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EFFECTS OF HANFORD OPERATIONS ON COLUMBIA
RIVER TEMPERATURES - INTERIM REPORT NO. 2

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Environmental Studies and Evaluations Operation
Radiation Protection Operation
Hanford Laboratories Operation

December 3, 1964

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TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION -----	5
SUMMARY -----	6
THE PROBLEM -----	8
PROGRAM SCOPE	11
Objective I - Net Temperature Effect of Reactor Effluent -----	11
Objective II - Local Distribution of Reactor Effluents -----	16
Objective III - Reactor Power Estimation from Off-Site ----- Temperature Measurements	17
EQUIPMENT -----	18
PROGRESS TO DATE	
Objective I-----	22
Objective II -----	33
Objective III -----	35
APPENDIX	
Heat Budget Expressions -----	37
Data Tables -----	40

LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Title</u>
1	Traverse Locations
2	The Heat Budget
3	Effects of Reactor Heat on River Temperatures
4	Temperature Increment - Priest Rapids to 300 Area - 1962-1963
5	Temperature Cross Sections at Hanford
6	Temperature Cross Sections Above 300 Area
7	Temperature Cross Sections at Pasco
8	River Gauge, Station - PRTR Intake
9	Resistance Thermometer Used for Temperature Traverses
10	Dye Measurement of River Samples with Fluorophotometer
11	Dye Equipment in Use in Boat
12	Portable Meteorological Station on Test
13	Recording Instruments at Portable Meteorological Station

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INTRODUCTION

The effluent cooling water from the Hanford reactors differs markedly from its Columbia River source in its high temperature (85-95° C) and chemical characteristics, as well as its radioactivity content. The effluents disperse slowly after discharge to the river, lateral variations being still measurable at Richland, some 30 miles downstream from the last reactor at 100-F Area. Direct measurement of these changes is difficult because of the uneven lateral distribution of the effluents, the variations with time due to rapidly varying water releases from Priest Rapids Dam, and external influences of weather and tributary and ground water inflows.

Columbia River temperatures are receiving increased attention by regulatory agencies (as well as potentially affected industries) because of the potential losses from increased temperatures of aquatic life, especially salmon. Increasing recognition of the thermal effects of dams in the rivers of the Pacific Northwest does not change the position of Hanford as the largest single man-made source of heat on the main stem of the Columbia. Accurate assessment of the actual impact of Hanford on river temperatures is, therefore, highly desirable. Related areas of local interest include local effluent distributions (for assessment of maximum concentration effects) and the accuracy with which Hanford production rates can be estimated from river temperatures (a plant security problem). In addition, detailed knowledge of changes in river chemical characteristics caused by reactor effluents is desired in order to evaluate the status of the river with respect to quality criteria for human consumption and for aquatic life.

A research and development project for study of the effects of reactor effluent on Columbia River water quality is being sponsored by the AEC Division of Production. Work was started in October, 1962, the first effort being aimed at furnishing an immediate answer to a security question: how closely can Hanford production be estimated by measurement of river temperatures? An interim progress report⁽¹⁾ gave the results of the preliminary investigation. During the calendar year 1963, the study was expanded to meet broader program objectives. This document is a progress report for the year, covering the temperature and effluent distribution phases of the program. Progress on the chemical characteristics phase of the program is documented separately.⁽²⁾ Figure 1 shows the section of the river under study.

SUMMARY

The first and major objective of the study program is determination of the net reactor heat effect on overall river temperatures. Progress during the year consisted primarily of instrument procurement and data collection. Investigation was started of the accuracy of existing upstream and downstream temperatures at the same locations, heat losses from the effluent between the reactors and the river, effluent travel times, and the adequacy of meteorological data from the Meteorology Tower for use along the river. Specific items of interest found included the probable inadequacy of any shoreline location as a direct monitoring point for river temperatures, and the probable existence of one or two points in every river cross section which would consistently give the mean cross section temperature with

¹ HW-76210 (SECRET), "Effects of Hanford Operations on Columbia River Temperatures - Interim Report", J. P. Corley, February 13, 1963.

² HW-84537 (UNCLASSIFIED), "Effects of Hanford Operations on Columbia River Chemical Characteristics", J. P. Corley, December 10, 1964.

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adequate accuracy ($\pm 0.2^{\circ}$ C). The average heat loss from the 107-F retention basin was 6% for November and December, larger than previous measurements had indicated, although barely measurable in the river. Meteorological measurements taken at K Area showed significant differences from those taken at the Meteorology Tower and pointed up the need for measurements along the river for use in heat budget calculations.

A statistical analysis was made of overall river temperature changes between the Priest Rapids gauge and both the 300 Area and Pasco river monitoring stations for the period of September, 1962 to August, 1963. The average reactor area temperature increment was 1.2° C during this period, with a maximum daily average of 2.6° C. Other than the reactor heat increment, there was essentially no net temperature change for the year from Priest Rapids to either 300 Area or Pasco, although the daily temperature differences ranged at Pasco and the 300 Area from -2.0 to $+2.1^{\circ}$ C. Several mathematical models, involving different arrangements of heat budget parameters, were tested on the daily average temperature differences. The best model found reduced the standard deviation of the daily temperature difference from 0.7 to 0.3° C, and accounted for better than 80% of the total variance.

Progress toward the second major objective, the determination of local effluent concentrations, consisted of a limited number of direct probings of river temperature in the effluent bubbles. In addition, dye concentrations were measured at several downstream locations following extended dye addition to the effluent lines. A minimum dilution factor of five for effluent concentration in the river was observed at the D Reactor outfall.

The third program objective is evaluation of the possibility of estimating reactor power levels from off-site measurements. Pasco temperature

data showed that the annual average reactor power level could be estimated to within 10% by simple temperature measurement at the river pumphouse of the Pasco water system. Presumably the same order of accuracy could be obtained at other locations between the plant boundary and the Snake River, if a full year of continuous temperature data were available and if sufficient cross sections were taken to relate the point temperature to the mean cross section temperature. Less accurate estimates would be obtained for shorter time intervals.

THE PROBLEM

A body of water exposed to the atmosphere will, in accord with the second law of thermodynamics, approach a thermal equilibrium. In a closed system, a uniform temperature with the surroundings would be essentially attained after an extended period of time. The case of interest to us is an open system, where the atmosphere and other environmental conditions are continually changing. In this case, a body of water will undergo continuous changes of temperature and mass in either direction, the direction of change at any instant being toward an equilibrium condition.

These temperature and mass changes have been studied employing the concept of the heat budget. Figure 2 shows schematically the more important terms involved. For a pond with no inlet or outlet streams, the net energy change rate would be:

$$WC_p \frac{dT}{dt} = A [q_s(1-\alpha) + q_{ra} - q_{rw} - q_e \pm q_c] \pm q_g + q_p$$

where

W = weight of water

C_p = heat capacity of water

$\frac{dT}{dt}$ = rate change of water temperature with time

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A = surface area

q_s = Solar radiation flux

α = fraction of solar radiation reflected from water surface

q_{ra} = long-wave radiation flux from air and environs to water

q_{rw} = long-wave radiation flux from water to environs

q_e = heat transfer rate per unit area due to evaporation

q_c = heat transfer rate per unit area between water and air from convection

q_g = heat transfer rate from direct heat conduction with the bed

q_p = heat input rate from artificial sources such as plant effluents

If tributary streams enter or leave, or if the net ground water flow is a significant fraction of the total water mass over the period considered, the expression can be adjusted accordingly. Additional terms which might be included under a given set of conditions would account for the heat released from biological or chemical activity. Methods are available in the literature for evaluating each of the terms given, if the necessary data can be obtained.

In a stream flowing in a uniform channel at a constant rate and at a constant initial temperature, the same factors apply. Computation of the net effect would be more difficult, since during a given time period different parts of the total water mass in a given reach would have encountered the energy flux for different periods. Some mixing of unit water masses would be occurring with unit masses having different energy transfer histories. The lateral distribution of any change occurring would be relatively constant, however. Given such uniform conditions, it would be possible to integrate the total energy input and output over the reach being studied.

When we consider a natural stream with varying flow rates and initial temperatures, a different order of complexity is introduced. In this case, both lateral and longitudinal distribution of temperature measurements are changing with time, especially those from point inputs such as plant effluents. Over a period of time long enough to dampen short-term variations, integrated energy balances at end sections may still be useful if one has sufficient cross section temperature distribution data. Overall changes estimated in this manner would not provide accurate information on temperature distribution at specific times at intermediate locations.

Figure 3 shows a typical fall and winter situation in the Hanford plant reaches of the Columbia. The solid line near zero ΔT shows the estimated natural temperature variation through the reach if no reactor effluents had been added. The step changes due to individual reactor area increments are shown, followed by the estimated temperature changes in a typical water mass proceeding downstream. The temperature of this mass if no downstream heat losses had occurred is shown as a dotted line. Brackets show observed maximum and minimum point temperatures for the same day at downstream locations. At the time of the year shown, the greatest part of the temperature variation is due to the fluctuation in river flow. In the early summer months, when the river flow is high and steady, the diurnal atmospheric cycle can frequently be responsible for the entire daily temperature variation.

Figures 5 to 7 show the envelopes of cross section temperatures measured during 1963 at three locations. Note that the temperatures across each section were plotted in all cases as departures from the mean for a particular traverse. The mean temperatures varied from 5 to 20° C. The climatic

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influence is obvious in the broad band at each end of the sections, as is the weakness in using point measurements per se along the shoreline to determine overall reactor effects.

PROGRAM SCOPE

This study has three general objectives.

- I. To determine the net effect of Hanford operations on overall river temperatures.
- II. To determine the local distributions of reactor effluents.
- III. To determine if reactor power levels can be reliably estimated from off-site measurements.

The concepts and methods being used to attain these objectives, with the specific parameters under study, are as follows:

Objective I - Net Temperature Effect

Accomplishment of this objective will require the determination and verification of a mathematical model based on the heat budget between points above and below the reactors. Both the plant and the atmospheric contributions to the heat budget must be accounted for. Ideally, an analytical solution should be found; a statistically-derived model will, however, meet the objective if the variance can be reduced to a sufficiently small value, especially if maximum short-term variations can be independently derived from estimates of reactor effluent concentrations.

A dual approach is, therefore, being used in the resolution of the net temperature effect. Objective IA is the determination of the mean overall temperature change of the river between the Priest Rapids gauge station and one or more locations below the production reactors, including the fractionation of this temperature change between the reactor heat contribution and atmospheric effects. A statistically-derived prediction equation

for the mean value of the latter will then be developed using appropriate meteorological and hydrological data.

Objective IB is the application of empirical heat budget calculations to determine temperature variations within the diurnal cycle at selected points downstream from the reactors. To date, the method used is to calculate time-sequenced temperature changes in a given mass of water as it flows through the plant reach of the river.

The algebraic expression is an adaptation of the heat budget equation given on page 8.

$$\Delta T = \left(\frac{A}{Q\rho C_p} \right) \cdot \left[\sum \frac{q}{A} + \frac{(q_p + q_g)}{Q\rho C_p} \right] = \frac{1}{Q\rho C_p} \left[\Delta A \cdot \sum \frac{q}{A} + q_p + q_g \right]$$

where

ΔT = net change in temperature in a given time interval

ΔA = surface area of the river reach traversed by the center of mass during the same time interval

Q = river flow rate

ρ = density of river water

C_p = specific heat of water

q_p = reactor heat input rate to the water mass in the reach traversed time interval

q_g = heat input rate from ground water inflow in the reach traversed during the given time interval

and $\sum \frac{q}{A}$ = total atmospheric heat flux during the given time interval

$$= q_s (1-\alpha) + q_{ra} - q_{rw} - q_e \pm q_c$$

q_s = solar radiation

α = fraction reflected from water surface

q_{ra} = long-wave radiation from the atmosphere

q_{rw} = long-wave radiation from the water surface

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q_e = evaporative heat loss to the air

q_c = convective heat exchange with the air

Evaluation of the terms for long-wave radiation interchange, evaporative heat loss, and convective heat loss has been discussed in the first report in this series.⁽¹⁾ The algebraic forms used are shown in the Appendix to this document. Basically, they are adapted from the USGS Lake Hefner Water Loss studies.⁽³⁾

Data required for Objective I and the corresponding work requirements include the following:

(1) Upstream temperature

Basic input temperature data is the record from the Priest Rapids gauge station. Aside from routine calibration of the gauge station instruments, it is necessary to determine the accuracy of this record as a measure of the mean river temperature at this location. Repeated temperature traverses over a range of river flows and over the annual climatic cycle will be made and comparison made of the gauge record vs. the cross section mean river temperature.

