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IMPROVED METHODS FOR PLANNING OF THERMAL DISCHARGES BEFORE SITE ACQUISITION WITH A SPECIFIC CASE EXAMPLE ON THE COLUMBIA RIVER*

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INTRODUCTION

The waste heat from the operation of Rankine cycle generating plants must in some way be dissipated to the environment. Freshwater streams and estuaries remain as a feasible intermediate in the ultimate discharge of thermal effluent to the atmosphere. However, because of the size of the thermal releases, it is necessary to carefully determine the capacity of proposed thermal effluent release areas. This capacity must be quantitatively related to the applicable water quality standards without the need for (1) elaborate special conditions which create an adverse effect on public acceptance of owners and (2) regulatory agencies to make statements about the effects on aquatic organisms outside of control zones.

In the United States, numerical values of temperature differences supplemented by qualitative interpretation by the individual states and Federal agencies having purview, have been adopted as a mean of defining mixing zones and thermally elevated conditions. In some cases temperature differences as little as 0.82 °C have been proposed as limits in estuarine circumstances. Means to evaluate numerical values of temperature with such precision on an integrated sample basis do not presently exist outside of research programs, or are not generally recognized as standard methods. An order of magnitude improvement in our understanding of the technology of mixing and heat dispersion phenomenon appears necessary. An even greater task lies ahead in the relationship of the physical parameters to the affected ecological species of interest. In the latter case the press for increased power requirements can be expected to occur at a rate which may exceed the ability of the ecological investigators to quantify the area of interest. The techniques described in the paper represent efforts towards the attainment of improved quantification and the presentation of the resulting information in an understandable manner.

DISCUSSION

An essential first element in the improved understanding of mixing processes is quantification of the actual concentrations below the point or points of discharge on a real time basis. Such improved knowledge avoids the necessity to develop mathematical generalizations before the actual physical processes are thoroughly understood. Eddy diffusivity is an example from the class of coefficients which have been derived before the fact in order to establish a means of quantification with very limited information.

Study of the Mixing Zone

Below a few hundred meters from the point of release, the discharges in a relatively turbulent stream have been shown to follow the classical work of Taylor; however, the use of a single value of the dispersion coefficient for entire reaches of the sample stream can produce erroneous results. A solution of the Taylor expression:

$$\frac{\partial \bar{c}}{\partial t} = \frac{\bar{u}\partial \bar{c}}{\partial x} + D_x \frac{\partial^2 \bar{c}}{\partial x^2}$$

where:

$\bar{c}$ = the cross-sectional mean concentration

$\bar{u}$ = the mean flow velocity

t = time

x = distance in the direction of mean flow

D_x = longitudinal dispersion coefficient

K_x = a scaling factor proportional to C_o, the original concentration can be written:

$$\bar{c}(x,t) = \frac{K_x}{t^{1/2}} \exp - \frac{(x - \bar{u}t)^2}{4D_x t}$$

Then, estimates of the variables K_x, D_x, $\bar{u}$ were obtained for a series of reaches for which real-time concentration data have been accumulated using a nonlinear least squares fitting method developed at Pacific Northwest Laboratory[1] and modified by Kottwitz (unpublished). The special program called LEARN/DISPERS employs the general relationship:

$$c = \frac{A_1}{(t^d)^{1/2}} \exp - \left[\frac{1}{4t}\left(\frac{(x - A_1 t)^2}{|A_2|} + \frac{(y - A_3 t)^2}{|A_4|} + \frac{(z - A_5 t)^2}{|A_6|}\right)\right]$$

where:

x, y, z = space coordinates

A_1, A_3, A_5 = convective speed parameters

A_2, A_4, A_6 = dispersion coefficients

A_7 = amplitude (concentration) parameter

d = number of space dimensions, e.g.,
if d = 1, y and z terms are omitted
if d = 2, z term is omitted
if d = 3, all terms are included.

The resulting program is capable of fitting separately a set of data for any number of discrete locations or fitting sequentially several sets of consecutive data sets. In addition to the numerical determination of the parameters, the program plots the results or graphical interpretation. An example of the output of such an analysis is shown in Figure 1. The numerical values obtained indicated that the combination of remote sensing for concentration input and the use of improved evaluation of D_x with relation to stream reach gives improved insight into predictive computations.

At present no well developed theory exists for predicting mixing in the lateral direction. Data summaries have been generally in the form suggested by Elder which estimates the value of D_y as follows:

$$Dy = 0.23 U_x h$$

where:

h = the depth of flow

u'_x = mean shear velocity of a vertical transect

In 1967, using boat data measured in the Hanford effluent plumes, Jaske[2] developed an expression which correlated the spreading velocity as a function of downstream travel time t.

where:

$$\frac{dy}{dt} = a \exp - (b\ x)$$

y, x = spacial parameters in consistent time frame

t = time

a, b = experimental constants

Using this expression, the external edge of the spreading mixing zone could be accurately predicted to the point where only one dimensional effects became paramount.

Currently, using remote sensing techniques, a new approach has yielded additional insight into numerical values of the lateral dispersion

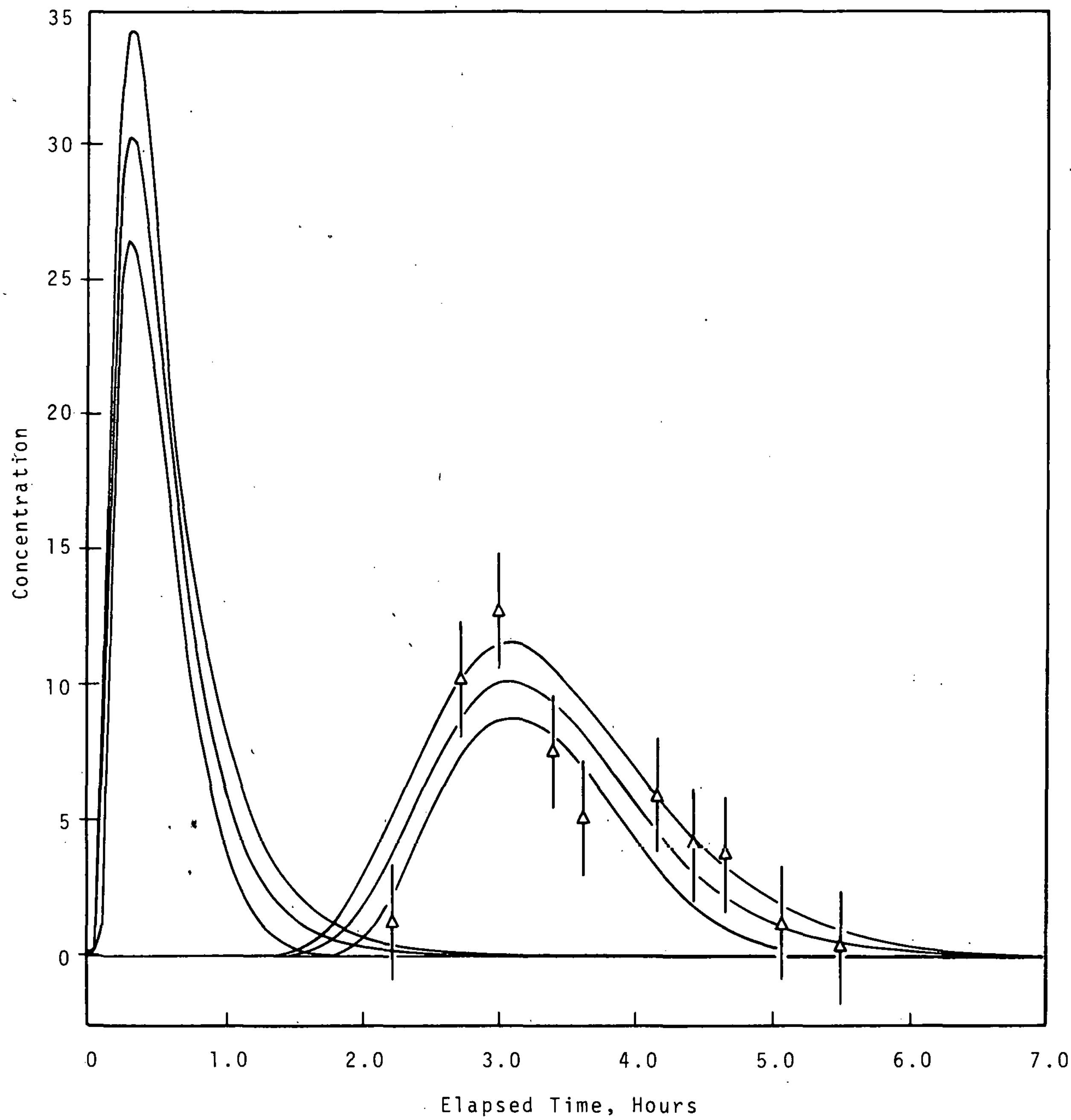

FIGURE 1. COMPUTER GENERATED OUTPUT OF BEST FIT TO ONE-DIMENSIONAL DISPERSION UNIT LEARN/DISPERS

coefficient D_y. If the assumption that the lateral distribution is Gaussian can be made, (generally true for reaches where momentum effects from the discharge jet or initial density differences are zero), the width of the plume at any distance (x) from the point of release can be described as:

$$\sigma_{(x)} = \sigma_D + \sigma_M$$

where:

- $\sigma_{(x)}$ = space variance at some distance from the release point
- σ_D = space variance due to the initial convective mixing
- σ_M = dispersion represented by the diffusion process

then:

$$\sigma_M = (2D_y t)^{1/2}$$

where: D_y = lateral diffusion coefficient (ft^2/sec)

Employing the theory of convolution and making the further assumption that 95% or 4σ of the tracer is the extent of the conservation of tracer to be included, it is possible to state:

$$D_y = \frac{W_{(x)}^2 - W_o^2}{32\Delta t}$$

where:

- $W_{(x)}$ = plume width @ a distance x from x_o
- W_o = initial width at tracer release point
- x_o = origin of the diffusion process

then:

$$D_y = \frac{W_{(x)}^2 - W_o^2}{32\left(\frac{\Delta x}{\bar{u}}\right)} \quad \text{or} \quad \frac{W^2_{(x)} - W^2_o}{32\left(\frac{x - x_o}{\bar{u}}\right)}$$

under the assumption that the conveyance velocity is uniform. Evaluations of the size of the spreading plume were made for both hot and cold conditions, all other effluent flow conditions being constant. The results are summarized in Table 1.

