx}(x)\, dx\right] + \ell\, dx\, [Q_{Rad} - Q_{Ref} - Q_{Back} - Q_{Evap} + Q_{Conv} + Q_{Misc}] = 0 \quad . \tag{D-2}$$

The first term is the enthalpy transport into the control volume; the second term is the analogous transport out of the control volume; the third term is the total heat flux at the air/water interface. Some minor algebra on equation (D-2) yields equation (1), assuming that the quantities u, A, and ℓ vary slowly along the stream.

The equation (1) holds between points at which flows and/or heated effluents are added to the stream. Many authors directly integrate equation (1) over a station length, Δx , assuming the fluxes and u, A, ℓ to be constant over that distance. The result is simply

$$\int_x^{x+\Delta x} \frac{uA}{\ell}\frac{dT}{dx}\, dx = \int_x^{x+\Delta x} [Q_{Rad} - Q_{Ref} - Q_{Back} + Q_{Evap} + Q_{Conv} + Q_{Misc}]\, dx \quad ,$$

$$\frac{uA}{\ell}\,[T(x + \Delta x) - T(x)] = [Q_{Rad} - Q_{Ref} - Q_{Back} - Q_{Evap} + Q_{Conv} + Q_{Misc}]\,\Delta x \quad ,$$

$$T(x + \Delta x) = T(x) + \frac{\ell}{uA}\,[Q_{Rad} - Q_{Ref} - Q_{Back} - Q_{Evap} + Q_{Conv} + Q_{Misc}]\,\Delta x \quad . \qquad \text{(D-3)}$$

It is possible to then incorporate heat fluxes not covered by those at the air/water interface in the Q_{Misc} term, simplifying the coding and the model considerably. Two aspects of this concept should be emphasized: 1) all models are similar to this model and are within a small error that is a function of the mesh size, and 2) the convergence of the procedure can be shown from previous literature.

Suppose that an alternate model is used in which the fluxes are redistributed, i.e., the total flux may be the same but the model assumptions causes a difference in the flux at any position x . Then this difference can be represented as a quantity proportional to the station length, Δx . For example:

$$Q_{Rad}(x + \Delta x) = Q_{Rad}(x) + O(\Delta x) \quad . \qquad \text{(D-4)}$$

But the introduction of this expression into equation (D-3) will introduce a term of order Δx^2 $(O(\Delta x^2))$, which can be made appropriately small by a suitable choice of Δx . Thus, all correctly formulated models will be a measurable error away from the general model described by equation (1).

The question of numerical convergence of the solution is discussed in general by Salvadori and Baron [1961], p. 116. Much of the information provided by them can be directly applied to this problem.

Suppose a general problem takes the form

$$\dot{y} = f(x, y) \quad ,$$

$$y(0) = y_0 \quad . \tag{D-5}$$

If Euler's method is taken as an example the form for the integration is

$$y_{i+1} = y_i + f(x_i , y_i)h \quad , \tag{D-6}$$

which is seen to be identical in form to equation (D-3). From p. 91 in Salvadori and Baron

$$y(x) = \int_a^x f(z)\, dz \quad ,$$

$$\dot{y}(x) = f(x) \quad ,$$

$$\ddot{y}(x) = \dot{f}(x) \quad ,$$

$$\overset{(n)}{y}(x) = f^{(n-1)}(x) \quad . \tag{D-7}$$

A Taylor's expansion about x yields:

$$y(x \pm h) = y(x) \pm \frac{h}{1!} f(x) + \frac{h^2}{2!} \dot{f}(x) \pm \frac{h^3}{3!} \ddot{f}(x) + --- \quad . \tag{D-8}$$

From this the following expressions can be evaluated

$$I_1 = \int_x^{x+h} f(z)\, dz = y(x+h) - y(x) \quad ,$$

$$= h[f(x) + \frac{h}{2!} \dot{f}(x) + \frac{h^3}{3!} \ddot{f}(x) + ---] \quad , \tag{D-9}$$

and

$$I_2 = \int_{x-h}^{x+h} f(z)\,dz = y(x+h) - y(x-h) \quad ,$$

$$= [2\,hf(x) + \frac{2h^3}{3!} f(x) + \frac{2h^5}{5!} f^{(IV)}(x) + ---] \quad . \tag{D-10}$$

From Taylor's theorem and equation (D-6)

$$y(x+h) = y(x) + hf(x) + \frac{h^2}{2!} \dot{f}(\hat{x}) \tag{D-11}$$

and the error is proportional to the maximum value of the second derivative. With these fundamentals set down the error for the equation

$$\frac{dT}{dx} = \frac{Q\ell}{uA\rho c} \tag{D-12}$$

can be readily found. From the general analysis the error is bounded by the expression

$$|T_{Approximate} - T_{Exact}| \leq \frac{x\ell}{uA\rho c} \left|\frac{dQ}{dx}\right|_{max} \Delta x \quad . \tag{D-13}$$

An expression similar to (D-13) is easily developed for bounding the station length

$$\Delta x \leq \frac{|\Delta T_{allowable}|}{\frac{x_{max}\,\ell}{uA\rho c} \left|\frac{dQ}{dx}\right|_{max}} \quad . \tag{D-14}$$

From experience, a convergent Δx can easily be obtained for this differential equation since the heat fluxes are generally very small and have small derivaties.

DATA AVERAGING

For small changes in temperature the equation (1) will be quasi-linear. Thus, the theory of linear equations can be applied to the problem. This is very important since average data will produce average output to such a model, while a nonlinear model will not yield results of this type.