(2) Reactor area heat input

Daily operating records from each reactor provide the reactor heat output for each day, as well as times of startup and shutdown. One factor which must be evaluated is the heat loss from the 107 retention basins. Outlet temperatures will be measured continuously at the various 107 basins for comparison with inlet temperatures. Heat loss from each type of basin will then be calculated as a percentage loss for the various periods of the climatic cycle.

³ U. S. Geological Survey, "Water-Loss Investigations - Lake Hefner Studies, Technical Report", USGS Professional Paper No. 269, 1954.

Heat sources from the reactor areas other than the main effluent streams include the area sewers, which carry filter backwash and condenser cooling water, and heated ground water from leaking basins and effluent lines and waste trenches. Area sewer temperatures will be measured and the corresponding heat load calculated. The underground water from beneath the reactor areas will be treated as part of the overall ground water effect discussed below.

(3) Estimation of River flow at point of heat injection

Basic river flow measurement for Objective IA is at the Priest Rapids gauge. Although occasional problems with the HAPO instrument calibration have been experienced, supplemental records are available from the USGS station.

River elevation data is also available at each reactor area, but the existing rating curves are of questionable reliability. Calculation for Objective IB of point to point temperature variations due to reactor heat input requires a value for river flow rate at the point and time of release.

Reactor area records will be matched against the Priest Rapids record to improve the rating curves, and machine computation used to improve flow estimates at downstream points.

(4) Measurement of flow times between each reactor and downstream points of interest.

A previous document⁽⁴⁾ gives good estimates of initial time of arrival of water masses starting at each reactor to various river locations as

⁴ HW-58312 REV (UNCLASS.), "Columbia River Flow-Time Calculations", J. K. Soldat, July 1, 1963.

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far as Pasco. For heat budget studies, however, the mean travel time (or residence time) through these reaches is needed. Spot dye releases from each reactor outfall will be made over a range of river flows to provide the needed data.

(5) Evaluation of underground water effects

Estimates of river temperature changes from the influx of underground water, both from the reactor areas and from the normal water table, have been made for stable river conditions.⁽⁵⁾ Although barely measurable under these conditions as a change in the mean river temperature, the potential for larger temperature effects during part of the daily flow cycle will be further evaluated. Previous measurements of local temperatures from reactor area drainage must be confirmed and expanded.

(6) Measurement of meteorological factors

Parameters normally used in heat budget calculations include solar radiation, air temperature, relative humidity (or atmospheric vapor pressure), and wind speed. Measurements of all of these are taken hourly or continuously at the Meteorological Tower near 200 West Area. To obtain data more nearly representative of conditions existing over the river surface, a meteorological station will be established along the river bank, and made portable so that some comparison may be made at different locations along the river. In order to improve the reliability of estimates of the net heat exchange by radiation processes, a net radiometer will be part of this installation.

⁵ HW-77170 (SECRET), "Status of the Ground Water Beneath Hanford Reactor Areas, January, 1962 to January, 1963", D. J. Brown, April 1, 1963.

(7) Downstream temperature determination

Fixed river temperature recorders have been in operation at the PRTR pump intake (at 300 Area) and at the Pasco water plant pumphouse for several years. To relate this data to the mean river temperature at these locations will require a series of temperature traverses through the annual flow and climatic cycle. To further interpret the data in terms of total heat transport at these locations will require velocity traverses at several river flow rates.

Additional locations will be sought for improved fixed temperature monitoring, including the Richland water plant pump intake, and the Hanford townsite for a location above the influence of ponding from McNary Dam.

(8) Influence of McNary ponding

Data from the several locations within the McNary pool as discussed above will provide some information on temperature effects within a run-of-the-river reservoir. Although not necessarily required for this study, the information may be of value in HAPO upstream temperature studies or to other agencies. Of similar nature are temperature measurements in several slough areas where effluent effects are normally absent.

Objective II - Local Distribution of Reactor Effluents

(1) Determination of maximum effluent concentrations below reactor outfalls

Little data is available from past studies regarding maximum effluent concentrations in the river immediately below the outfall line discharge points or along the shorelines. This information is of interest for evaluation of maximum temperature and chemical concentrations to which river biota may be subjected.

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With the actual effluent outlet temperatures established as in I-(2), it will be possible to determine river concentrations for several hundred yards below each outfall by simple temperature measurement. Data at different river flows will be required.

(2) Determination of equilibrium effluent concentrations at downstream locations

For effluent concentrations at longer distances downstream, continuous dye additions to each reactor outfall line in turn at different river flows will provide equilibrium effluent concentrations at various points of interest. In addition to aiding evaluation of chemical additions, this data will also permit comparison of calculated vs. measured temperature increments as a check on the heat budget calculations made for Objective I.

Objective III - Reactor Power Estimation from Off-Site Temperature Measurements

(1) Comparison of upstream and downstream temperature data vs. reactor heat input

Data obtained for Objective I will be reviewed carefully for indicated locations below the plant boundary where direct temperature measurement would permit close estimation of total reactor power levels. It is recognized that careful off-site data collection and skillful use of heat budget calculations would probably enable this to be done for extended periods in any case.

(2) Search for locations of accurate single-point river temperature measurement

Shoreline temperature traverses will be made below the plant boundaries in search of a location where direct point temperature measurement would provide an accurate estimate of mean river temperature. Finding such a location would also be of value for Objective I.

EQUIPMENT USED

Temperature Measurement

Fixed-point temperature measurement is being done primarily by liquid-filled bulb, long capillary, fully-compensated, mechanically-driven recorders. Both Foxboro and Taylor instruments are in use. The accuracy of these instruments has been found to be generally $\pm 1\%$, but routine re-calibration on a semiannual schedule provides $\pm 1/2\%$ full-scale. River temperature monitors in use have a range of 0-30° C. Figure 8 shows the installation at the 300 Area Plutonium Recycle Test Reactor raw water intake. The recorder is in the white shelter above the intake, with the sensor bulb suspended from a plastic float. A staff gauge for checking river level is also shown.

The exception to the above is the Priest Rapids temperature recorder, which consists of a thermistor sensor recording on a Leeds and Northrup strip-chart recorder. The electrical signal to the recorder is also transmitted via FM radio, along with river elevation and turbidity at the gauge station, to a repeater station at the 183-B water treatment head house. The record is taken from the repeater chart except when occasional transmission difficulties show the need to use the original chart at the gauge station. Although the thermistor system has a nominal accuracy to within 0.05° C, chart and recorder accuracy are at best $\pm 1/2\%$, or $\pm 0.15^\circ$ C. This system has been previously described in HWSA-2481.^(e)

Earlier river temperature traverses were made with a Wallace and Tiernam bathy-thermograph, described in Reference (1). These traverses are now made with an Atkins Instrument Co. resistance thermometer. The thermistor provides a signal to a multi-scaled meter which can be read

^e Kramer, H. A., and Rand, J. L., "A Telemetry Installation to Report Columbia River Data by Radio", HWSA-2481, March 1, 1962.

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directly as well as recorded on a potentiometric-type recorder. The time constant of the instrument is about ten seconds. Although the calibration curves for this instrument show absolute errors as large as 0.55° C, use of the curves gives a temperature record accurate to $\pm 0.1^{\circ}$ C. This calibration is checked monthly against a standard laboratory mercury thermometer. Figure 9 shows the meter and probe.

Depth and Distance

Measurements of river depth and distance from shore are taken during river traverses for cross sectional area weighting of temperature or dye measurements. A fathometer is permanently mounted in the boat used for this work. Calibration against a measured cable permits depth measurement to ± 1 foot under favorable conditions.

A sextant type stadimeter is used to measure cross section distance. Painted barrels with a known spacing are posted along the shore where cross section measurements are to be taken. The accuracy of the instrument is $\pm 2\%$, although errors in measurement of up to 5% sometimes occur if the boat is not held on the line of the cross section.

Dye Concentration

The dye-stuff currently in use is Rhodamine B, furnished and used in a 40% solution in acetic acid. Dye concentration is measured by the intensity of the 590 m μ secondary emission peak from a 546 m μ peak excitation beam. The instrument used is a Turner Model 111 Fluorometer, with either a continuous-flow cuvette for continuous measurement of river water or a standard fixed cuvette holder for laboratory use and calibration. In practice, the detectable dye concentration levels with this combination are similar to those reported elsewhere^(7,8), i.e., 0.015 ppb with the continuous-flow

⁷ Merritt, W. F., "A Study of Dilution in the Ottawa River Using Rhodamine B", CRER-1128, December, 1962.

⁸ Fuerstein, D. L., and Selleck, R. E., "Tracers for Dispersion Measurements in Surface Waters", Sanitary Engineering Research Laboratory Report No. 63-1, College of Engineering, University of California, February, 1963.

cuvette, and 0.04 ppb with standard cuvette. The accuracy of the measurement is estimated to be $\pm 10\%$ of the indicated value over the most sensitive range of the instrument.

The Fluorometer can be read directly, but for convenience and permanent record the output signal is recorded on either a Varian Model G-14 or a Baush & Lomb Model V.O.M.-5 portable potentiometric recorder. Both instruments have proven serviceable when operated in a boat with either a small gasoline generator or storage batteries and voltage inverter for power supply.

Water is pumped through the Fluorometer's continuous-flow cuvette with a small Jabsco centrifugal pump. Although the flow rate is not critical, it is generally set at 1 gpm with a rotameter; this rate avoids air bubbles which occur at higher flow rates and which give false signals on the Fluorometer. The lead-in hose causes a 10 second lag between sample pickup and instrument response. Sampling at depths up to 50 feet is possible with an inlet-hose extension.

For boat use of the Fluorometer, piping, pump, rotameter, continuous-cuvette door, and a sensing element for the Atkins resistance thermometer have been mounted on a transportable base. Mounting of the door on the Fluorometer and connection of signal and power leads to the recorder and power leads to the pump and Fluorometer from a gasoline generator permits continuous traversing of cross sections or fixed station recording for any desired time interval. The recorder trace gives a continuous record of the dye concentration; depth, distance, and temperature are read and recorded on the chart at appropriate intervals. Figures 10 and 11 show the equipment in use.

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Meteorological Instrumentation

A net radiometer has been procured from Middleton and Co., Ltd., of Australia for direct measurement of the net radiation interchange between the river and the environs. This instrument, developed and calibrated by the Commonwealth Scientific and Industrial Research Corporation of Australia, consists of a two-sided thermopile, protected by thin-walled polythene hemispheres filled with dry nitrogen under low pressure. The net electrical signal from the difference between the upper and lower hemispheres is fed to a battery-powered potentiometric recorder. Calibration data furnished with the instrument show essentially the same response at 20° C to solar (short-wave) and black-body (long-wave) radiation, 0.450 vs. 0.452 millivolt/milliwatt/cm². Although the instrument was received too late in 1963 to be placed in service, it should eliminate certain variables whose effects on the radiation heat flux are not too well known, i.e., wave reflection, cloud cover and humidity.

A Bacharach portable hygrothermograph will be used for recording air temperature and humidity. The accuracy of this instrument is stated to be $\pm 1^{\circ}$ F for the air temperature and $\pm 5\%$ for the relative humidity indication.

Wind velocity and direction will be measured and recorded with a recording vane anemometer system by Science Associates, Inc. Wind velocity can be read to 1 mph and is stated to be accurate to $\pm 5\%$ at higher velocities. Wind direction is indicated on a 16-point compass scale on a battery-operated recorder. Figure 12 shows the station on test at one of the reactor water plants. Figure 13 is a closeup of the instruments recording (clockwise from top left) radiometer reading, pressure, water temperature, air temperature, and humidity and wind speed and direction.