TABLE 1

SUMMARY OF LATERAL DIFFUSION COEFFICIENTS

River Flow (cumec)	Effluent Condition	D_y m^2/sec
1,420	cold	0.177
2,850	cold	0.184
2,270	hot	0.492
3,130	hot	0.680
4,120	hot	0.271

The cases involving cold effluent or essentially neutral bouyant conditions reveal a lateral diffusion coefficient approximately equal to 0.18 m^2/sec. These results agree well with the work performed independently by Glover.[3] Under heated conditions, the lateral diffusion coefficient was generally higher. The assumption that dye particles are of zero size can be made, and for very low dye concentrations, (less than 10 ppb) the mixture of fluid and dye should have essentially the same density and kinematic viscosity as the normal, heated effluent. Therefore, the use of dye does not change the hydrodynamic character of the heated or cold plume to any measurable extent. This being the case, the results suggest that the thermal eddy diffusivity of the heated plume is greater than the natural eddy diffusivity of the river for the current ranges examined. This observation also suggests that as the momentum of the receiving water increases, the difference between the two coefficients will decrease asymptotically to a value identical with the eddy diffusivity of the river itself. These tentative conclusions appear to indicate that mixing from heated plumes is greater in the cases where initial momentum differences between the receiving stream and the point of discharge are the greatest. This relationship has been qualitatively suggested in a number of publications and reports at Pacific Northwest Laboratory and is the basis for the recommendation that high velocity single point discharges are superior to canal discharges as a means of minimizing the temperatures of the mixing zone. This recommendation runs counter to standard design practice in many countries.[4]

Regional Simulation of Thermal Effluents

The development of the basic thermal simulation model COLHEAT has been fully described.[5],[6] This system describes the thermal regimen of a river or estuary and permits advance estimates of thermal effects of impoundments, single thermal plants, or an extended series of thermal and hydro installations with overlapping effects on a single or regionally combined watershed. The basic operation is a two step process: multiple shell or zonal transport system with adjustable allocation of inter-and-intra-shell transport. In its present form, the model receives inputs on a mixed basis into the assigned shells without attempting to fully model the transition from the point of discharge to the fully mixed condition. Nominally, it is a one-dimensional model. Reference [5] contains an extensive description of the logic diagram of the basic system.

Rather than using the ordinary differential equation to describe the mechanics of mixing and transport, due to the complexity of properly combining simultaneously the large number of dimensionalities, a finite difference approximation was used initially. Such a system was designed to satisfy the constraints of continuity while retaining the flexibility of describing the temporal and spacial variations of a substance in a flowing field. Both a thermal and a chemical-radionuclide transport version have been developed for use in evaluation of other parameters of interest to water quality management such as oxygen.

The computational system operates on the assumption that most streams will be turbulent and relatively homogeneous in hydraulic characteristics and that, within this assumption, the distribution of velocity contours within the stream is similar for width to depth ratios exceeding 24. Based on this concept, the model sets up a series of difference equations and, using applicable budget methods based on continuity, iteratively computes the downstream temperatures as a function of the input parameters. For simplicity, in a two shell system, the following system is used.

$$T_{i+1,\ j+1} = (1-B)\left(T_{i,j} + \Delta T^{(1)}_{i,j} + \Delta T^{(2)}_{i,j}\right) + B\left(T_{i,j-1} + \Delta T^{(1)}_{i,j-1} + \Delta T^{(2)}_{i,j}\right) \qquad (1)$$

where:

$T_{i,o}$ = average temperature of water entering the system during the i^{th} time interval, °C

$T_{i,j}$ = average water temperature of the beginning of the j^{th} flow increment at the end of the i^{th} time increment (flow day), °C

$\Delta T^{(1)}_{i,j}$ = the temperature change during the first half of the i^{th} time interval in the j^{th} flow increment as determined from surface heat exchange plus advected energy (heat budget) in °C

$\Delta T^{(2)}_{i,j}$ = same as above except for the second half of the i^{th} time interval, in °C

B = the fractional part of the water in the inner fast moving trough.

A flow day of water is approximately the mean daily transit time of all the water in the system.

The above definitions have analogous meanings for time increments other than a day; for example, flow-hour.

Operation of the temperature model requires the following data:

1) Water temperature and discharge at the inlet end (time increment appropriate).

2) Flow discharge at the outlet end.

3) Water temperature at the outlet end (optional, for statistical comparison where available).

4) Meteorological data (wind velocity for time period, mean air temperature, dew point, sky cover in tenths, shortwave radiation).

5) River or reservoir dimensions reduced to equivalent nonparallel trapezoidal cross sections (volume, surface, or bottom areas are derived as functions of flow).

6) Advected heat quantities (megawatts per time incrementation).

The model permits the advection of heat chemicals or any other exchangeable material into any of the input defined troughs. The flow day(s) of water corresponding to the advected heat troughs are adjusted in temperature to simulate the addition of heat.

In its initial operation, the rudimentary system was used to evaluate the manipulation of the discharges of Grand Coulee Dam. A lower river temperature was created in August and September to enhance operation of direct cooled reactors from 1958 to 1968. Such an approach was made necessary by the construction of many intervening dams and impoundments which lengthened the travel time and the hydrodynamic complexity of the river. Figure 2 illustrates the excellence of the fit of the simulated temperatures.

In order to have a better basis for examination of the goodness of fit, the simulation system uses the nonparametric U test method for comparison of sets of paired data when the distribution of and populations from which the sets are taken are unknown. If the populations were known to be normal, then the parametric t and F test would be used. The U test is one of the more powerful nonparametric tests available to the model developer. In the case illustrated, the U test indicated that the computer information matched the original data to better than 95% confidence.

A Case Example on the Lower Columbia

A practical test of the application of these methods has been presented in the preliminary work concerned with the certification of two power reactor

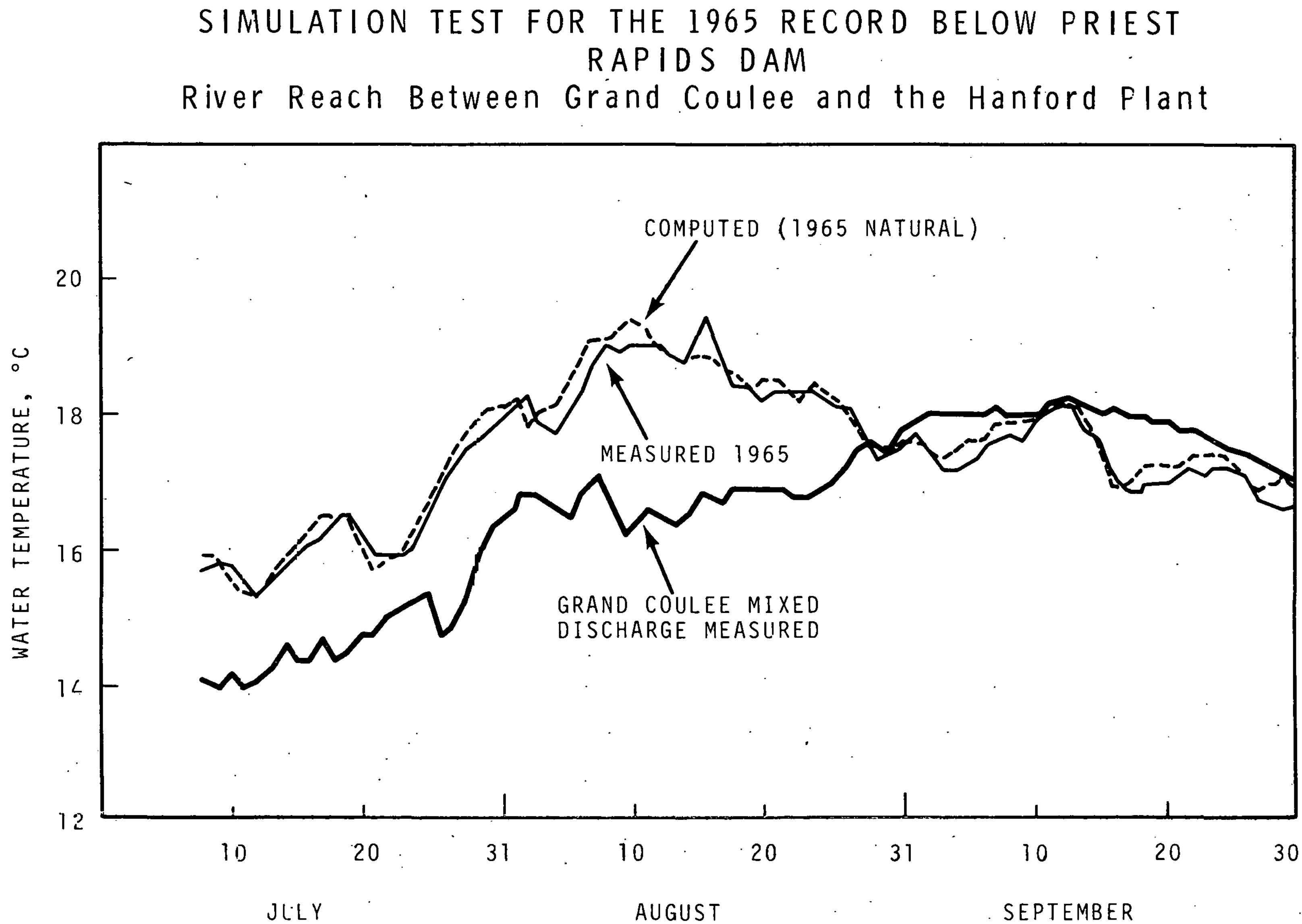

FIGURE 2. SIMULATION TEST FOR THE 1965 RECORD BELOW PRIEST RAPIDS DAM (River Reach Between Grand Coulee and the Hanford Plant)

sites on the Lower Columbia River in a reach which is affected by tides, but above the salinity intrusion at all times. Figure 3 is a general site map showing the two power reactor sites, Trojan and Kalama in relation to the City of Portland, Oregon and the Columbia River estuary. The narrative which follows concerns an investigation of the Kalama or upstream site at Columbia River Mile 78 which is still under consideration as a direct discharge site.[7] At an earlier stage, both the Trojan and Kalama sites were planned for direct discharge, however, a cooling tower is now included at the Trojan reactor now under construction, and thus the thermal interaction between the Kalama reactor and the Trojan reactor at Mile 72.8 would be minimal.