To prove this it is necessary to examine the theory from a different viewpoint. For example, the temperature at any point x downstream from the disturbance can always be represented from the linear equation in the form

$$T(x) = \sum_{i} \int_{0}^{x} K_i(x, \xi)\, Q_i(\xi)\, d\xi \qquad \text{(D-15)}$$

where the integral occurs over the domain of interest and the kernel function $K_i(x, \xi)$ relates the effect of the i'th heat flux $Q_i(\xi)$ at the position ξ to the temperature $T(x)$ at the position x ; the sum produces the effects of all of the heat fluxes. Since the expression is linear , it can be summed over several sets of heat fluxes to obtain the sum of temperatures as follows

$$\sum_{j}^{n} T_j(x) = \sum_{i} \sum_{j}^{n} \int_{0}^{x} K_i(x, \xi)\, Q_{ij}(\xi)\, d\xi \quad . \qquad \text{(D-16)}$$

Suppose that equation (D-16) is rearranged and both sides of the equation divided by the number of temperatures n :

$$\frac{1}{n} \sum_{j}^{n} T_j(x) = \sum_{i} \int_{0}^{x} K_i(x, \xi) \sum_{j}^{n} \frac{Q_{ij}}{n}(\xi)\, d\xi \quad . \qquad \text{(D-17)}$$

This proves that the effects of the heat fluxes can be averaged and the equation used to compute an average temperature. This would not be true for a nonlinear equation and is a significant result.

THE SENSITIVITY ANALYSIS

The fundamental equation for the sensitivity analysis is developed by varying both sides of the solution equation (1):

$$\frac{d\delta T}{dx} = \frac{\ell}{Au}\,\delta Q \quad , \tag{D-18}$$

where δQ is the change in the heat fluxes and δT the resulting change in the stream temperature. The initial condition for the equation is

$$\delta T(0) = \delta T_0 \quad , \tag{D-19}$$

i.e., an initial error in temperature δT_0 is known at a point in the stream, which allows the computation of the error at points downstream.

On closer examination of δQ the linearity of the solution emerges. The individual terms are

$$\delta Q_{Solar} = 1.9 \sin \bar{\alpha}\,(-0.0018\, C^2\, \delta C)(0.61)$$

$$+ (1.0 - 0.0006\, C^3)(1.9 \cos \bar{\alpha}\;\; \delta\bar{\alpha})(0.061) \quad ,$$

$$\delta Q_{Reflected} = \frac{3}{\bar{\alpha}}\,\delta Q_{Solar}(0.061) - \frac{6}{\bar{\alpha}^2}\,Q_{Solar}\;\; \delta\bar{\alpha}\,(0.061) \quad ,$$

$$\delta Q_{Back} = (1.0 - 0.0765\, C)\left(\frac{1}{69.72}\right)\left(-\, 0.09\left(\frac{5}{9}\,\delta T\right) - 0.046\,\delta\phi\right)$$

$$-\, 0.0765\,\delta C\left(\frac{1}{69.72}\right)\left(14.38 - 0.09\left(\frac{5}{9}(T - 32)\right) - 0.046\,\phi\right) \quad ,$$

$$\delta Q_{Evaporation} = \frac{\rho h_{fg}}{240} (0.35)(1.0 + 9.8 \times 10^{-3} W_2)(\delta e_W - \delta e_a)$$

$$+ \frac{\rho h_{fg}}{240} (0.35)(9.8 \times 10^{-3} \delta W_2)(e_W - e_a) \quad ,$$

$$\delta Q_{Convection} = 39.0 \ (0.077 \ \delta W_2)(T - T_a)(\tfrac{5}{9})(0.061)$$

$$+ 39.0 \ (0.26 + 0.077 \ W_2)(\delta T - \delta T_a)(\tfrac{5}{9})(0.061)$$

(D-20)

Note that small changes in the heat fluxes imply like changes in δT. Thus, the justification in linearizing the analysis. The equation (D-18) is solved in this investigation using numerical analysis procedures. However, for constant coefficients in equation (D-18), the equation can be solved in closed form. Symbolically the equation can be written as:

$$\frac{d\delta T}{dx} = \frac{\ell}{Au} [-C_1{}' \delta T + C_2 + C_3 + --- C_m] \quad , \qquad \text{(D-21)}$$

where the C_i are constants. The solution to this equation is found in two parts, a homogeneous solution decaying with distance and particular solutions that are constant. The homogeneous solution is found by assuming it in the form

$$\delta T = \bar{A} \ e^{-\alpha x} \quad , \qquad \text{(D-22)}$$

where $\bar{A}$ is an initial amplitude and α is the decay rate. Substitution into equation (D-21) yields

$$-(\alpha) \ \bar{A} \ e^{-\alpha x} = \frac{\ell}{Au} [- C_1 \ \bar{A} \ e^{-\alpha x}] \quad , \qquad \text{(D-23)}$$

which finds α to be

$$\alpha = \frac{\ell}{Au} C_1 \quad . \qquad \text{(D-24)}$$

The particular solutions are found from

$$\delta T_i = \frac{C_i}{C_1} , \qquad \text{(D-25)}$$

where $i = 2, ---, m$. It is on this basis that the sensitivity analysis is completed.

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16. ABSTRACT

This work is an evaluation of existing, one-dimensional stream temperature prediction techniques for accuracy and precision. A sensitivity analysis of a general model is used in conjunction with statistical methods to determine solution errors. Data taken in 1973 at the Vernon, Vermont nuclear plant are used as a data base. These data are used with Burlington, Vermont airport weather station data to 1) gain insight into the orders-of-magnitude of the various errors and 2) carry out a detailed data analysis to establish probabilities of meeting given error requirements.

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