PROGRESS DURING 1963

Objective I

Table I summarizes temperature data for the first year for which calibrated downstream temperatures are available. The variables are defined:

$$DDT_3 = (T_3 - T_{pr}) - \Delta T_R$$

$$DDT_P = (T_P - T_{pr}) - \Delta T_R$$

$$\Delta T_R = \frac{\Sigma P}{k \rho Q}$$

where T_3 = daily average temperature at 300 Area for the following day
 T_P = daily average temperature at Pasco for the following day
 T_{pr} = daily average temperature at the Priest Rapids gauge
 ΣP = daily average total power level - all reactors
 Q = Daily average river flow rate
 ρ = density of water
 k = conversion factor

Dates on which the maxima or minima occurred are shown in parentheses. Each column is independent, i.e., the date of maximum flow rate is not the date of any maximum temperature or temperature difference. The final row of annual averages includes estimated corrections to the downstream point measurements based on cross section observations during the past year. From the table, it can be seen that the average temperature change for the year between Priest Rapids and both downstream locations was due almost entirely to reactor operations. On a number of winter days, however, the heat loss to the atmosphere was greater than the reactor heat input, giving a net temperature decrease.

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TABLE I

TEMPERATURE DIFFERENCES - PRIEST RAPIDS TO 300 AREA AND PASCO
September, 1962 to August, 1963

(All temperatures in °C)

	<u>Q - cfs</u>	<u>T_{PR}</u>	<u>T₃</u>	<u>T_P</u>	<u>ΔT_R</u>	<u>ΔT₃</u>	<u>ΔT_P</u>	<u>DDT₃</u>	<u>DDT_P</u>
Maximum Hour	310,000(6/16)	19.9(8/13)	22.5(8/13)	21.1(8/12)	4.3(3/19)	-	-	-	-
Minimum Hour	35,500(11/16)	2.7(1/31)	3.6(1/29)	2.9(2/2)	0.3(6/20)	-	-	-	-
Maximum Day	308,000(6/16)	19.5(8/13)	21.8(8/11)	21.0(8/12)	2.6(9/16)	3.8(3/24)	3.1(3/25)	2.4(5/21)	1.7(5/21)
Minimum Day	48,700(9/16)	3.0(2/2)	3.7(1/31)	3.2(1/30)	0.3(6/20)	-1.0(1/10)	-1.4(1/10)	-2.1(1/10)	-2.5(1/10)
Maximum Week	302,000	19.2	21.1	20.5	2.3	3.1	2.4	1.9	1.3
Minimum Week	57,800	3.6	4.1	3.8	0.4	0.5	0	-1.0	-1.4
Average Annual	111,900	11.0	12.9	12.2	1.2	1.8	1.1	0.5	-0.1
With estimated correction			12.5	12.3	-	1.4	1.2	0.1	0

Notes: 1. For meaning of headings, see page 22.

2. Numbers in parentheses are the dates on which the indicated maxima and minima occurred.

3. Estimated correction from recorded temperatures to mean river temperature is given only for the annual averages. Different correction factors would apply to shorter periods.

Weekly averages of temperatures observed at the Priest Rapids gauge and at 300 Area are shown in Figure 4. The difference between these temperature plots is cross-hatched. The calculated temperature at 300 Area ($T_3 - \Delta T_R$) if no reactor heating had occurred is shown as a broken line.

As a first attempt at defining a mathematical model, machine processing has been used to compute correlation coefficients for a number of meteorological variables vs. observed temperature data from the 300 Area and Pasco fixed river temperature monitors. Values of the coefficient approaching +1 indicate a strong positive correlation, values approaching -1 a strong negative correlation, and values near zero a weak correlation.

Table II shows the computed correlation coefficient ($r = \frac{S^2_{xy}}{S_x S_y}$) for nine months of data from September, 1962 through May, 1963. Data for June and July, 1963 was not available for the 300 Area due to high water. Although each of the variables listed is used in calculating the several parts of the heat budget, only solar radiation (q_s) gives a strong correlation. River flow rate (Q_r) and air temperature (t_a) correlate less strongly. River temperature at Priest Rapids (t_w), relative humidity (R), and wind speed (U) show relatively weak correlation. The lack of correlation with wind speed is surprising, and may reflect the inadequacy of the wind data used.

Without limiting the variables to those showing moderate to strong correlation, several mathematical models for calculating DDT_3 and DDT_p were devised using heat budget parameters, and multiple regression coefficients determined. Table III shows the two models which gave the minimum residual standard deviation. It can be seen that the largest

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TABLE II
CORRELATION COEFFICIENTS - 9/62 - 5/63

$$r = \frac{S_x^2}{S_x S_y}$$

	<u>DDT₃</u>	<u>DDT_P</u>
Q _r	0.50	0.49
q _s	0.67	0.73
t _v	-0.21	-0.10
t _a	0.51	0.60
R	-0.34	-0.42
U	0.13	0.16
Q ²	0.44	0.45
t _v ²	-0.19	-0.07
t _a ²	0.47	0.56
R ²	-0.33	-0.41
U ²	0.08	0.11
t _v ⁴	-0.21	-0.10
t _a ⁴	0.50	0.59
U t _v	-0.03	0.06
U t _a	0.32	0.38
UR t _a	0.13	0.16
q _s /q	0.49	0.56
t _v /q	-0.34	-0.25
t _a /q	0.05	0.13
R/q	-0.53	-0.59
U/q	-0.07	-0.03
t _v ⁴ /q	-0.48	-0.44
t _a ⁴ /q	-0.24	-0.19
U t _v /q	-0.18	-0.09
U t _a /q	0.12	0.18
UR t _a /q	-0.06	-0.04

TABLE III

HEAT BUDGET - MODEL III
September - May only

$$DDT_{(P)}^{(3)} = b_0 + b_1 q_s + b_2 t_a + b_3 t_w + b_4 R + b_5 U + b_6 Q$$

<u>DDT₃</u>			<u>DDT_P</u>		
<u>i</u>	<u>$\hat{b}_i$</u>	<u>S_{b_i}</u>	<u>i</u>	<u>$\hat{b}_i$</u>	<u>S_{b_i}</u>
0	-1.911	0.22	0	-2.585	0.210
1	0.00138	0.00025	1	0.00144	0.00023
2	0.0562	0.0032	2	0.0523	0.0031
3	-0.138	0.0095	3	-0.113	0.0071
4	0.00728	0.00196	4	0.00593	0.00186
5	-0.0329	0.0076	5	-0.0262	0.0072
6	0.00381	0.00130	6	0.00434	0.00123

$$\frac{T}{DE_3} = 0.41$$

$$\frac{T}{DDP} = -0.18$$

$$S_D = 0.802 \text{ (original data)}$$

$$S_D = 0.776$$

$$S'_D = 0.327 \text{ (with model shown)}$$

$$S'_D = 0.310$$

$$\text{Multiple Correlation } \left(\sqrt{\frac{S^2 - S'^2}{S^2}} \right) = 0.913 \quad \text{M.C.} = 0.917$$

$$\text{Maximum Deviation} = 0.8$$

$$\text{Maximum Deviation} = 0.9$$

HEAT BUDGET - MODEL IV
All months except June

$$DDT_{(P)}^{(3)} = b_0 + b_1 \left(\frac{q_s}{Q} \right) + b_2 \left(\frac{t_w^4}{Q} \right) + b_3 \left(\frac{t_a^4}{Q} \right) + b_4 \left(\frac{U t_w}{Q} \right) + b_5 \left(\frac{U t_a}{Q} \right) + b_6 \left(\frac{U t_a R}{Q} \right) \\ + b_7 \left(\frac{t_w}{Q} \right) + b_8 \left(\frac{t_a}{Q} \right) + b_9 \left(\frac{t_a}{Q} \right) \left(\frac{t_w}{Q} \right)$$

DDT₃

DDT_P

$$S'_D = 0.336$$

$$S'_D = 0.303$$

$$\text{M.C.} = 0.901$$

$$\text{M.C.} = 0.911$$

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multiple correlation coefficient derives from the simplest model of all those tested, with linear terms only. Table IV shows month by month residual deviations for one of these models.

The data used for this analysis are not the best but were the most readily available. The lag times used are only approximations and the meteorological data from the Meteorological Tower is known not to be accurate for wind, temperature, and humidity along the river. Even so, the results are sufficiently encouraging to continue this method of attack as better data became available.

Heat budget calculations made during the fall of 1962 on individual water masses showed consistent success in predicting downstream temperatures as far as Hanford to within $\pm 0.2^{\circ}$ C. Larger errors resulted from extending this rather simple method to locations within McNary Pool. The same methods applied to six data runs between August 22 and November 19, 1963, gave prediction errors as large as 0.4° C at Hanford. Accomplishment of Objective IB will require a more sophisticated treatment, probably using a time averaging procedure to account for mixing of water masses.

Progress toward resolution of the various parameters listed under Objective I in the section titled "Program Scope" is as follows:

(1) Upstream temperature

Temperature traverses at the Priest Rapids Gauge continued to show gauge temperature readings within 0.15° C of the cross section mean, the estimated limit of gauge accuracy. Table A-1 of the Appendix gives data taken during 1963.

(2) Reactor area heat input

An outlet temperature recorder was established at 107-F retention basin during December, 1963. Comparison of the recorded outlet

TABLE IV

MODEL III - STANDARD DEVIATIONS - MONTH BY MONTH

<u>Month</u>	<u>DDT₃</u>		<u>DDT_P</u>	
	<u>w/o Model</u>	<u>w/Model</u>	<u>w/o Model</u>	<u>w/Model</u>
September, 1962	0.48	0.27	0.53	0.28
October	0.31	0.20	0.35	0.26
November	0.30	0.22	0.32	0.26
December	0.34	0.20	0.32	0.16
January, 1963	0.77	0.52	0.67	0.31
February	0.29	0.18	0.44	0.24
March	0.27	0.20	0.34	0.24
April	0.33	0.30	0.32	0.26
May	0.49	0.25	0.34	0.17
-				
July	0.40	0.35	0.30	0.09
August	0.37	0.26	0.25	0.15

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temperature with the effluent temperature leaving the reactor showed a temperature loss in the basin of 3 to 6° C for the last half of the month, with an average of 5° C. This represents an average loss of 6% of the reactor heat input. The data is shown in Table A-9.

The F Area sewer temperature was also recorded continuously during September and October, 1963. This temperature cycled between 2 and 10° C higher than the raw water temperature, and represents a total heat input to the river of less than 1% of the reactor heat, or less than 0.01° C in the river at all times. The data is summarized in Table A-10.

(3) Downstream river flow rate estimation

No progress was made on this part of the study for lack of a satisfactory base. Recorded gauge elevations when translated to river flow rates showed consistent errors when compared with water release rates from Priest Rapids Dam as reported by Grant County P.U.D. The source of this error had not yet been found by the end of the calendar year. (Prior to issuing this report, the major source of error was found in a piece of mis-matched equipment at the gauge station. Corrections have been made and satisfactory base flow data established for proceeding with this part of the study.)