In order to study the Columbia River below St. Helens, Oregon, special techniques were needed to account for flow variations due to tidal influences. These techniques became known as the COLHEAT estuary model. The estuary model, merely a refinement of the original COLHEAT model, has been added to the COLHEAT digital simulation as a set of subroutines.[8] This formal report fully describes the technical development of the simulation system as it applies to the study case and has been recently issued.

The formal program for investigation of the feasibility of direct discharge consisted of the following steps:

- Installation of a long range thermal monitoring program with frequent calibration and river transect data collection to validate the stations over the calendar year. In all, six thermal monitoring stations were installed and remain in operation, spaced at strategic locations above and below the plant site (Figure 3).

- Determination of the mixing characteristics of the Columbia River in the vicinity of the proposed plant and for distances five kilometers above and ten kilometers below the point of effluent discharge. This program involved the establishment of a series of sampling stations where current meter readings were taken over critical portions of the tidal cycle in order to establish the current filed and the timing of the tidal pulses in relation to standard published tidal data at Astoria, Oregon, one-hundred kilometers downstream. Dye tests were carried out for various effluent discharge locations on both the Oregon and Washington side of the River and the mixing of the effluent predicted for conservative river stages.

- Using the values of dispersion coefficients predicted from the established flow fields, the special estuarine version of COLHEAT was used to predict the longitudinal distribution of thermal input to the River. This distribution was supplemented by detailed calculations of the plume size and shape for the tidal extremes. Since the actual outfall has yet to be designed, the resulting predictions are in terms

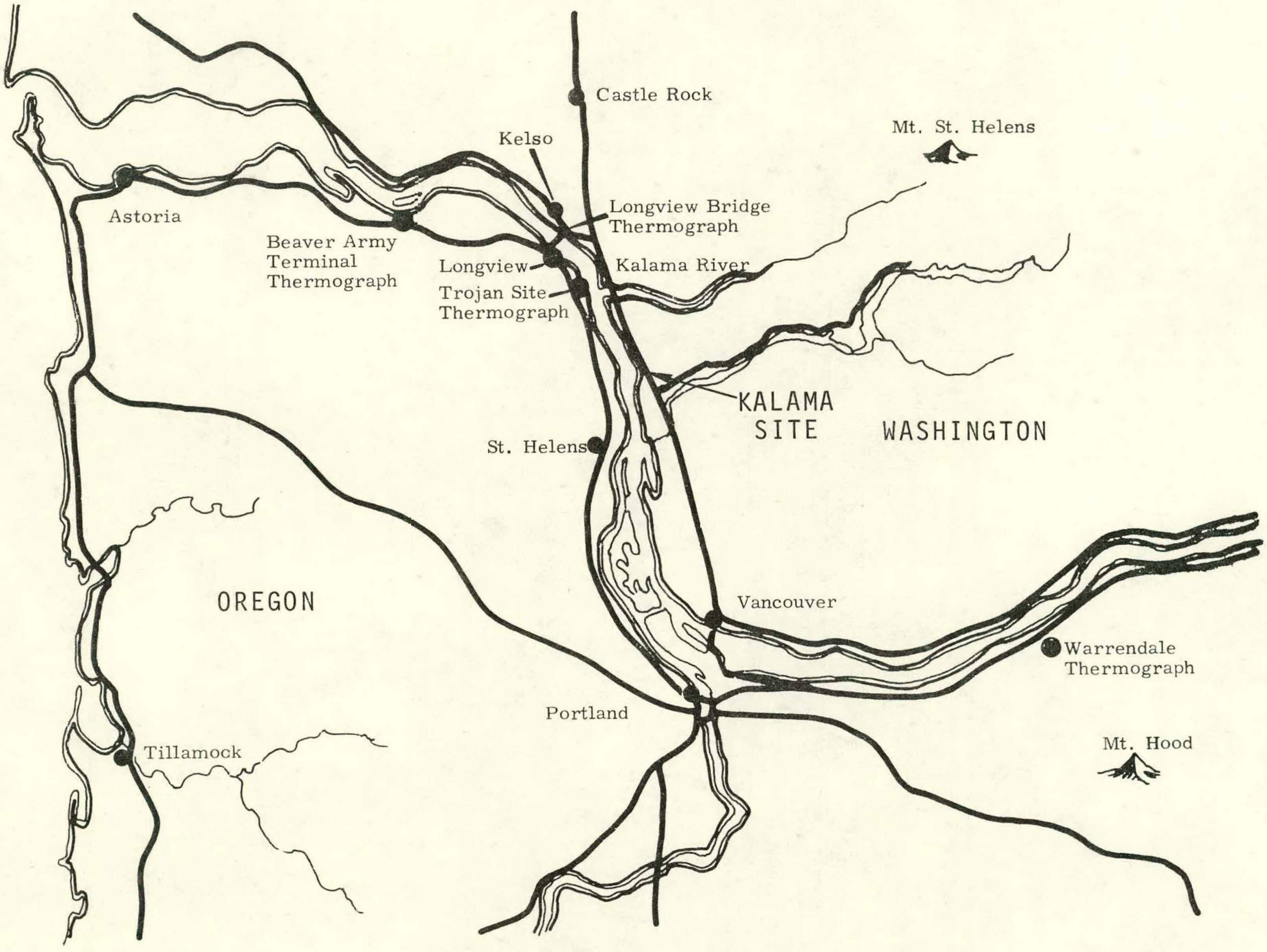

FIGURE 3. GENERAL AREA OF SITING STUDY

of the design temperature differential, yet to be determined, across the condenser. A value of 10 °C has been used for discussion purposes, but does not represent a firm proposal.

The discussion to follow enlarges on some of the details of the basic steps in the research program and the actual results which were provided to the Clark and Cowlitz County Public Utility Districts, the sponsors of the reactor project.

Current measurements were collected on a 40-hr a week basis. The sampling program began on October 7, 1968 and ended on December 20, 1968. Except for a four day period during the week of October 21 through 25, when the entire effort centered around measuring dispersion characteristics, the program ran continuously.

The principal study area was located between River Miles 82 and 74 (Figure 4). After detailed examination of the reach in question, a matrix consisting of 10 sampling locations was considered sufficient to define the regime. As indicated, five of these stations were located along the Oregon side of the main navigation channel and the other five along the Washington side of the main channel.

Previous experience also indicated that the flood in the portion of the estuary under examination would occur from 2 to 4 hrs. after high water at Astoria. Since it was of interest to measure the flow in this portion of the flow cycle, the work schedule was designed around this aspect whenever possible. Table 2 summarizes the selected sample program.

A four-point anchoring system was employed because, measurements were collected in relatively deep water and the seasonal runoff pattern experienced during the sampling period was higher than the normal amount. Once the boat was anchored, current measurements were collected at 2-meter intervals beginning at the surface and continuing to the bottom of the channel. Once the bottom was reached, the process was reversed. Each measurement required about 5 minutes. Thus, one measurement was made every 5 minutes for the entire work day.

In total, approximately 5000 individual current measurements were made at the ten sampling locations shown in Figure 4.

The measurements were reduced to an average velocity in the vertical plane for the four sets of measurements. The magnitude of the average velocity was then plotted as a function of time with respect to high water at Astoria. Figures 5 and 6 show the results of this analysis.

As indicated from the preceding discussion, for streams with $\bar{u}$ greater than 0.2 m/sec complete mixing in the vertical plane occurs within 1200 meters of the release point. At this point, a two-dimensional solution to the general diffusion equation is applicable. The two-dimensional solution previously shown is:

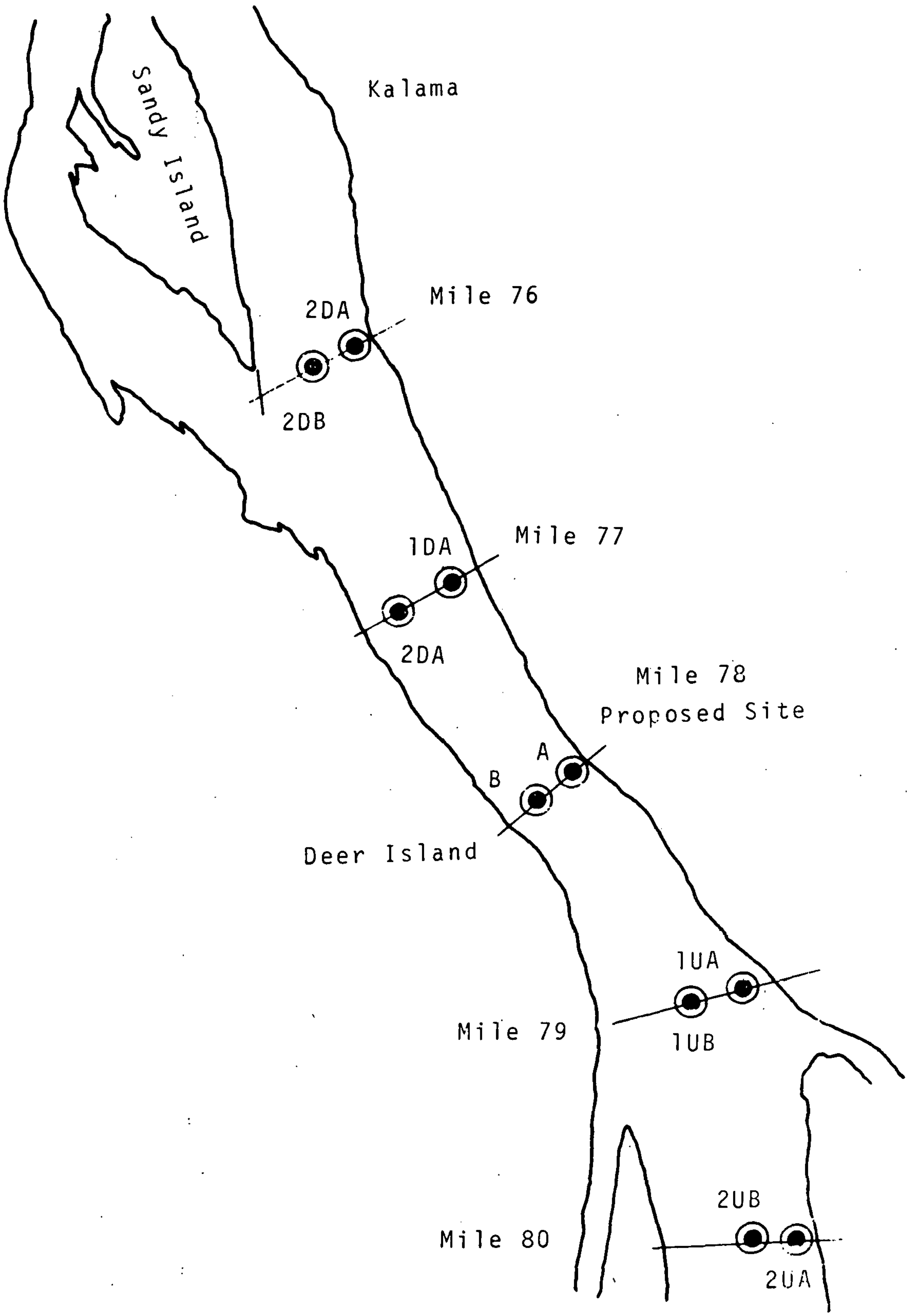

FIGURE 4. MATRIX OF SAMPLING LOCATIONS

TABLE 2. WORK SCHEDULE

Date	Location	Time of Measurement	Date	Location	Time of Measurement
10/7/68	2DA	10 am to 6 pm	11/15/68	2UB	10 am to 6 pm
10/8/68	1DB	10 am to 6 pm	11/18/68	2UB	9am to 5 pm
10/9/68	A	11 am to 7 pm	11/19/68	1UA	9 am to 5 pm
10/10/68	1UA	11 am to 7 pm	11/20/68	B	9 am to 5 pm
10/11/68	2UA	12 noon to 8 pm	11/21/68	1DA	10 am to 6 pm
10/14/68	2UB	6:30 am to 2:30 pm	11/22/68	2DB	10 am to 6 pm
10/15/68	1UA	6:30 am to 2:30 pm	11/25/68	2DA	9 am to 5 pm
10/16/68	1DA	7 am to 3 pm	11/26/68	1DB	9 am to 5 pm
10/17/68	2DC	8 am to 4 pm	11/27/68	A	10 am to 6 pm
10/18/68	B	9 am to 5 pm	11/28/68	1UB	10 am to 6 pm
10/21/68	2DB	10 am to 6 pm	11/29/68	2UA	10 am to 6 pm
10/25/68	2UB	11 am to 7 pm	12/2/68	2DC	9 am to 5 pm
10/28/68	2DC	8 am to 4 pm	12/3/68	2DA	10 am to 6 pm
10/29/68	A	8 am to 4 pm	12/4/68	1DB	10 am to 6 pm
10/30/68	B	8 am to 4 pm	12/5/68	1DA	10 am to 6 pm
10/31/68	1DA	8 am to 4 pm	12/6/68	1UB	10 am to 6 pm
11/1/68	1DB	8 am to 4 pm	12/9/68	2UA	7 am to 3 pm
11/4/68	2DA	10 am to 6 pm	12/10/68	1UA	7 am to 3 pm
11/5/68	1DB	10 am to 6 pm	12/11/68	B	7 am to 3 pm
11/6/68	A	10 am to 6 pm	12/12/68	1DA	7 am to 3 pm
11/7/68	1UB	11 am to 7 pm	12/13/68	2DB	7 am to 3 pm
11/8/68	2UA	11 am to 7 pm	12/16/68	2UA	8 am to 4 pm
11/11/68	2DB	8 am to 4 pm	12/17/68	2DB	8:30 am to 4:30 pm
11/12/68	1DA	8 am to 4 pm	12/18/68	B	9 am to 5 pm
11/13/68	B	9 am to 5 pm	12/19/68	2UB	9:30 am to 5:30 pm
11/14/68	1UA	9 am to 5 pm	12/20/68	A	10 am to 6 pm