(4) Flow time measurement

A total of five instantaneous dye releases were made from various reactors from which time of travel measurements could be taken. The travel time data is summarized in Table V. The times of dye arrival were fairly close to those estimated from reference 3, but

TABLE V

FLOW TIME TESTS WITH DYE RELEASES

Date	Q-cfs	Location	Time	Downstream Location	Estimated*	Observed		Time of Max. Conc.		Time of Last Dye	
					Time of Arrival	Time of Channel	Shore	Channel	Shore	Channel	Shore
8-22-63	80,000- 115,000	Vernita Ferry	0600	100-K	0800	-	-	0815	0845	0915	>0945
				100-D	0900	-	1000	0945	1015	-	>1045
				100-H	1000	-	1115	1030	1200	-	>1300
				100-F	1100	1115	1130	1145	1215	-	1400
				Hanford	1400	1315	1430	1330	1515	1530	>1600
8-30-63	55,000- 80,000	Hanford	0740	Ringold	0900	1030	>1100	1045	-	-	-
				Above 300 Area	1300	1400	>1600	1445	-	-	-
				Richland Ferry	1500	1600	>1800	1630	-	-	-
10-22-63	45,000- 55,000	100-H	0810	100-F	0900	0930	1000	0945	1015	>1015	>1130
				Hanford	1230	1215	>1230	-	-	-	-
				Above 300 Area	1800	>1830	-	-	-	-	-
11-5-63	50,000- 70,000	100-D	0820	100-H	1000	1000	1015	-	-	-	-
				100-F	1130	1115	1130	1145	>1200	>1200	-
				Hanford	1430	1400	>1445	1415	-	>1445	-
				ACRMS-300 Area	2100	-	0030 (11/6)	-	0200 (11/6)	-	0330 (11/6)
11-19-63	40,000- 60,000	100-K	0745	100-N	0830	0830	0900	0345	-	-	-
				100-D	0915	0915	>1100	0930	-	-	-
				100-H	1045	1130	1200	1145	-	-	-
				100-F	1215	1300	1315	1330	-	>1445	-
				Hanford	1515	1545	>1645	1600	-	>1645	-
				ACRMS- 300 Area	2100	-	2330	-	(11/20) 0030	-	-

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HW-80888

the maximum concentration was found to lag the time-of-arrival in every case. Where sufficient dye concentration was present, the shape of the concentration vs. time curve for the main stream showed the classical skewed shape, with an abrupt leading edge and an extended trailing edge. The delayed arrival and persistence along the shorelines was quite marked and is not accounted for in the usual solutions of the diffusion equations which are based on the assumption of uniform cross-sectional velocities. The shoreline delay will be significant in following unusual effluent discharges.

(5) Underground water effects

Many observations, mostly undocumented, have been made by the author and others of temperatures in the heated ground water flowing into the river from leaks in the reactor area effluent systems. Temperatures of 30 to 40° C are common in these "hot springs", and at several locations, notably the 181-B forebay and a slough south of F Area, temperatures between 60 and 70° C have been observed. The visible flow rate from most of these areas is very small, but probably represents only a small fraction of the total underground flow. In reference (4), D. J. Brown of the Geochemical and Geophysical Research Operation has estimated the temperature change of the river at a flow rate of 50,000 cfs to be about 0.15° C during the winter months from total ground water flow between Priest Rapids and the 300 Area. About 1/3 of the flow is from the combined reactor area effluent leakage and the remaining two-thirds from the natural underground water flow into the river.

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(6) Meteorological Data

The wind system and hygrothermograph procured for the portable meteorological station were set up at the KE water plant to obtain an initial comparison of data from the Meteorological Tower with data from a location more typical of the river. Both instruments were checked against the Tower instruments before use. Wind velocities at the Tower were about twice those observed at K Area above a base velocity of about 2 miles per hour. Relative humidity averaged about 13% lower at the Tower and air temperatures were about 1° F lower. This data applies only to the K water plant and only to the month of November, 1963, but shows the need for more applicable data than from the Meteorological Tower location for heat budget calculations. The radiometer was not yet available at the time this data was taken.

(7) Downstream temperatures

Repeated temperature traverses were taken during the year at Hanford above 300 Area, at Richland Ferry, and at Pasco to relate mean cross section temperatures to continuous temperature records at these locations.

Figures 5 to 7 presented earlier show envelopes of all individual cross section points from Hanford, 300 Area, and Pasco plotted around the mean temperature for each traverse. At each location, at least one point in the section adequately represents the mean temperature for every traverse. At Hanford, for example, the 175-yard distance from the plant shore is always within 0.25° C of the mean.

Fixed temperature recorders were not installed at Hanford or Richland before the end of 1963, but the recorders at 300 Area and Pasco were

maintained in service, except for recalibration periods and a period of seven weeks when the 300 Area recorder was flooded out. Recalibrations of these recorders twice during the year showed maximum errors of $\pm 0.2^{\circ}$ C.

The relationship between water temperatures recorded by the fixed point recorders and the mean river temperatures at the 300 Area and Pasco is required to determine the net change between these points and the Priest Rapids gauge. This relationship was estimated for the 1962-1963 data by comparing the recorder temperature and the mean cross section temperature for each traverse as shown in Table VI. The difference between the two ranged from 0 to 1.0° C at the 300 Area with a weighted average of 0.4° C higher at the recorder. At Pasco, the difference ranged from -0.4 to $+0.3^{\circ}$ C, with a weighted average of 0.1° C lower at the recorder. These average values were used in preparing Table I.

(3) Influence of McNary ponding

From the data for 1962-1963 summarized in Table I, little change occurred in the annual average river temperature between 300 Area and Pasco.

Objective II

(1) Maximum effluent concentrations

Temperature probing of reactor effluent plumes was done on three occasions. The maximum temperature increment observed in any of the plumes was 14.3° C in the D effluent bubble. Minimum dilution factors ranged from 5 to 14. Visual observation confirmed the relative magnitude of the observed temperature increments, i.e., the more

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TABLE VI

CROSS SECTION MEAN VS. RECORDED TEMPERATURES

<u>Location</u>	<u>Date</u>	<u>Time</u>	<u>Approximate River Flow-cfs</u>	<u>Recorder Temp.-°C</u>	<u>Mean River Temp.-°C</u>	<u>ΔT(Recorder -mean)</u>
300 Area	11-29-62	1330	80,000	10.2	10.2	0
	2-12-63	0800		5.4	4.8	+0.6
	4-2-63	1400	75,000	7.3	6.5	+0.8
	4-18-63	1200	95,000	8.0	7.7	+0.3
	5-23-63	1130	80,000	14.5	13.9	+0.6
	6-24-63	1100	285,000	16.2	15.2	+1.0
	6-27-63	1100	280,000	16.8	15.8	+1.0
	7-18-63	1330	230,000	18.0	17.3	+0.7
	8-7-63	1300	105,000	20.0	19.6	+0.4
	8-30-63	1800	70,000	20.9	20.9	0
	10-10-63	1100	70,000	18.1	17.7	+0.4
	10-16-63	1630	60,000	18.8	18.8	0
	10-29-63	1330	75,000	15.0	14.9	+0.1
	10-31-63	1330	65,000	14.5	14.4	+0.1
	12-11-63	1400	75,000	8.3	8.2	+0.1
	12-16-63	0930	50,000	9.5	9.5	0
Pasco	2-20-63	1630	85,000	5.6	5.3	+0.3
	4-3-63	1400	85,000	6.6	6.7	-0.1
	5-8-63	1400	125,000	10.0	9.7	+0.3
	5-16-63	1330	102,000	12.2	12.3	-0.1
	6-13-63	1000	280,000	14.7	15.0	-0.3
	6-18-63	1200	305,000	15.6	15.9	-0.3
	7-11-63	1100	225,000	16.4	16.1	+0.3
	10-10-63	1400	70,000	18.0	18.4	-0.4
	12-9-63	1400	80,000	8.6	8.9	-0.3
	12-13-63	1330	65,000	8.0	8.4	-0.4

prominent the effluent bubble, the greater the maximum temperature change. Where no bubble could be seen (B and H especially), the dilution factors were large and the maximum temperature increment relatively small. The observations are tabulated in Table A-11.

(2) Equilibrium effluent concentrations

Continuous dye additions were made at F and H area outfalls in attempts to establish equilibrium effluent concentrations at downstream locations. Since the river flow rate was showing the usual daily variation during each of these additions, the observed concentrations should be considered as being relative, somewhat different values being possible with a different flow cycle. In each case, however, the dye addition period covered the minimum flow part of the daily cycle and should have given near maximum concentrations. The data is given in Table A-12.

Objective III

A review of Table I will show that an excellent estimate (to within 10%) of the annual average total reactor power level for 1962-1963 could be made by simply comparing river temperatures at the Priest Rapids gauge and at the Pasco water plant pump house. This is to some degree fortuitous, occurring as a result of off-setting errors. Single or even scattered measurements are apt to give larger errors in the power level estimate.

At present, I conclude that continuous temperature measurements for a year at any point between the reactors and Pasco, when corrected by occasional traverses to relate the mean river temperature to the point being measured, would permit similarly close estimates of total reactor

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power. The accuracy of the estimate will depend to some degree on the intelligence or plain luck in choosing the exact point to be measured. All shoreline locations measured during spring and summer have shown predominantly higher temperatures than the cross section mean. In back-water areas, even of small extent, this effect is magnified. On the other hand, at every cross section location one or two points tend to give the mean river temperature directly. A bridge pier or navigation buoy might well provide such an indicator point at other cross section locations.

ACKNOWLEDGEMENT

The bulk of the data for this program was collected by Environmental Monitoring Operation personnel, supervised by R. W. Meisinger. The assistance of J. J. Fuqua, Manager, and D. E. Jenne of the Atomospheric Physics Operation in selecting and obtaining the meteorological instrumentation is gratefully acknowledged.

APPENDIX
HEAT LOSS CALCULATIONS

Meteorology data used in the calculations is taken from routine measurements made at the Meteorology Tower, near 200 West Area.

Solar Radiation - q_s

A direct measurement of this term is available by pyrrheliometer in units of average langleys (gram - calorie per square centimeter) per minute for each hour of the day. Conversion to units of BTU per hour per square foot is necessary to use the term directly, and application of the assumed adsorptivity for river water of 0.97. The expression used is:

$$q_s = 220 \times L \text{ BTU/hr-ft}^2$$

where L is in gram-calorie per square centimeter per minute.

Net Long-Wave Radiation - q_r

The water mass radiates long-wave radiation to the atmosphere and the environs, and vice versa, at a rate dependent on the respective temperatures. The assumption is made that ground surfaces that can be seen by the water mass are at air temperature. Air temperatures are averaged from hourly readings. Using the Stefan-Boltzmann equation, a value of 0.97 for the emissivity and absorptivity of the water, and an average cloud factor of 0.85 for the atmospheric radiation, the expression used is:

$$q_r = 1.66 \times 10^{-9} (t_w^4 - 0.85 t_a^4) \text{ BTU/hr-ft}^2$$

where t_w and t_a are in $^{\circ}\text{R}$.

Evaporation Loss - q_e

The expression derived from the Lake Hefner studies was

$$E = 1.77 \times 10^{-3} U (e_w - e_a)$$

where E = inches of water evaporated per day.

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Using 1060 BTU per pound for the heat of vaporization, the heat flux expression used is:

$$- q_e = 10.3 \times U (e_w - \frac{\%R.H.}{100} \times e_{as})$$

where U = average wind speed in miles per hour

e_w = vapor pressure of saturated air at water temperature in inches of mercury

%R.H. = percent relative humidity determined from the psychrometric chart for average dry bulb and wet bulb air temperatures

e_{as} = vapor pressure of saturated air at average dry bulb temperature

Conduction Loss - q_c

Conduction of heat to the air only is considered at this time, although a significant heat interchange with adjacent soil areas is possible with extremes of air temperature. The expression is based on the well-known Bowen ratio of conduction losses to evaporation losses, where

$$R = \frac{q_c}{q_e} = C \frac{(t_w - t_a) \times P}{e_w - e_a \times 1000}$$

For this study, a value for C of 0.61 is used, and the final expression is:

$$q_c = 3.58 \times 10^{-3} U P (t_w - t_a)$$

where U = average wind velocity in miles per hour

P = average atmospheric pressure in inches of mercury,
and t_w and t_a are in °F.