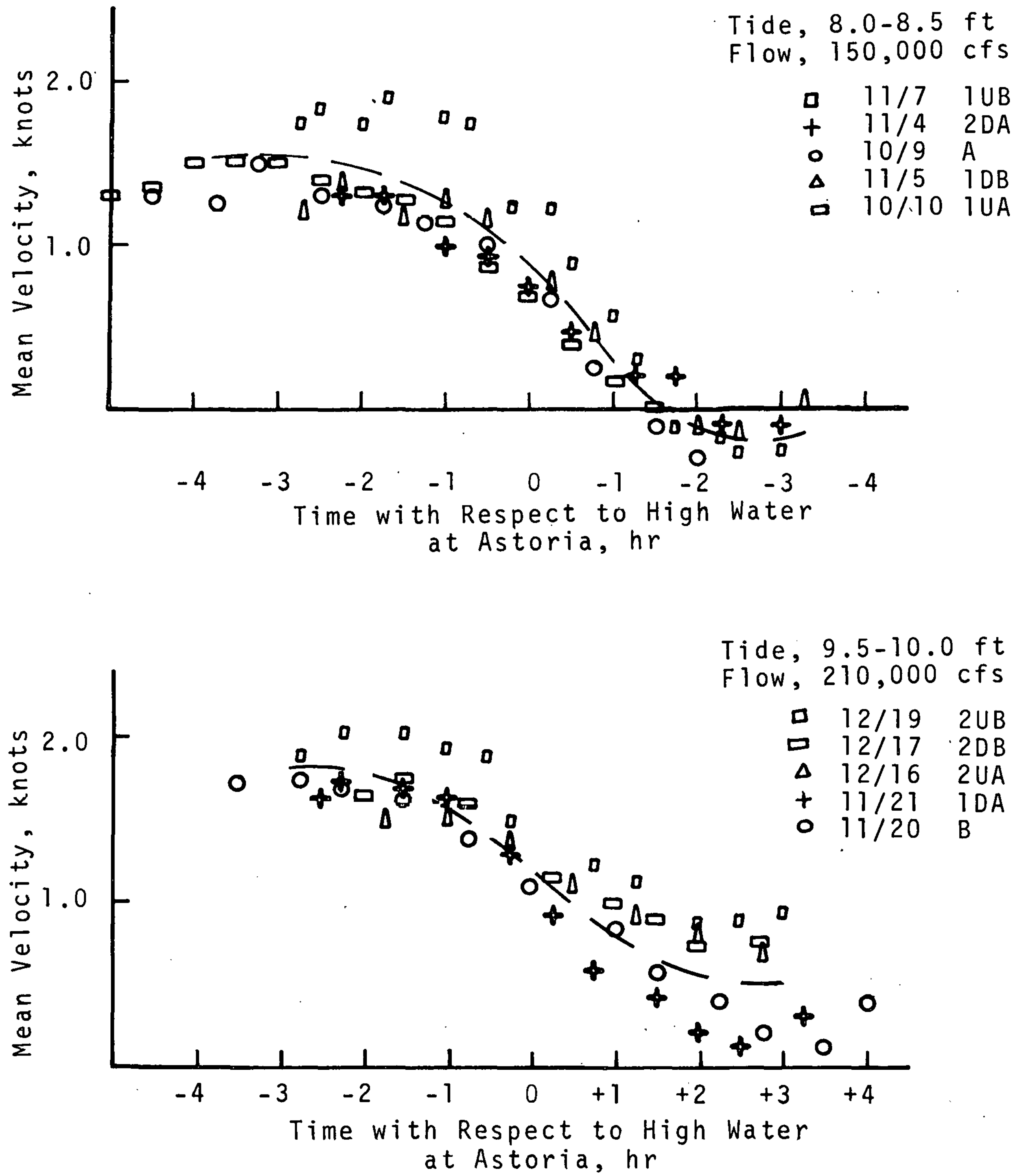

FIGURE 5. TWO SETS OF CURRENT MEASUREMENTS COLLECTED DURING HIGH TIDES

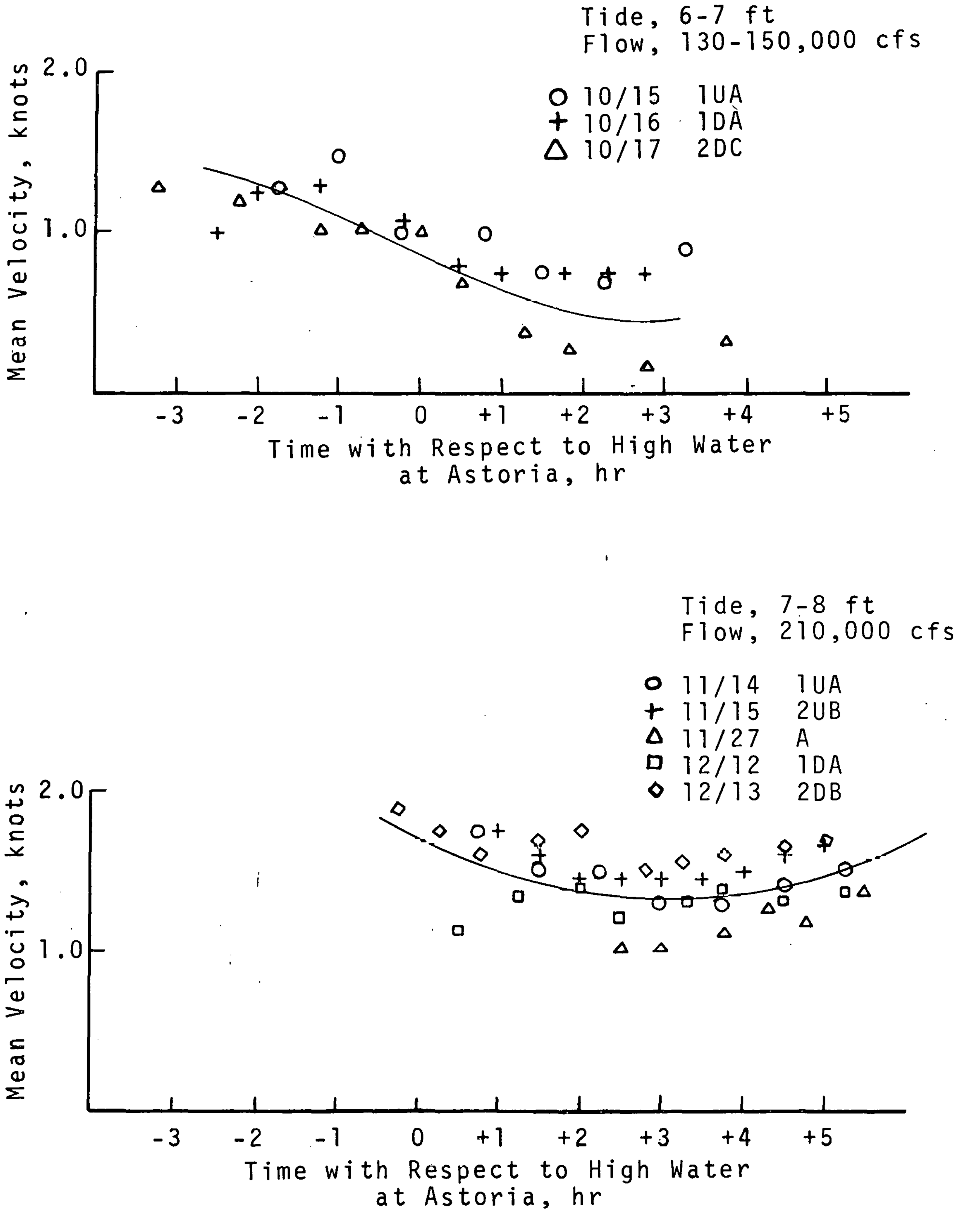

FIGURE 6. TWO SETS OF CURRENT MEASUREMENTS

$$C = \frac{K_{xy}}{t} e^{-1/4t \; (x-ut)^2/D_x \; + \; (x-vt)^2/D_y}$$

Considering only dispersion in the lateral direction, the uniform flow, and the tracer to be normally distributed, the expression can be reduced to the following form:

$$C_{(x,y)} = Ax^{-\alpha} f(y)$$

where $f(y) = \frac{1}{\sigma (2\pi)^{1/2}} e^{-y^2/2\sigma^2}$

Using this expression to describe the response of the dye in the receiving body, the maximum concentration at various locations downstream can be found by setting (y=0). The maximum concentration becomes:

$$C_{(x)} = Ax^{-\alpha}$$

Figure 7 shows the maximum concentrations measured downstream from the release along the Washington shore. Figure 8 shows the maximum concentration measured downstream from the release point for release along the Oregon shore. During this release, samples from both of the sampling systems were collected. Excellent agreement was found between the two sets of data shown in Figures 7 and 8, as well as for the results obtained on separate days. The data in Figures 7 and 8 indicate the typical linear relationship of centerline concentration experienced with the use of dye tracers by many investigators. Tests and analyses described in the earlier section also indicate the validity of this approach with respect to thermal modeling.

With the current field and dispersion information on hand, the construction of the predicted effluent mixing zones followed. As indicated previously, the values of T in Figures 9 and 10 refer to the design temperature differential across the condenser. The use of these diagrams is essential in the development of second stage evaluations of the potential effects of the thermally modified river regimen relative to the stream biota. This discussion does not cover any of the ecological evaluation. The flow fields included show the expected temperature fields at the tidal extremes and provide a basis for the value judgement regarding the impact on fisheries.

The computer model reach for the case studies extended from St. Helens to the lower end of Puget Island (River Mile 37.6). River sections 303 meters long were used to simulate the reach between St. Helens and Longview. From Longview, the longer 1600 meter estuary sections were used to simulate the reach to the lower end of Puget Island. The water inlet temperature at St. Helens was held at 18.9 °C for the two 5-day periods simulated.

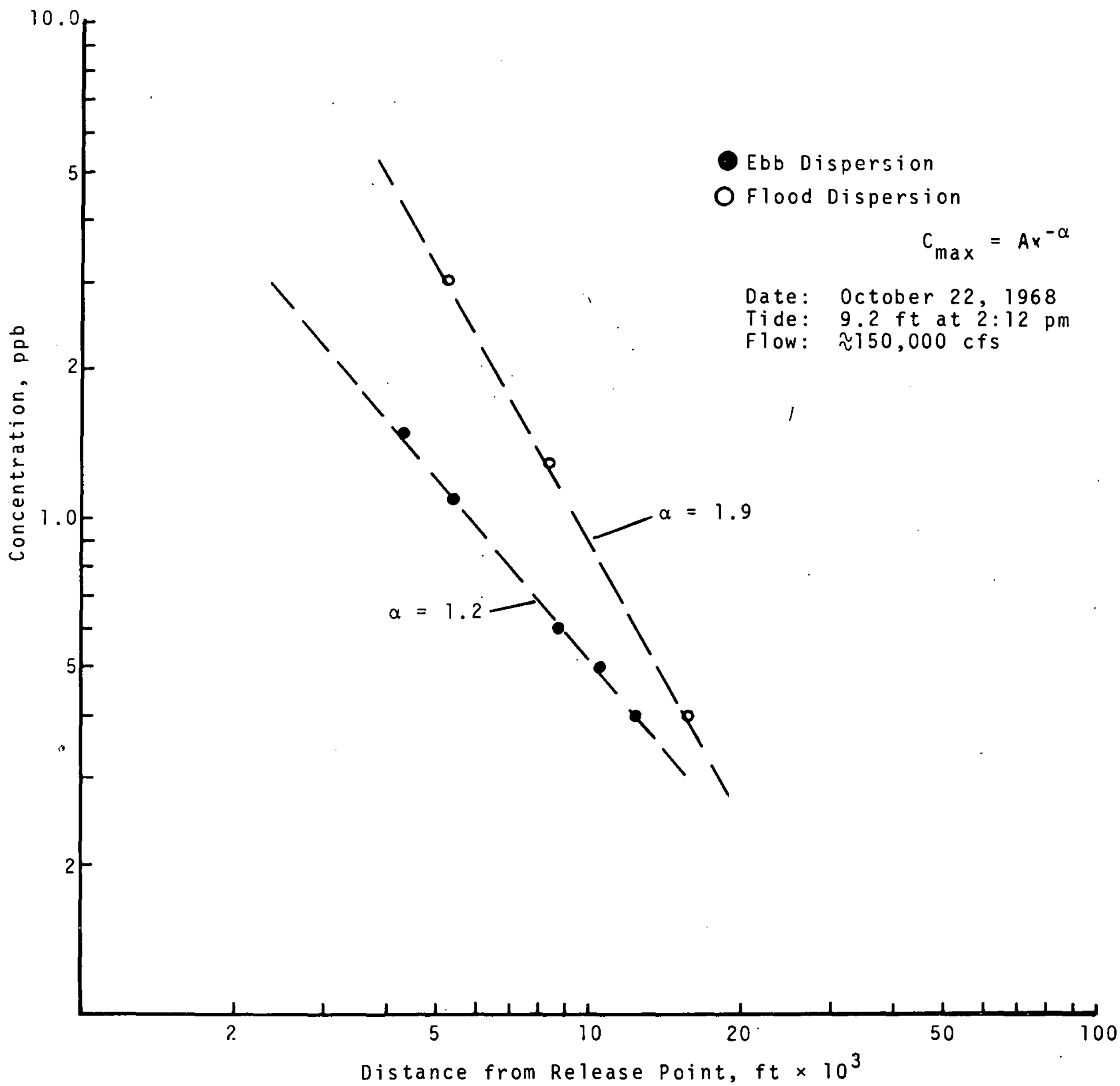

FIGURE 7. PLOT OF MAXIMUM CONCENTRATION AS A FUNCTION OF DISTANCE FOR RELEASE (Along Washington Shore)