Temperature Change

With conversion of units, the net temperature change of the water mass due to

atmospheric effects at a given hour of travel is:

$$\Delta T_m = 2.47 \times 10^{-8} \frac{q_t \times A}{Q_r} \text{ } ^\circ\text{C}$$

where q_t = net heat flux in BTU/hr-ft²

A = average river area in square feet in distance traveled in hour

Q_r = river flow in cubic feet per second

Heat Input

The temperature increment from each reactor must be added to the river temperature at the appropriate time interval. With a 5% heat loss in the 107 basin,

$$\Delta T_p = 8.03 \frac{P}{Q_r}$$

where P = power level in megawatts

Q_r = river flow in cubic feet per second

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TABLE A-1

RIVER TEMPERATURE TRAVERSES - PRIEST RAPIDS GAUGE

River Mile: 395.4

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HW-80888

Date: 1-3-63			Date: 4-3-63			Date: 5-21-63			Date: 7-26-63		
Time: 1120			Time: 1000			Time: 1200			Time: 1040		
Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C
2	4	7.4	2	3	5.0	5	1	12.4	3	4	17.0
50	28	7.5	40	27	5.0	40	27	11.8	45	30	17.1
100	31	7.5	90	32	4.9	90	30	11.7	95	38	17.0
150	35	7.5	140	32	5.0	140	30	11.7	145	38	16.9
200	32	7.5	190	29	4.9	190	28	11.6	195	34	17.0
250	29	7.4	240	27	5.0	240	25	11.6	245	33	17.0
300	27	7.4	290	24	5.1	290	25	11.5	295	32	16.9
350	20	7.4	340	21	5.1	340	22	11.5	345	27	17.0
380	3	7.5	390	3	5.0	390	13	11.7	395	17	17.0
						405	1	13.7	435	5	17.2
$A_t = 30,100$			$A_t = 28,700$			$A_t = 28,900$			$A_t = 37,400$		
$T_m = 7.46$			$T_m = 4.99$			$T_m = 11.65$			$T_m = 16.98$		
Gauge = 7.3			Gauge = 5.0			Gauge = 11.65			Gauge = 17.0		

TABLE A-2

RIVER TEMPERATURE TRAVERSES - REACTOR AREAS

Location:	Below 1904-K		Location:	Below 181-D		Location:	Below 181-D	
River Mile:	381.5		River Mile:	376.3		River Mile:	376.3	
Date:	8-22-63		Date:	8-22-63		Date:	8-22-63	
Time:	0830		Time:	0940		Time:	1000	
Distance from Plant <u>Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	Distance from Plant <u>Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	Distance from Plant <u>Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>
5	3	18.8	5	3	19.3	20	5	19.4
100	8	19.0	15	4	19.3	70	8	19.4
130	11	19.2	25	6	19.3	100	9	19.35
175	19	18.9	55	8	19.3	115	10	19.4
230	31	18.9	95	9	19.3	135	10	19.4
270	25	19.5	115	10	19.35	155	10	19.4
300	17	20.1	140	10	19.4	185	11	19.45
355	12	18.8	185	11	19.4	200	11	19.5
375	8	18.5	200	11	19.5	225	12	19.5
430	6	18.4	220	12	19.5	245	12	19.5
450	4	18.4	290	11	19.5	275	12	19.5
			310	11	19.5	295	11	19.5
			335	10	19.5	320	10	19.45
			365	11	19.45	345	11	19.4
			395	12	19.4	365	11	19.3
			415	13	19.3	390	12	19.25
			445	13	19.2	415	13	19.15
			470	12	19.1	440	13	19.0
			495	11	19.0	475	12	18.9
			525	8	18.9	495	11	18.8
			550	6	18.9	525	8	18.7
			570	4	18.8	570	4	18.7

$$A_t = 23,800 \text{ ft}^2$$

$$T_m = 19.04^\circ \text{ C}$$

$$A_t = 17,500 \text{ ft}^2$$

$$T_m = 19.32^\circ \text{ C}$$

$$A_t = 17,300 \text{ ft}^2$$

$$T_m = 19.25^\circ \text{ C}$$

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TABLE A-2
(Continued)

RIVER TEMPERATURE TRAVERSES - REACTOR AREAS

Location:	Above 181-F	Location:	Above 181-F	Location:	Above 181-F
River Mile:	369.3	River Mile:	369.3	River Mile:	369.3
Date:	8-22-63	Date:	8-22-63	Date:	10-22-63
Time:	1120	Time:	1130	Time:	0915

<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>
25	13	20.25	45	23	20.2	5	5	17.3
55	28	20.2	80	41	20.15	25	11	17.45
70	36	20.2	100	40	20.15	50	26	17.5
90	41	20.15	120	40	20.1	85	35	17.5
110	40	20.1	150	37	20.0	135	33	17.5
135	39	20.1	165	33	19.95	185	23	17.25
175	31	20.0	200	28	19.95	210	19	17.2
190	29	19.95	225	25	19.9	235	17	17.05
215	26	19.9	250	22	19.9	285	12	16.95
235	24	19.85	275	19	19.9	310	9	16.85
270	20	19.8	295	18	19.85	335	8	16.9
295	18	19.8	320	16	19.8	360	7	17.0
320	16	19.8	350	15	19.7	385	6	17.0
350	15	19.8	370	13	19.7	410	4	16.9
375	13	19.8	400	12	19.8	435	3	16.85
400	12	19.75	440	11	19.8			
425	11	19.75	500	6	19.85			
455	11	19.8						
480	10	19.8						

$$A_t = 32,400 \text{ ft}^2$$

$$T_m = 19.98^\circ \text{ C}$$

$$A_t = 32.200 \text{ ft}^2$$

$$T_m = 19.98^\circ \text{ C}$$

$$A_t = 22,900 \text{ ft}^2$$

$$T_m = 17.30^\circ \text{ C}$$

TABLE A-2
(Continued)

RIVER TEMPERATURE TRAVERSES - REACTOR AREAS

Location:	Above 181-F		Location:	Above 181-F		Location:	Above 181-F	
River Mile:	369.3		River Mile:	369.3		River Mile:	369.3	
Date:	10-22-63		Date:	10-22-63		Date:	10-29-63	
Time:	0950		Time:	1005		Time:	1045	
<u>Distance</u> <u>from Plant</u> <u>Shore-yds</u>	<u>Depth</u> <u>feet</u>	<u>Temp.</u> <u>°C</u>	<u>Distance</u> <u>from Plant</u> <u>Shore-yds</u>	<u>Depth</u> <u>feet</u>	<u>Temp.</u> <u>°C</u>	<u>Distance</u> <u>from Plant</u> <u>Shore-yds</u>	<u>Depth</u> <u>feet</u>	<u>Temp.</u> <u>°C</u>
5	5	17.5	5	5	17.55	5	5	15.5
25	18	17.5	25	18	17.5	25	20	15.6
50	24	17.5	50	18	17.5	50	29	15.6
85	34	17.45	85	32	17.45	75	39	15.6
135	36	17.35	135	40	17.4	125	36	15.5
185	28	17.3	185	29	17.15	175	27	15.4
210	23	17.2	210	24	17.0	200	22	15.3
235	18	17.15	235	19	16.85	225	18	15.25
285	14	17.05	260	15	16.85	250	16	15.2
310	11	16.95	285	13	16.9	275	14	15.2
335	9	16.9	310	10	16.95	300	11	15.15
360	7	16.9	335	9	16.95	325	10	15.1
385	6	16.85	360	8	16.95	350	9	15.05
410	5	16.85	385	7	16.9	375	8	14.95
435	3	16.9	410	5	16.85	400	6	14.9
			435	4	16.8	425	5	14.85
			460	3	16.8	450	4	14.8
						475	4	14.8

$$A_t = 24,900 \text{ ft}^2$$

$$T_m = 17.31^\circ \text{ C}$$

$$A_t = 25,000 \text{ ft}^2$$

$$T_m = 17.21^\circ \text{ C}$$

$$A_t = 26,000 \text{ ft}^2$$

$$T_m = 15.38^\circ \text{ C}$$

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 TABLE A-2
 (Continued)

RIVER TEMPERATURE TRAVERSES - REACTOR AREAS

Location:	Above 181-F	Location:	Above 181-F	Location:	Above 181-F
River Mile:	369.3	River Mile:	369.3	River Mile:	369.3
Date:	10-29-63	Date:	11-5-63	Date:	11-5-63
Time:	1100	Time:	1045	Time:	1150

<u>Distance</u> <u>from Plant</u> <u>Shore-yds.</u>	<u>Depth</u> <u>feet</u>	<u>Temp.</u> <u>°C</u>	<u>Distance</u> <u>from Plant</u> <u>Shore-yds</u>	<u>Depth</u> <u>feet</u>	<u>Temp.</u> <u>°C</u>	<u>Distance</u> <u>from Plant</u> <u>Shore-yds</u>	<u>Depth</u> <u>feet</u>	<u>Temp.</u> <u>°C</u>
5	4	15.7	5	5	14.4	10	11	14.65
25	20	15.65	25	19	14.3	25	21	14.65
50	26	15.65	50	27	14.25	50	34	14.65
75	36	15.55	75	28	14.2	75	37	14.65
125	37	15.45	100	38	14.15	100	38	14.65
175	28	15.35	125	36	14.1	125	36	14.6
200	23	15.3	150	32	13.95	150	31	14.55
225	18	15.25	175	27	13.9	175	27	14.45
250	16	15.2	200	21	13.75	200	21	14.35
275	14	15.05	225	18	13.7	225	17	14.2
300	11	15.0	250	15	13.65	250	15	14.25
325	10	15.0	275	12	13.65	275	12	14.25
350	9	14.95	300	10	13.6	300	10	14.2
375	6	14.85	325	17	13.55	325	8	14.15
400	6	14.85	350	14	13.45	350	7	14.15
425	6	14.85	375	10	13.45	375	5	14.1
450	4	14.8	400	7	13.45	400	4	14.05
475	3	14.8	425	5	13.5	425	4	14.05
			450	5	13.5			

$$A_t = 26,100 \text{ ft}^2$$

$$T_m = 15.35^\circ \text{ C}$$

$$A_t = 25,200 \text{ ft}^2$$

$$T_m = 13.91^\circ \text{ C}$$

$$A_t = 24,300 \text{ ft}^2$$

$$T_m = 14.49^\circ \text{ C}$$

TABLE A-2
(Continued)

RIVER TEMPERATURE TRAVERSES - REACTOR AREAS

Location:	Below 181-N	Location:	Above 181-D	Location:	Above 181-F
River Mile:	379.6	River Mile:	378.0	River Mile:	369.3
Date:	11-19-63	Date:	11-19-63	Date:	11-19-63
Time:	0820	Time:	0935	Time:	1350

<u>Distance from Plant Shore-yds</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds</u>	<u>Depth feet</u>	<u>Temp. °C</u>
5	4	12.5	20	4	12.85	10	6	13.8
50	23	12.7	40	6	13.05	50	30	13.75
85	22	13.15	65	7	13.15	75	39	13.7
110	20	13.25	115	9	13.3	100	38	13.65
135	17	13.3	140	12	13.35	125	35	13.55
160	15	13.35	165	13	13.3	150	31	13.5
185	15	13.35	190	12	13.3	175	25	13.4
210	14	13.3	215	13	13.25	200	19	13.35
235	15	13.25	240	9	13.15	225	17	13.25
260	25	13.15	265	8	13.05	250	14	13.25
285	30	12.95	290	9	12.95	275	12	13.25
310	29	12.8	315	11	12.8	300	8	13.3
335	30	12.45	340	11	12.7	325	8	13.25
360	29	12.2	365	11	12.6	350	6	13.25
385	22	11.95	390	9	12.45	375	5	13.2
410	18	11.85	415	9	12.35	400	4	13.2
435	13	11.6	440	10	12.25	425	3	13.15
495	3	11.1	465	14	12.2	450	3	13.15
			490	15	12.05			
			515	9	11.7			
			540	4	11.45			

$$A_t = 28,300 \text{ ft}^2$$

$$T_m = 12.70^\circ \text{ C}$$

$$A_t = 15,600 \text{ ft}^2$$

$$T_m = 12.76^\circ \text{ C}$$

$$A_t = 23,600 \text{ ft}^2$$

$$T_m = 13.50^\circ \text{ C}$$

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TABLE A-3RIVER TEMPERATURE TRAVERSES - HANFORD FERRY

River Mile: 361.6

Date: 1-3-63

Date: 2-26-63

Date: 4-17-63

Time: 1325

Time: 0900

Time: 1400

<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>
2	3	9.5	45	9	6.3	3	2	8.2
50	10	9.5	95	11	6.4	35	9	8.2
100	13	9.5	145	16	6.0	85	15	8.0
150	14	9.4	195	17	6.0	135	16	7.9
200	14	9.3	245	17	5.8	185	20	7.6
250	15	9.3	295	18	5.1	235	19	7.5
300	18	9.2	345	17	5.1	285	20	7.6
350	23	9.1	395	14	4.8	335	19	7.5
400	23	9.0	445	11	4.5	385	21	7.5
450	20	8.9	495	2	4.5	435	17	7.4
500	15	8.8				485	7	7.4
550	2	8.6				505	1	7.5