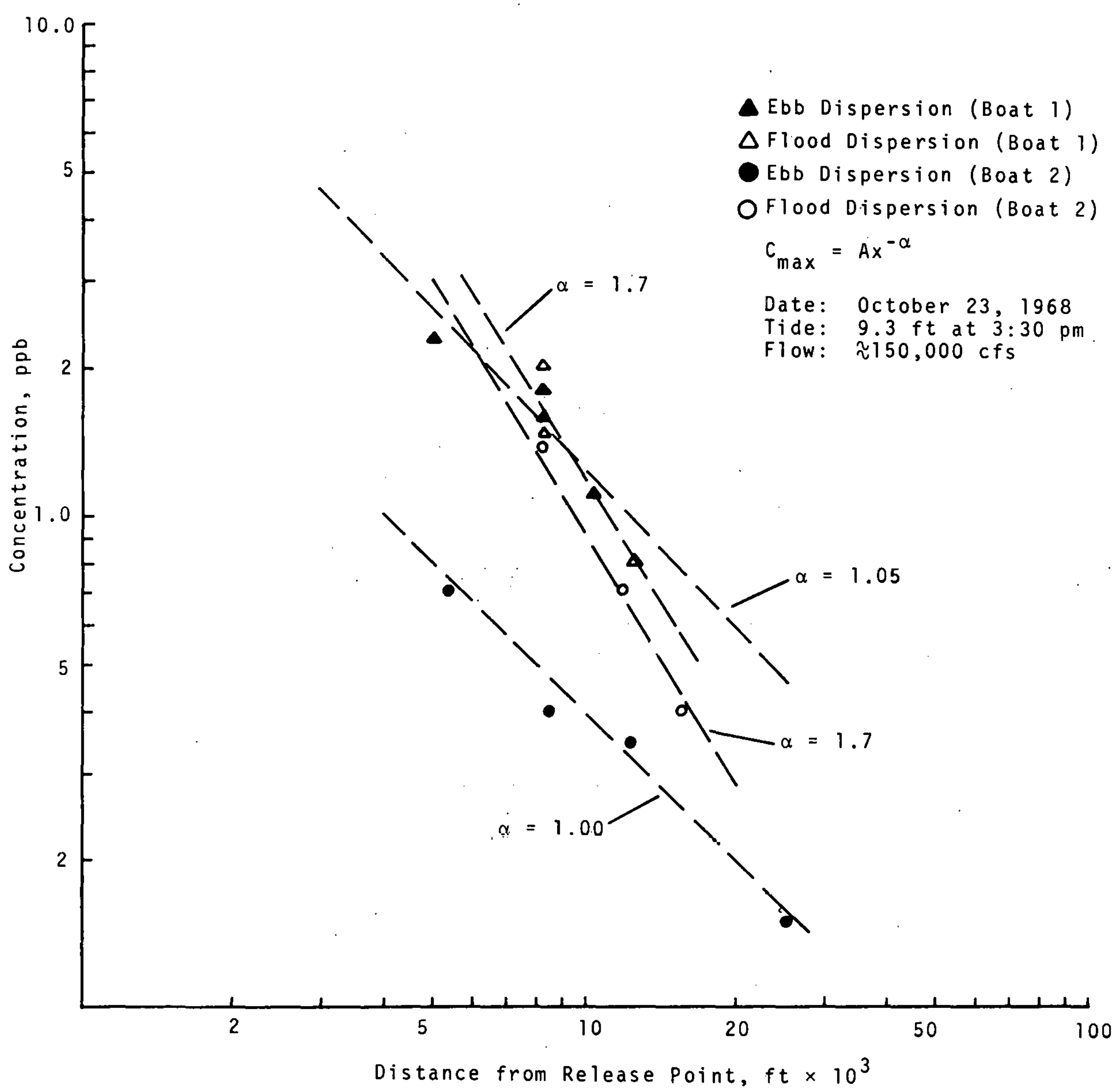

FIGURE 8. PLOT OF MAXIMUM CONCENTRATION AS A FUNCTION OF DISTANCE FROM RELEASE (Along Oregon Shore)

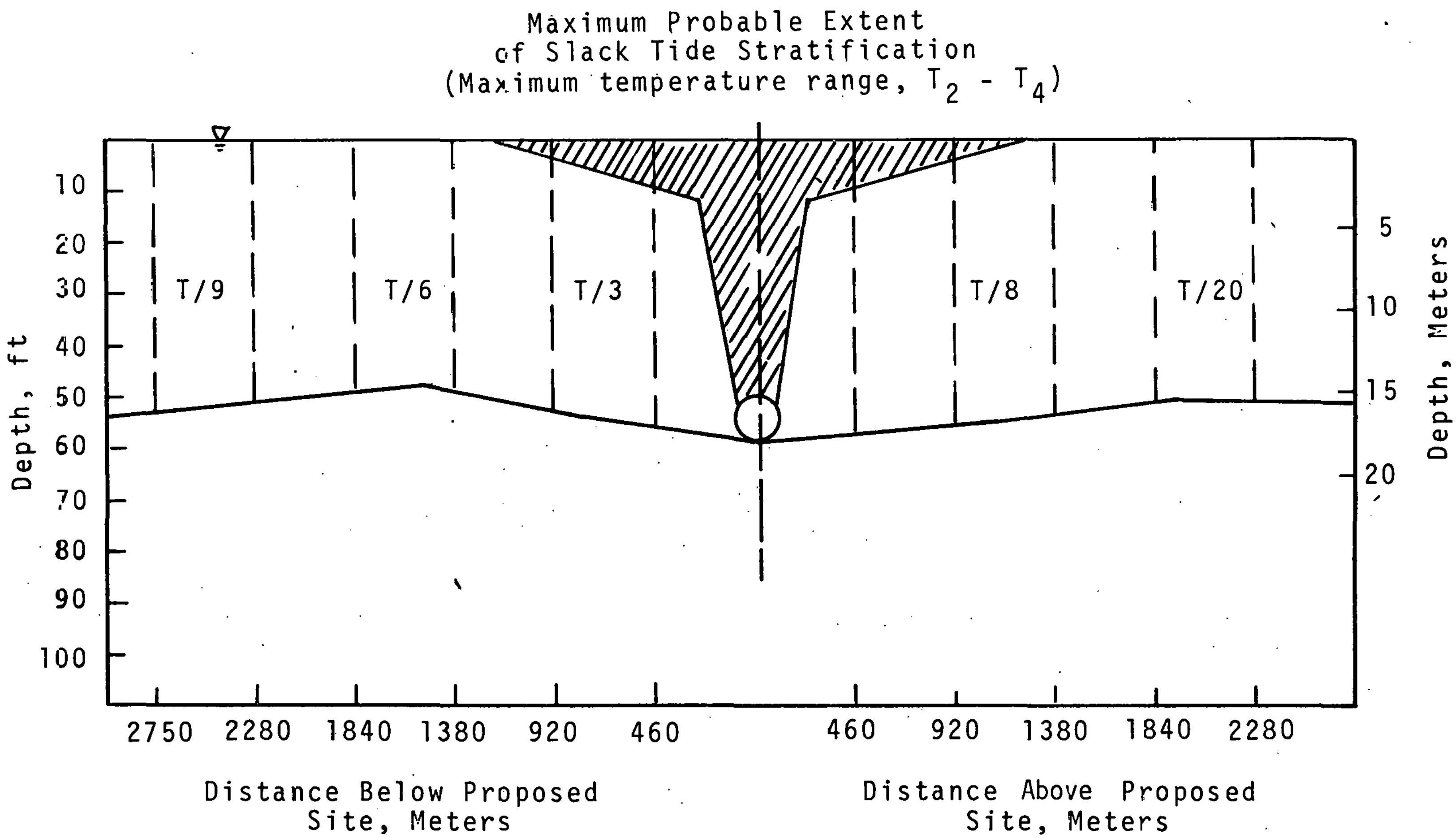

FIGURE 9. APPROXIMATE CENTERLINE TEMPERATURE PROFILE FOR EBB, SLACK, AND FLOOD TIDE CONDITIONS

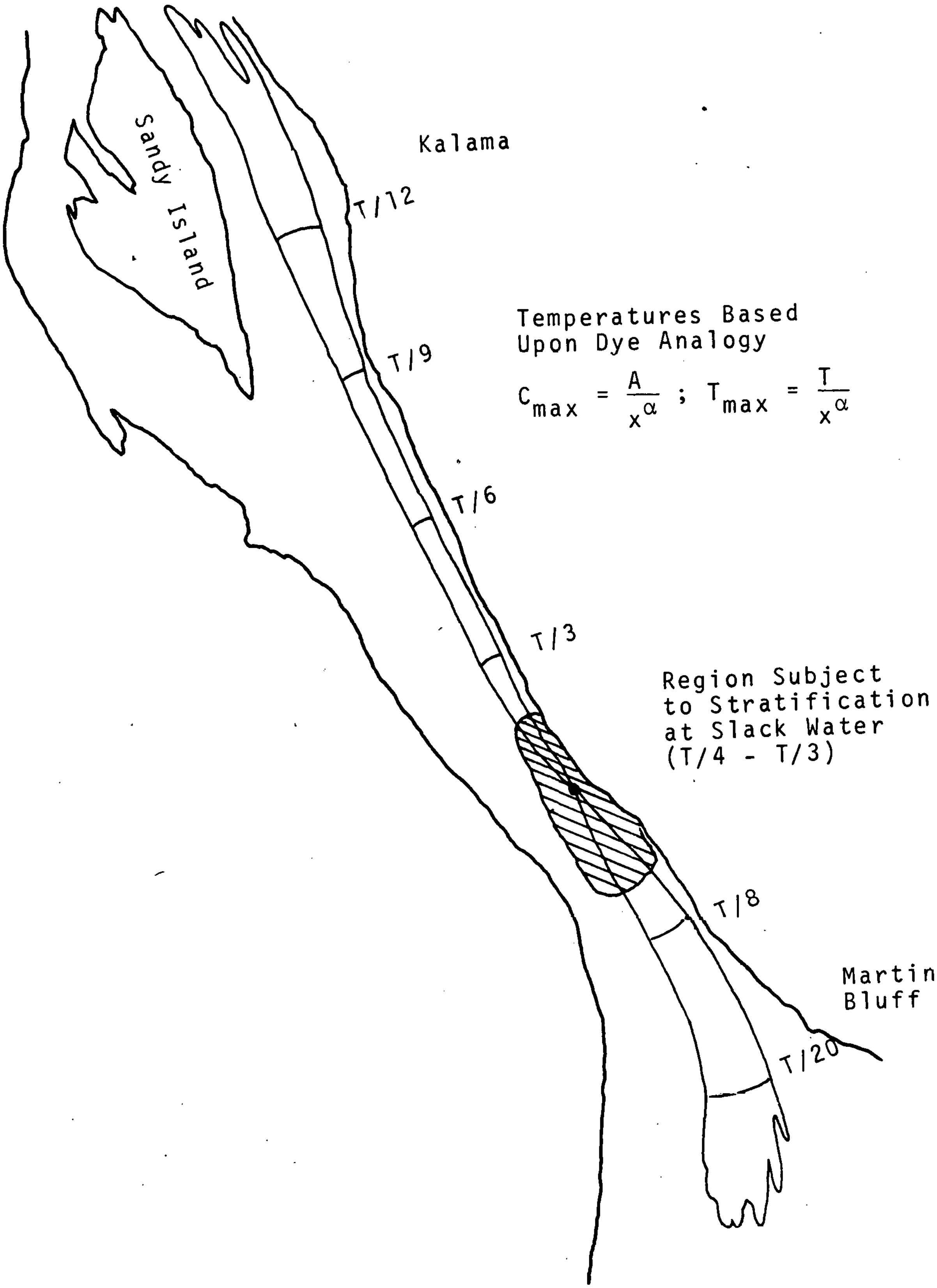

FIGURE 10. APPROXIMATE DISPERSION PATTERN OF A SINGLE POINT DISCHARGE NEAR THE WASHINGTON SHORE (Temperatures are maximum)

This assumption was used to represent a temperature near the maximum which would clearly permit operation under Oregon standards.