 $A_t = 25,100 \text{ ft}^2$ $T_m = 9.17^\circ \text{ C}$ $A_t = 19,600 \text{ ft}^2$ $T_m = 5.53^\circ \text{ C}$ $A_t = 24,300 \text{ ft}^2$ $T_m = 7.64^\circ \text{ C}$

TABLE A-3
(Continued)

RIVER TEMPERATURE TRAVERSES - HANFORD FERRY

River Mile: 361.6

Date: 6-20-63

Date: 8-7-63

Date: 8-22-63

Time: 1130

Time: 1200

Time: 1235

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C
2	2	16.0	10	5	20.6	30	11	21.25
50	20	16.1	40	12	20.5	65	16	21.15
100	26	16.3	120	14	20.3	85	18	21.0
150	31	16.1	175	19	20.0	115	20	20.95
200	35	16.2	200	17	19.9	130	22	20.85
250	32	16.1	225	21	19.8	150	22	20.75
300	34	16.0	250	22	19.7	190	24	20.65
350	33	16.0	275	21	19.65	200	24	20.6
400	32	16.0	300	21	19.55	215	25	20.5
450	32	16.0	325	20	19.5	250	25	20.45
500	30	16.0	350	20	19.45	280	24	20.4
550	18	16.1	375	19	19.4	315	24	20.35
600	16	16.1	400	20	19.35	335	23	20.25
670	1	16.0	425	17	19.25	365	23	20.2
			450	10	19.1	400	21	20.15
			475	9	19.1	425	20	20.0
			500	4	19.1	445	19	19.95
			545	2	19.1	475	12	19.9
						490	9	19.85

$$A_t = 53,100 \text{ ft}^2$$

$$T_m = 16.07^\circ \text{ C}$$

$$A_t = 24,150 \text{ ft}^2$$

$$T_m = 19.74^\circ \text{ C}$$

$$A_t = 29,700 \text{ ft}^2$$

$$T_m = 20.48^\circ \text{ C}$$

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TABLE A-3
(Continued)RIVER TEMPERATURE TRAVERSES - HANFORD FERRY

River Mile: 361.6

Date: 8-22-63

Date: 8-22-63

Date: 8-22-63

Time: 1410

Time: 1445

Time: 1505

<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>
10	6	21.7	5	3	21.85	5	3	21.75
25	10	21.7	35	12	21.85	85	18	21.45
40	12	21.7	70	17	21.75	110	20	21.1
80	17	21.7	85	18	21.65	135	23	20.85
105	20	21.6	110	20	21.4	160	22	20.7
135	23	21.25	140	23	21.1	185	23	20.6
155	22	21.05	170	22	20.75	200	24	20.5
190	24	20.85	215	25	20.35	215	25	20.45
205	24	20.7	250	25	20.25	240	26	20.4
230	26	20.6	280	24	20.2	265	25	20.35
260	25	20.5	295	24	20.15	285	24	20.3
285	24	20.4	345	23	20.15	315	24	20.3
310	24	20.3	370	23	20.15	355	23	20.25
335	23	20.3	390	22	20.15	395	22	20.2
360	23	20.25	420	20	20.2	420	20	20.2
380	23	20.25	440	19	20.25	455	17	20.2
400	21	20.25	470	13	20.35	475	12	20.35
430	20	20.3				510	3	20.9
460	15	20.3						

$$A_t = 29,800 \text{ ft}^2$$

$$T_m = 20.72^\circ \text{ C}$$

$$A_t = 29,700 \text{ ft}^2$$

$$T_m = 20.59^\circ \text{ C}$$

$$A_t = 29,300 \text{ ft}^2$$

$$T_m = 20.56^\circ \text{ C}$$

TABLE A-3
(Continued)

RIVER TEMPERATURE TRAVERSES - HANFORD

River Mile: 361.0

Date: 9-25-63

Date: 10-16-63

Date: 10-16-63

Time: 0930

Time: 0920

Time: 1000

Distance from Plant Shore-vds.	Depth feet	Temp. °C	Distance from Plant Shore-vds.	Depth feet	Temp. °C	Distance from Plant Shore-vds.	Depth feet	Temp. °C
5	3	19.85	5	3	18.75	5	3	19.0
25	7	19.75	50	13	18.65	25	7	18.85
50	10	19.7	75	16	18.4	75	17	18.65
75	13	19.6	95	18	18.35	125	23	18.6
100	15	19.5	125	23	18.3	165	21	18.3
125	17	19.4	175	18	18.0	200	15	18.1
150	18	19.25	205	14	17.75	225	12	18.05
175	20.5	18.95	230	11	17.7	250	9	17.9
200	19.5	18.75	255	9	17.65	275	8	17.8
225	15	18.7	285	7	17.6	300	8	17.9
250	11	18.65	305	7	17.55	325	8	17.75
275	8.5	18.6	350	7	17.5	350	8	17.6
300	7	18.6	385	7	17.45	375	8	17.55
325	6.5	18.55	400	7	17.4	405	8	17.5
350	7	18.45	425	7	17.3	425	7	17.5
375	7	18.4	450	6	17.2	445	7	17.45
400	7	18.35	505	2	16.85	475	7	17.5
425	7	18.35				500	3	17.35
465	7	18.35						
515	6	18.4						
540	3	18.9						

$A_t = 17,000 \text{ ft}^2$

$T_m = 18.92^\circ \text{ C}$

$A_t = 15,700 \text{ ft}^2$

$T_m = 17.94^\circ \text{ C}$

$A_t = 17,100 \text{ ft}^2$

$T_m = 18.22^\circ \text{ C}$

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TABLE A-3
(Continued)

RIVER TEMPERATURE TRAVERSES - HANFORD

River Mile: 361.0

Date: 10-16-63

Date: 10-16-63

Date: 10-16-63

Time: 1030

Time: 1120

Time: 1200

<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>
5	3	19.1	10	6	19.2	10	6	19.4
25	7	19.05	25	13	19.1	25	6	19.4
70	14	18.95	75	16	19.0	50	9	19.5
125	23	18.6	125	22	18.75	75	14	19.5
175	18	18.35	150	20	18.6	100	18	19.35
200	15	18.3	175	17	18.5	125	19	19.2
225	11	18.2	200	15	18.35	150	19	18.95
250	10	18.15	225	9	18.2	175	19	18.8
275	8	18.05	250	8	18.15	200	14	18.65
300	7	18.05	275	6	18.1	225	9	18.5
325	7	18.0	300	6	18.05	250	7	18.5
350	7	17.95	325	6	18.0	275	6	18.45
375	7	17.9	350	6	18.0	300	6	18.4
400	7	17.75	375	6	17.95	325	6	18.4
425	7	17.75	400	8	17.9	350	6	18.3
455	6	17.7	425	6	17.85	375	6	18.3
475	7	17.5	450	5	17.65	400	6	18.25
495	4	17.6	470	3	17.5	425	6	18.15
						450	5	18.1
						475	3	18.0

$$A_t = 16,300 \text{ ft}^2$$

$$T_m = 18.33^\circ \text{ C}$$

$$A_t = 15,300 \text{ ft}^2$$

$$T_m = 18.51^\circ \text{ C}$$

$$A_t = 13,700 \text{ ft}^2$$

$$T_m = 18.85^\circ \text{ C}$$

TABLE A-3
(Continued)

RIVER TEMPERATURE TRAVERSES - HANFORD

River Mile: 361.0

Date: 10-16-63

Date: 10-22-63

Date: 10-22-63

Time: 1245

Time: 1110

Time: 1230

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C
5	3	19.6	10	4	17.6	10	4	17.65
15	6	19.65	25	5	17.8	25	5	17.7
50	10	19.7	50	7	17.85	80	17	17.85
75	11	19.6	95	14	17.7	120	21	17.55
125	20	19.3	120	16	17.55	170	17	17.3
175	20	19.1	170	18	17.4	195	13	17.15
200	18	18.9	195	14	16.85	220	10	16.95
225	13	18.8	220	9	16.95	245	8	16.95
250	9	18.7	245	7	16.9	270	5	16.9
385	7	18.45	270	5	16.85	295	5	16.9
415	7	18.4	295	5	16.85	320	5	16.85
435	7	18.35	320	5	16.7	345	5	16.85
465	6	18.3	345	6	16.65	370	5	16.8
475	5	18.3	370	6	16.8	395	6	16.75
			395	6	16.55	420	6	16.65
			420	5	16.5	445	4	16.55
			450	4	16.5	470	3	

$$A_t = 15,500 \text{ ft}^2$$

$$T_m = 19.00^\circ \text{ C}$$

$$A_t = 12,000 \text{ ft}^2$$

$$T_m = 17.27^\circ \text{ C}$$

$$A_t = 12,800 \text{ ft}^2$$

$$T_m = 17.30^\circ \text{ C}$$

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TABLE A-3
(Continued)

RIVER TEMPERATURE TRAVERSES - HANFORD

River Mile: 361.0

Date: 10-29-63

Date: 10-31-63

Date: 11-5-63

Time: 1130

Time: 1115

Time: 1300

<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>
5	3	15.75	5	3	15.1	5	2	14.2
20	6	15.8	30	6	15.3	50	10	14.3
40	12	16.0	50	11	15.4	70	13	14.35
65	15	16.1	70	15	15.35	95	10	14.35
85	17	15.9	95	21	15.05	120	20	14.35
115	19	15.7	120	21	14.85	145	20	14.3
140	19	15.55	145	19	14.55	170	18	14.25
175	20	15.4	170	17	14.6	195	12	14.05
195	14	15.2	195	13	14.5	220	8	14.05
215	11	15.1	220	9	14.55	245	6	14.0
245	9	15.05	245	7	14.45	270	5	14.0
270	8	15.0	270	6	14.45	295	5	13.9
295	7	15.0	295	6	14.4	320	5	13.9
320	7	14.95	320	6	14.4	345	6	13.85
340	7	14.9	345	6	14.4	370	6	13.8
365	7	14.85	370	6	14.2	395	6	13.75
395	7	14.7	395	6	14.2	420	5	13.6
425	6	14.7	420	5	14.2	445	5	13.55
465	3	14.7	445	4	14.2	450	3	13.55

$$A_t = 14,700 \text{ ft}^2$$

$$T_m = 15.35^\circ \text{ C}$$

$$A_t = 13,600 \text{ ft}^2$$

$$T_m = 14.70^\circ \text{ C}$$

$$A_t = 11,300 \text{ ft}^2$$

$$T_m = 14.12^\circ \text{ C}$$

TABLE A-3
(Continued)