Seven-year average Portland weather was used and appropriate dates were chosen to correspond approximately with the water inlet temperature.

Several cases were constructed for placing plants at the Kalama and Trojan sites. Plants were assumed to be 31.25% efficient, thus a 1000 MW plant would advect 2200 MW of heat into the main channel of the Columbia River. Initially a case was run with no advected heat to establish base or natural river temperatures as a function of time and distance on the River. The two cases shown in the following tabulation were run to predict river temperatures with advected heat as a function of time and distance on the River.

Case No.	Plant at Kalama Site (Generating Capacity, MW)	Plant at Trojan Site (Generating Capacity, MW)
1	1000	0
2	2000	0

Temperatures for all runs were recorded every hour at certain river mile locations. These temperatures were an average for the flow through a given river cross section every hour. Then the temperature excesses, i.e., temperature differences between the case with no advected heat and one with advected heat were calculated for each case every hour and at each of the listed river miles.

79.4	72.6
78.5	71.8
77.9	70.7
78.0 (Kalama Site)	69.7
77.5	68.3
76.6	67.2
75.4	66.0
74.1	53.5
73.0	46.0
72.8 (Trojan Site)	38.0

These temperature excesses, plotted by computer, are shown for Case 1 and Case 2 in Figures 11 and 12. The horizontal axis represents time in days, the vertical axis represents the temperature excess in degrees centigrade, and the oblique axis at 30° to the horizontal represents distance

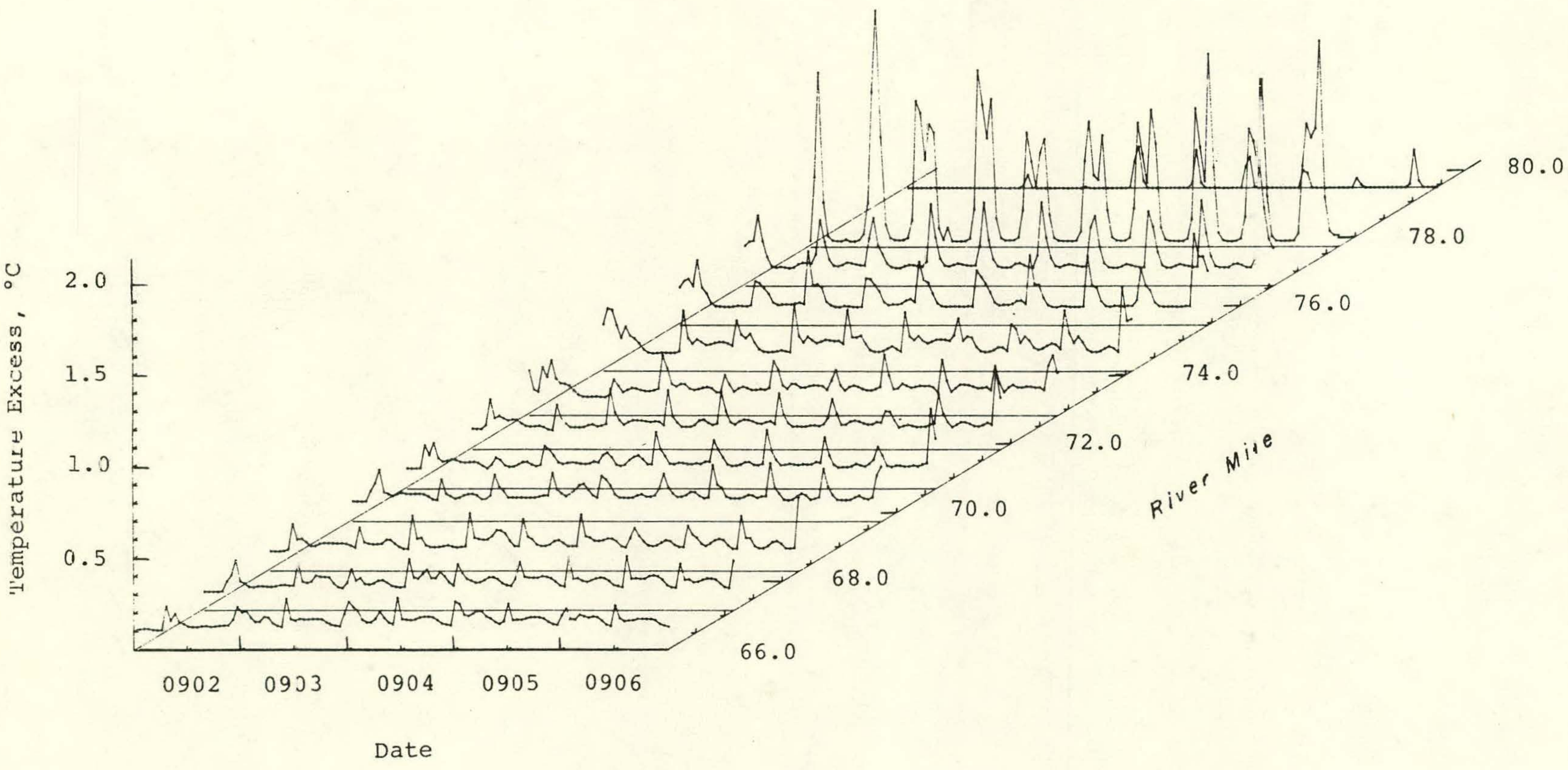

FIGURE 11. TEMPERATURE EXCESS SURFACE FOR CASE 1:
1000 MW PLANT AT KALAMA SITE

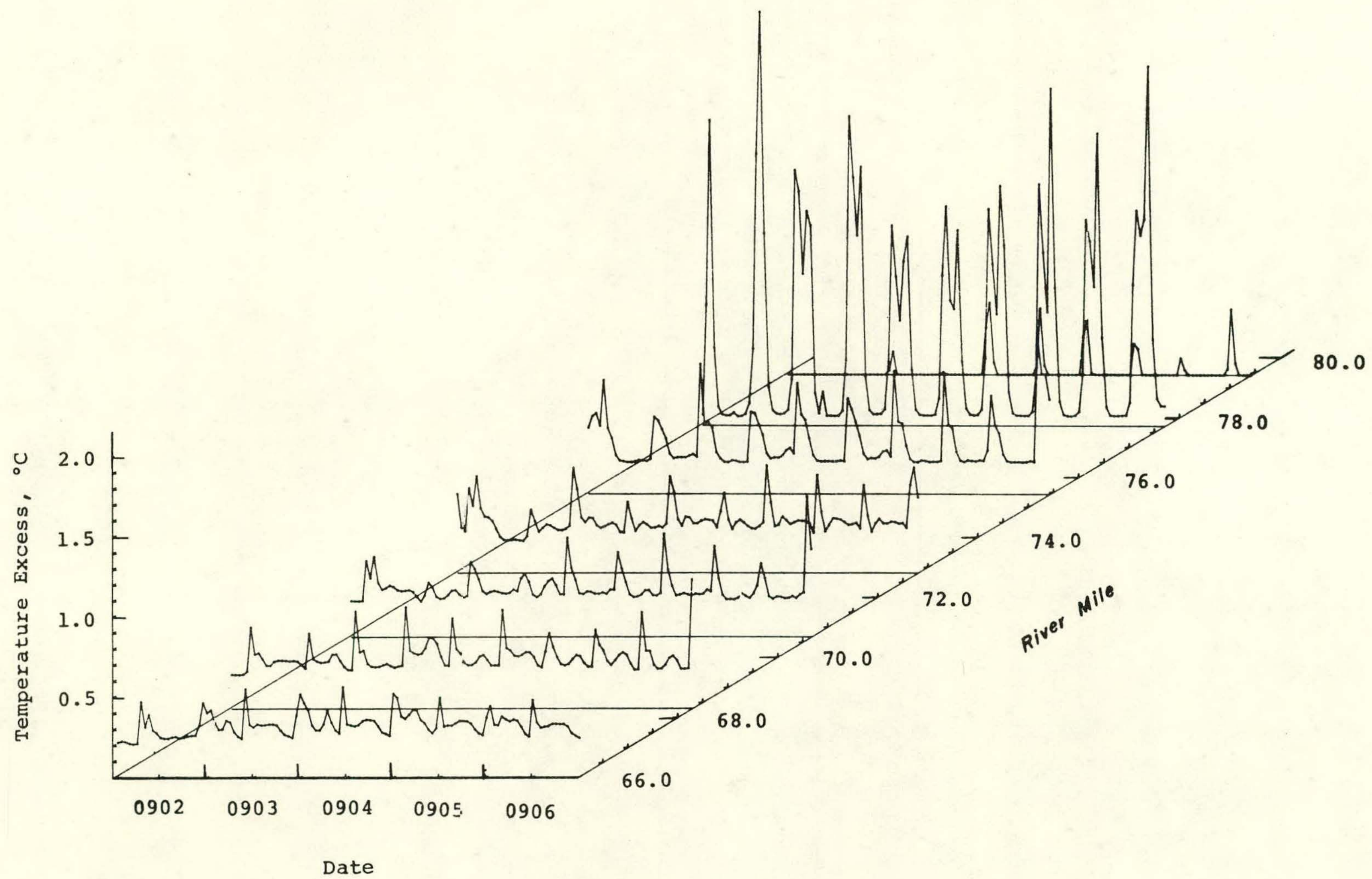

FIGURE 12. TEMPERATURE EXCESS SURFACE FOR CASE 2:
2000 MW PLANT AT KALAMA SITE

upstream from the mouth of the Columbia River. Some data have been deleted in each figure for graphical clarity, while information below Longview has not been presented in these figures.