RIVER TEMPERATURE TRAVERSES - HANFORD

River Mile: 361.0

Date: 11-19-63

Date: 11-19-63

Date: 12-17-63

Time: 1550

Time: 1630

Time: 1230

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C
25	5	14.4	5	3	14.3	5	4	9.55
50	6	14.4	20	4.5	14.3	25	10	10.15
75	15	14.45	25	5	14.35	50	13	10.2
110	17	14.35	35	7	14.45	75	14	10.1
125	21	14.0	80	15	14.3	100	17	10.0
150	15	13.45	110	17	14.15	125	18	10.0
175	11	13.3	140	19	13.75	150	19	9.35
200	8	13.2	165	17	13.5	175	19	9.2
225	6	13.2	185	13.5	13.45	200	14	8.95
255	7	13.2	210	10.5	13.35	225	10	8.8
275	6	13.2	230	7.5	13.35	250	6	8.7
300	6	13.15	260	7	13.3	275	4	8.65
325	6	13.1	280	6	13.3	300	4	8.6
350	7	13.05	310	6	13.25	325	5	8.5
375	6	13.05	335	6.5	13.25	350	5	8.45
400	6	13.0	355	6.5	13.2	375	5	8.35
425	5	12.85	380	6	13.15	400	5	8.3
450	4	12.45	405	6	13.05	425	4	8.15
475	1	12.15	440	4.5	13.0	450	3	7.95

$$A_t = 12,800 \text{ ft}^2$$

$$T_m = 13.60^\circ \text{ C}$$

$$A_t = 12,600 \text{ ft}^2$$

$$T_m = 13.68^\circ \text{ C}$$

$$A_t = 12,600 \text{ ft}^2$$

$$T_m = 9.31^\circ \text{ C}$$

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DECLASSIFIED

-54-

HW-80888

TABLE A-4

RIVER TEMPERATURE TRAVERSES - PINGOLD

River Mile: 354.4

Date: 2-26-63

Date: 6-24-63

Date: 8-30-63

Time: 1110

Time: 1320

Time: 1030

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C
30	7	5.7	2	3	16.2	25	4	20.8
80	12	5.6	50	14	15.6	80	14	20.6
130	10	6.0	100	15	15.4	130	12	20.5
180	7	5.7	150	19	15.5	180	9	20.45
230	7	5.6	200	24	15.4	230	9	20.4
280	7	5.5	250	26	15.4	280	9	20.3
330	4	5.6	300	22	15.3	330	6	20.3
380	6	5.4	350	20	15.2	380	8	20.25
430	6	5.5	400	19	15.1	405	8	20.2
480	10	5.2	450	18	15.1	430	8	20.2
530	20	5.0	500	18	15.1	455	10	20.2
580	7	4.8	550	20	15.1	480	12	20.1
630	3	6.2	600	24	15.1	505	17	20.1
			650	30	15.1	530	22	20.1
			700	34	15.1	555	16	20.1
			750	21	15.2	580	9	20.1
			800	18	15.3	605	7	20.0
			850	10	15.4	630	5	20.0
			900	8	15.5	675	4	20.0

$$A_t = 15,400 \text{ ft}^2$$

$$A_t = 54,300 \text{ ft}^2$$

$$A_t = 20,600 \text{ ft}^2$$

$$T_m = 5.44^\circ \text{ C}$$

$$T_m = 15.26^\circ \text{ C}$$

$$T_m = 20.30^\circ \text{ C}$$

TABLE A-4
(Continued)

RIVER TEMPERATURE TRAVERSES - RINGOLD

River Mile: 354.4

Date: 8-30-63

Date: 10-22-63

Date: 10-29-63

Time: 1035

Time: 1350

Time: 1225

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C
25	4	20.8	25	3	17.05	10	2	15.5
50	9	20.8	75	10	17.35	25	3	15.5
80	14	20.7	125	12	17.3	50	6	15.45
105	13	20.7	175	7	17.3	75	9	15.45
130	12	20.6	225	6	17.3	125	15	15.4
155	11	20.6	275	5	17.25	175	9	15.35
180	9	20.5	325	4	17.2	225	8	15.3
205	9	20.5	375	5	17.15	275	7	15.3
230	9	20.4	425	6	17.05	325	6	15.25
255	9	20.4	475	10	16.95	375	6	15.2
280	9	20.4	525	16	16.85	425	7	15.15
305	8	20.3	575	18	16.7	475	11	15.1
330	6	20.3	625	20	16.6	525	17	15.0
355	7	20.3	650	3	16.5	575	20	15.0
380	8	20.3				625	9	14.95
405	8	20.2				675	3	14.95
430	8	20.2						
455	10	20.2						
480	12	20.2						
505	17	20.1						
530	22	20.1						
555	16	20.1						
580	9	20.1						
605	7	20.1						
630	5	20.0						
655	4	20.0						

$$A_t = 19,300 \text{ ft}^2$$

$$T_m = 20.34^\circ \text{ C}$$

$$A_t = 17,400 \text{ ft}^2$$

$$T_m = 16.99^\circ \text{ C}$$

$$A_t = 16,300 \text{ ft}^2$$

$$T_m = 15.15^\circ \text{ C}$$

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-56-

HW-80888

TABLE A-4
(Continued)

RIVER TEMPERATURE TRAVERSES - FINGOLD

- River Mile: 354.4

Date: 10-31-63

Time: 1200

<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>
10	2	15.0
25	5	14.85
50	5	14.85
85	9	14.8
110	13	14.8
135	10	14.8
160	9	14.75
185	7	14.7
210	7	14.75
225	7	14.75
260	7	14.7
285	6	14.7
310	5	14.7
335	5	14.65
360	6	14.65
385	6	14.6
410	6	14.6
435	8	14.6
460	5	14.5
485	13	14.45
510	16	14.4
535	15	14.35
560	19	14.3
585	11	14.25
635	3	14.4

$$A_t = 15,800 \text{ ft}^2$$

$$T_m = 14.62^\circ \text{ C}$$

TABLE A-5

RIVER TEMPERATURE TRAVERSES - POWER LINE CROSSING

River Mile: 350.5

Date: 2-26-63

Date: 8-30-63

Date: 8-30-63

Time: 1215

Time: 1200

Time: 1245

<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>
55	8	6.0	5	3	21.5	5	3	21.9
105	14	5.8	80	16	21.2	80	16	21.4
155	18	5.6	130	21	21.0	130	21	21.05
205	16	5.5	180	24	20.85	180	24	21.0
255	15	5.4	230	25	20.7	230	25	20.7
305	17	5.2	280	26	20.5	280	26	20.6
355	18	5.2	330	26	20.4	330	26	20.55
405	5	5.5	380	19	20.35	380	19	20.6
455	3	6.1	430	11	20.45	430	11	20.7
			480	5	20.45	480	5	20.65
			500	3	20.5	500	3	20.7

$$A_t = 16,900 \text{ ft}^2$$

$$A_t = 26,400 \text{ ft}^2$$

$$A_t = 26,300 \text{ ft}^2$$

$$T_m = 5.47^\circ \text{ C}$$

$$T_m = 20.65^\circ \text{ C}$$

$$T_m = 20.81^\circ \text{ C}$$

DECLASSIFIED

DECLASSIFIED

-58-

HW-80888

TABLE A-5
(Continued)

RIVER TEMPERATURE TRAVERSES - POWER LINE CROSSING

River Mile: 350.5

Date: 8-30-63

Date: 8-30-63

Date: 8-30-63

Time: 1355

Time: 1230

Time: 1400

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C
5	3	21.9	5	3	21.9	5	3	21.9
130	21	20.9	30	9	21.5	30	9	21.6
180	24	20.8	55	13	21.4	55	13	21.6
230	25	20.7	80	16	21.2	80	16	21.4
280	26	20.6	105	19	21.0	105	19	21.1
330	26	20.4	130	21	21.0	130	21	21.0
380	19	20.5	155	23	20.9	155	23	20.9
430	11	20.55	180	24	20.8	180	24	20.8
480	5	20.6	205	25	20.7	205	25	20.7
500	3	20.6	230	25	20.6	230	25	20.7
			255	26	20.5	255	26	20.6
			280	26	20.5	280	26	20.5
			305	26	20.5	305	26	20.5
			330	26	20.5	330	26	20.4
			355	23	20.5	355	23	20.4
			380	19	20.5	380	19	20.5
			405	15	20.6	405	15	20.5
			430	11	20.6	430	11	20.6
			455	8	20.6	455	8	20.6
			480	5	20.6	480	5	20.6
			500	3	20.7	500	3	20.7

$$A_t = 26,700 \text{ ft}^2$$

$$A_t = 27,300 \text{ ft}^2$$

$$A_t = 27,300 \text{ ft}^2$$

$$T_m = 20.75^\circ \text{ C}$$

$$T_m = 20.73^\circ \text{ C}$$

$$T_m = 20.75^\circ \text{ C}$$

TABLE A-5
(Continued)

RIVER TEMPERATURE TRAVERSES - POWER LINE CROSSING

River Mile: 350.5

Date: 10-16-63

Date: 10-16-63

Date: 10-16-63

Time: 1340

Time: 1410

Time: 1415

<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>
10	6	19.4	10	6	19.4	5	3	19.7
25	8	19.25	25	8	19.25	25	12	19.3
50	11	19.2	50	15	19.1	75	18	19.05
75	18	19.1	75	18	19.0	100	20	19.0
100	22	18.95	100	24	18.95	125	24	18.95
125	23	18.85	125	23	18.9	150	24	18.85
150	23	18.8	150	23	18.85	175	25	18.8
175	24	18.75	175	24	18.75	200	25	18.75
200	24	18.7	200	26	18.7	225	26	18.6
225	25	18.65	225	26	18.6	250	27	18.5
250	26	18.6	250	27	18.55	275	27	18.45
275	26	18.5	275	28	18.5	300	27	18.45
300	26	18.4	300	26	18.45	325	27	18.45
325	26	18.4	325	27	18.45	350	26	18.45
350	26	18.4	350	26	18.4	375	19	18.5
375	26	18.4	375	23	18.4	400	11	18.55
400	12	18.4	400	14	18.4	425	10	18.7
425	8	18.3	425	6	18.3	450	6	18.75
						475	5	18.85

$$A_t = 27,200 \text{ ft}^2$$

$$T_m = 18.66^\circ \text{ C}$$

$$A_t = 27,200 \text{ ft}^2$$

$$T_m = 18.66^\circ \text{ C}$$

$$A_t = 27,700 \text{ ft}^2$$

$$T_m = 18.71^\circ \text{ C}$$

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DECLASSIFIED

-60-

HW-80888

TABLE A-5
(Continued)

RIVER TEMPERATURE TRAVERSES - POWER LINE CROSSING

River Mile: 350.5

Date: 10-16-63

Date: 10-16-63

Date: 10-16-63

Time: 1445

Time: 1510

Time: 1530

<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>
5	3	19.7	5	3	19.75	5	3	19.6
25	12	19.5	25	11	19.3	25	10	19.3
75	18	19.2	50	12	19.2	50	12	19.25
100	20	19.1	75	17	19.1	75	18	19.2
125	24	19.05	100	20	19.05	100	22	19.1
150	24	18.95	125	24	18.95	125	23	19.0
175	25	18.9	150	24	18.9	150	24	19.0
200	26	18.85	175	25	18.85	175	25	18.95
225	26	18.8	200	26	18.75	200	25	18.9
250	27	18.7	225	26	18.65	225	26	18.8
275	27	18.6	250	27	18.6	250	26	18.7
300	28	18.55	275	28	18.55	275	27	18.7
325	27	18.5	300	27	18.55	300	26	18.6
350	25	18.55	325	28	18.5	325	26	18.6
375	19	18.55	350	27	18.5	350	25	18.6
400	11	18.55	375	22	18.5	375	22	18.6
425	6	18.55	400	21	18.55	400	16	18.6
450	4	18.55	425	11	18.55	425	16	18.6
475	4	18.55	450	6	18.55	450	6	18.6
			475	5	18.55	475	5	18.6

$$A_t = 27,700 \text{ ft}^2$$

$$A_t = 28,600 \text{ ft}^2$$

$$A_t = 28,600 \text{ ft}^2$$

$$T_m = 18.80^\circ \text{ C}$$

$$T_m = 18.70^\circ \text{ C}$$

$$T_m = 18.82^\circ \text{ C}$$

TABLE A-5
(Continued)