Figures 13 and 14 are plots of calculated river temperature excesses for the second 5-day period. These are graphed for each of the four cases at River Mile 66.0 (Longview Bridge), River Mile 53.5, and River Mile 38.0.

SUMMARY

The need for increased levels of input information for the judgment of the suitability of sites for industrial activity, especially the nuclear power industry has required a supplementary order of magnitude increase in the sophistication of the analytical methodology. Using the experience gained in the analysis of the effects of nuclear reactor operation at the Hanford plant as a base, Battelle-Northwest has introduced a number of new concepts and methods to the field and tested these under conditions of critical public review. The experience shows that, in addition to the need for a full professional treatment of the scientific information developed, there is a corresponding need for specialized treatment of the study output in order to make it understood by the wide variety of professional and lay persons who have some degree of purview over the siting approval process. The experience suggests increased emphasis on combinations of words, mathematics and graphics portrayed by use of display type, and interactive computers as the next generation step in the visualization and conceptualization of technical information.

The use of simulation techniques can be expected to become of increasing importance in the allocation and adjudication of resources involving dynamic conditions. These supplemented by visual display computer equipment can be expected to become the standard means of portraying predictions to regulatory agencies and the public in the forseeable future.

Simulation models will have to be extensively validated and the output as well as the input data will require specific accuracies depending on the sensitivity of the effects of a given parameter. Since some investigators are reluctant to fully accept the results of a simulation even though the numerical results are highly indicative of success, it is incumbent upon the simulation model technology to carry forward means of testing the accuracy of the methodology in a fully auditable and meaningful way.

An investigation of the criteria for satisfaction yields four important points for consideration:

1) Were the data measured in a standard manner and was the population sampled representative of the entire sample?
2) Were the mathematical tests which were applied sufficiently objective to preclude built-in bias or subjectivity?

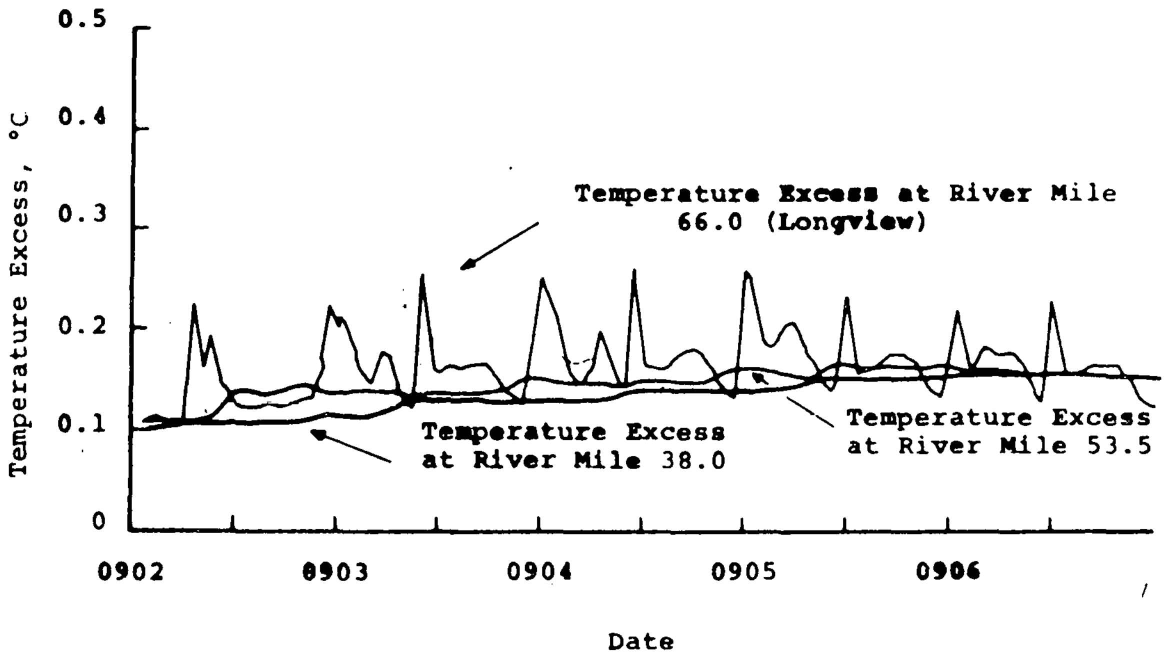

FIGURE 13. TEMPERATURE EXCESS CURVES BELOW LONGVIEW FOR CASE 1: 1000 MW PLANT AT KALAMA SITE

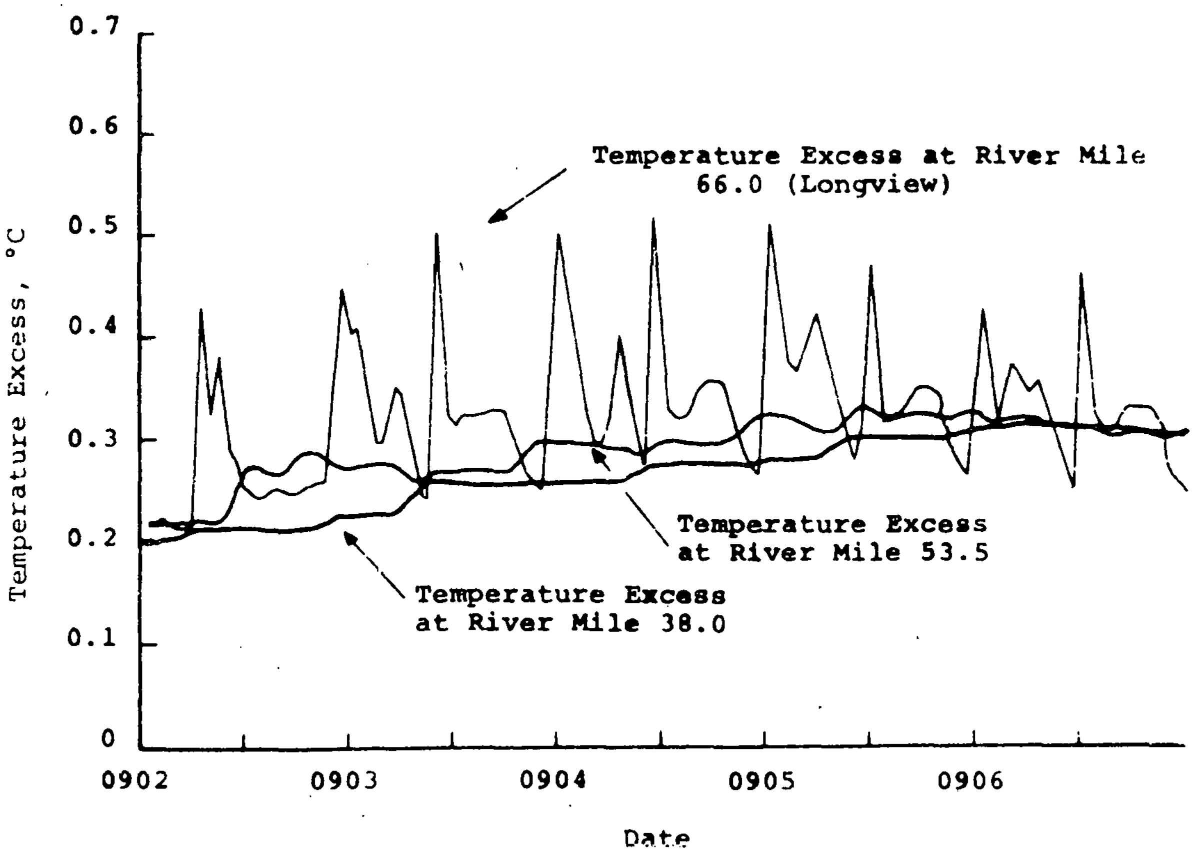

FIGURE 14. TEMPERATURE EXCESS CURVES BELOW LONGVIEW FOR CASE 2: 2000 MW PLANT AT KALAMA SITE

3) Would the model system be subject to exterior bias such as sabotage, electronic malfunction or inquiry from unauthorized persons without the ability to detect or abort such influences?

4) Is the use of electronic simulation with the possibility of compensating error ever tractable in terms of legal or quantitative proof in cases involving institutional systems such as law where statistics are often inadmissible in testimony?

The answers to the first three questions lie in adoption of strict and rigorous in-house rules regarding the validity and quality of input data and the development of rapport between and among the scientific community and the developers of a multilevel system. It would be considered an essential of the system to have built-in checking procedures such as specialized applications of statistical tests such as Student's nonparametric "U" test. However, in the final analysis, there is no substitute for appropriate rapport among developers and users of a system and the completion of successful subprograms.

Taken as a whole, the use of advanced simulation as a planning aid must take the same status in the future as the present highly developed state of the art for electrical transmission stability studies. Without this type of advanced planning, the power industry will be subject to arbitrary treatment in this significant area. As a result, attacks from uninformed persons on a wide variety of fronts will weaken or destroy public confidence in the systematic development of resources as a joint responsibility of industry and regulatory agencies.

The investigations have also revealed the need for improved theory to explain the mixing process immediately below the point of discharge. These locations are critical in the regulatory process in the United States at the present stage of legal development. Additional confirming research to fully validate the principal finding of this presentation, namely that the hot discharge has a higher eddy diffusivity than the corresponding cold discharge are essential in order to allow continued justification of the use of dye tests or physical modeling in the prediction of thermal effluent mixing for licensing activities. The importance of the prompt mixing obtained by the use of relatively high velocity discharges directed into the thalweg was demonstrated by the high dilutions portrayed in the Figures of this presentation and other related published information gained from study of the effects of Hanford reactor operation. This new information about the character of the thermal mixing process close to the point of discharge is expected to be of great significance in modifying design concepts to decrease the prompt temperature increase in the littoral zone and to fully control the size and shape of the mixing zone itself in conformance to regulatory agency standards.

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