RIVER TEMPERATURE TRAVERSES - POWER LINE CROSSING

River Mile: 350.5

Date: 10-29-63

Date: 10-29-63

Date: 10-31-63

Time: 1250

Time: 1255

Time: 1235

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C
5	3	15.35	5	2	15.4	5	3	14.7
25	12	15.35	25	8	15.45	30	8	14.75
50	11	15.4	50	10	15.45	55	12	14.8
75	19	15.35	75	17	15.45	80	13	14.8
100	22	15.35	100	21	15.4	105	23	14.75
125	24	15.3	125	23	15.35	130	23	14.7
150	24	15.25	150	25	15.3	155	23	14.65
175	25	15.2	175	25	15.25	180	24	14.6
200	26	15.2	200	25	15.15	205	25	14.55
225	26	15.15	225	26	15.15	230	24	14.5
250	27	15.1	250	27	15.1	255	27	14.4
275	28	15.05	275	28	15.05	280	26	14.35
300	27	15.0	300	28	15.0	305	26	14.3
325	27	14.95	325	27	14.95	330	26	14.3
350	27	14.9	350	27	14.9	355	23	14.3
375	20	14.85	375	24	14.8	380	22	14.25
400	15	14.8	400	15	14.75	405	6	14.2
425	9	14.8	425	9	14.8	430	4	14.15
450	5	14.75	450	5	14.8	455	4	14.15
475	3	14.75	475	4	14.85	480	4	14.15
500	3	15.1	500	3	14.85			

$$A_t = 28,400 \text{ ft}^2$$

$$T_m = 15.12^\circ \text{ C}$$

$$A_t = 27,900 \text{ ft}^2$$

$$T_m = 15.08^\circ \text{ C}$$

$$A_t = 25,800 \text{ ft}^2$$

$$T_m = 14.48^\circ \text{ C}$$

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DECLASSIFIED

-62-

HW-80888

TABLE A-6

RIVER TEMPERATURE TRAVERSES - ABOVE 300 AREA

River Mile: 344.9

Date: 2-12-63

Date: 4-2-63

Date: 4-18-63

Time: 0730

Time: 1300

Time: 1110

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C
5	3	5.2	3	5	7.9	2	1	8.2
30	14	5.1	50	12	7.2	50	15	7.8
80	21	5.1	85	13	7.0	85	21	7.9
125	32	5.0	135	30	6.6	125	31	7.8
180	30	5.0	185	25	6.5	175	32	7.7
230	18	4.8	235	20	6.4	225	18	7.7
275	15	4.9	285	10	6.4	275	18	7.7
325	13	4.7	335	12	6.4	325	13	7.7
375	10	4.7	385	8	6.4	375	9	7.7
425	10	4.8	435	7	6.3	425	9	7.7
465	11	4.8	485	6	6.3	475	8	7.7
520	11	4.6	535	4	6.3	525	9	7.7
575	12	4.6	585	8	6.3	575	10	7.7
630	14	4.6	635	10	6.3	625	12	7.7
680	16	4.6	685	11	6.3	675	12	7.6
740	15	4.7	735	11	6.3	725	13	7.6
785	10	4.5	785	13	6.5	775	10	7.6
830	3	4.6	835	8	6.5	875	3	8.3
			865	3	8.0			

$$A_t = 38,000 \text{ ft}^2$$

$$A_t = 31,100 \text{ ft}^2$$

$$A_t = 36,700 \text{ ft}^2$$

$$T_m = 4.84^\circ \text{ C}$$

$$T_m = 6.52^\circ \text{ C}$$

$$T_m = 7.72^\circ \text{ C}$$

$$\text{PPTP Recorder} = 5.4^\circ \text{ C}$$

$$\text{PPTP Recorder} = 7.2^\circ \text{ C}$$

$$\text{PPTR Recorder} = 8.0^\circ \text{ C}$$

TABLE A-6
(Continued)

RIVER TEMPERATURE TRAVERSES - ABOVE 300 AREA

River Mile: 344.9

Date: 5-23-63

Time: 1100

Date: 6-24-63

Time: 1040

Date: 6-27-63

Time: 1100

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp.. °C
2	2	15.3	2	3	15.7	5	5	16.3
50	13	14.6	37	20	15.5	85	27	16.1
100	21	14.2	87	27	15.3	185	38	15.75
150	32	13.9	137	40	15.3	285	24	15.7
200	32	13.8	187	38	15.1	385	20	15.65
250	18	13.8	237	27	15.1	485	16	15.65
300	14	13.7	287	24	15.1	585	19	15.65
350	13	13.7	337	23	15.1	685	21	15.65
400	9	13.7	387	20	15.1	785	23	15.65
450	8	13.7	437	18	15.1	885	21	15.85
500	8	13.7	487	16	15.1	935	13	15.85
550	8	13.6	537	18	15.1	955	3	15.9
600	9	13.6	587	19	15.1			
650	13	13.7	637	19	15.1			
700	9	13.8	687	21	15.1			
750	11	13.8	737	21	15.0			
800	11	14.0	787	23	15.1			
840	3	15.3	837	22	15.1			
			887	21	15.1			
			937	19	15.2			
			987	13	15.2			
			1027	2	16.4			

$$A_t = 33,900 \text{ ft}^2$$

$$T_m = 13.91^\circ \text{ C}$$

$$\text{PRTT Recorder} = 14.5^\circ \text{ C}$$

$$A_t = 66,900 \text{ ft}^2$$

$$T_m = 15.16^\circ \text{ C}$$

$$\text{PRTT Recorder} = 16.2^\circ \text{ C}$$

$$A_t = 64,900 \text{ ft}^2$$

$$T_m = 15.77^\circ \text{ C}$$

$$\text{PRTT Recorder} = 16.8^\circ \text{ C}$$

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DECLASSIFIED -64-

HW-80888

TABLE A-6
(Continued)

RIVER TEMPERATURE TRAVERSES - ABOVE 300 AREA

River Mile: 344.9

Date: 7-18-63

Date: 8-30-63

Date: 10-10-63

Time: 1330

Time: 1500

Time: 1100

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C
5	5	17.9	25	9	21.5	5	3	17.6
75	23	17.6	50	16	21.4	50	16	17.7
175	38	17.3	75	19	21.3	80	19	17.8
275	20	17.3	100	22	21.2	130	28	17.8
375	15	17.25	125	27	21.2	180	33	17.7
475	14	17.25	150	32	21.0	230	25	17.7
575	15	17.2	175	33	21.0	280	19	17.7
675	17	17.2	200	33	21.0	330	17	17.6
775	20	17.2	225	26	20.9	380	12	17.6
875	17	17.25	250	19	20.9	430	10	17.6
975	10	17.5	275	19	20.9	480	9	17.6
1005	5	17.7	300	19	20.8	630	12	17.6
			325	17	20.8	880	5	17.5
			350	14	20.8	920	3	17.4
			375	12	20.8			
			400	10	20.8			
			425	10	20.8			
			450	10	20.8			
			475	9	20.7			
			500	9	20.7			
			525	10	20.7			
			550	10	20.7			
			575	11	20.7			
			600	11	20.7			
			625	12	20.8			
			650	13	20.8			
			675	13	20.8			
			700	13	20.8			
			725	14	20.8			
			750	14	20.9			
			775	13	20.9			
			800	11	20.9			
			825	9	20.9			
			850	7	21.0			
			875	5	21.2			
			900	4	21.5			

$$A_t = 55,400 \text{ ft}^2$$

$$T_m = 17.32^\circ \text{ C}$$

$$\text{PRTF Recorder} = 18.0^\circ \text{ C}$$

$$A_t = 40,000 \text{ ft}^2$$

$$T_m = 20.24^\circ \text{ C}$$

$$\text{PRTF Recorder} = 20.9^\circ \text{ C}$$

$$A_t = 37,900 \text{ ft}^2$$

$$T_m = 17.66^\circ \text{ C}$$

$$\text{PRTF Recorder} = 18.1^\circ \text{ C}$$

TABLE A-6
(Continued)

RIVER TEMPERATURE TRAVERSES - ABOVE 300 AREA

River Mile: 344.9

Date: 10-16-63

Date: 10-29-63

Date: 10-31-63

Time: 1615

Time: 1330

Time: 1340

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C
10	8	19.3	20	5	15.15	5	3	14.6
25	8	19.3	50	7	15.15	25	9	14.65
50	13	19.25	100	12	15.2	70	18	14.65
70	16	19.2	150	33	15.05	120	29	14.65
95	30	19.05	200	27	15.0	170	31	14.5
170	31	18.75	250	18	15.0	220	17	14.45
195	19	18.7	300	14	14.95	270	14	14.4
220	15	18.7	350	12	14.9	320	11	14.45
245	14	18.7	400	10	14.9	370	8	14.35
270	14	18.7	450	10	14.85	420	7	14.3
295	12	18.65	500	10	14.85	470	7	14.35
320	12	18.65	550	9	14.85	520	8	14.3
355	9	18.6	600	12	14.8	570	8	14.25
370	8	18.65	650	13	14.8	620	12	14.3
395	7	18.65	700	14	14.75	670	12	14.2
420	7	18.7	750	15	14.75	720	14	14.2
445	6	18.7	800	14	14.75	770	12	14.1
470	6	18.7	850	4	14.8	820	12	14.2
495	6	18.7				870	3	14.3
520	6	18.7						
545	7	18.7						
570	7	18.7						
595	8	18.7						
620	9	18.5						
670	11	18.65						
720	12	18.65						
770	14	18.6						
820	11	18.6						
870	10	18.7						
900	6	18.7						

$$A_t = 33,600 \text{ ft}^2$$

$$A_t = 34,800 \text{ ft}^2$$

$$A_t = 33,400 \text{ ft}^2$$

$$T_m = 18.77^\circ \text{ C}$$

$$T_m = 14.92^\circ \text{ C}$$

$$T_m = 14.4^\circ \text{ C}$$

$$\text{PPTR Recorder} = 18.8^\circ \text{ C}$$

$$\text{PPTR Recorder} = 15.0^\circ \text{ C}$$

$$\text{PPTR Recorder} = 14.5^\circ \text{ C}$$

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-66-

HW-80888

TABLE A-6
(Continued)

RIVER TEMPERATURE TRAVERSES - ABOVE 300 AREA

River Mile: 344.9

Date: 12-11-63

Date: 12-16-63

Time: 1400

Time: 0930

<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>
5	3	7.75	5	4	9.15
50	11	7.85	25	8	8.95
75	18	8.15	50	18	9.5
125	35	8.25	75	17	9.75
175	31	8.3	125	33	9.8
225	18	8.25	175	30	9.65
275	15	8.3	225	17	9.55
325	13	8.3	275	14	9.5
375	10	8.25	325	12	9.45
425	10	8.2	375	9	9.45
475	10	8.2	425	10	9.45
525	9	8.15	475	10	9.4
575	10	8.15	525	9	9.4
625	12	8.1	575	10	9.35
675	12	8.1	625	12	9.35
725	15	8.05	675	13	9.3
775	11	8.0	725	13	9.25
805	12	8.0	775	12	9.15
825	9	7.9	825	7	9.05

$$A_t = 36,500 \text{ ft}^2$$

$$A_t = 35,000 \text{ ft}^2$$

$$T_m = 8.18^\circ \text{ C}$$

$$T_m = 9.49^\circ \text{ C}$$

$$\text{PRTR Recorder} = 8.2^\circ \text{ C}$$

$$\text{PRTR Recorder} = 9.5^\circ \text{ C}$$

TABLE A-7

RIVER TEMPERATURE TRAVERSES - RICHLAND FERRY

River Mile: 340.9

Date: 2-12-63

Date: 4-18-63

Date: 5-9-63

Time: 0935

Time: 0915

Time: 1345

<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>
5	4	5.2	2	1	7.7	2	3	10.4
50	14	5.0	50	11	7.6	50	17	10.0
100	15	5.0	100	15	7.5	100	17	10.0
140	13	5.0	150	12	7.5	150	15	9.9
185	11	4.9	200	8	7.5	200	11	9.9
235	8	4.6	250	7	7.5	250	9	9.9
295	23	5.0	300	16	7.6	300	17	10.0
340	25	4.9	350	24	7.5	350	21	9.9
390	23	4.9	400	26	7.5	400	28	9.9
455	12	4.9	450	20	7.5	450	26	9.8
505	10	4.7	500	11	7.5	500	17	9.8
540	10	4.7	550	10	7.5	550	14	9.8
595	10	4.7	600	7	7.5	600	15	9.8
640	10	4.9	650	10	7.5	650	15	9.7
695	11	4.9	700	13	7.5	700	16	9.8
750	17	4.2	750	16	7.5	750	19	9.8
805	25	5.0	800	22	7.5	800	25	9.8
840	26	4.8	850	23	7.5	850	26	9.8
850	25	4.7	900	13	7.5	900	23	10.0
885	16	4.9	955	2	8.5	1000	3	10.5
915	6	4.4						

$$A_t = 41,400 \text{ ft}^2$$

$$T_m = 4.87^\circ \text{ C}$$

$$A_t = 35,300 \text{ ft}^2$$

$$T_m = 7.53^\circ \text{ C}$$

$$A_t = 52,000 \text{ ft}^2$$

$$T_m = 9.90^\circ \text{ C}$$

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TABLE A-7
(Continued)

RIVER TEMPERATURE TRAVERSES - RICHLAND FERRY

River Mile: 340.9

Date: 5-16-63

Date: 6-18-63

Date: 6-26-63

Time: 1045

Time: 1340

Time: 1340

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C
3	1	12.4	2	5	16.5	2	3	16.2
43	13	12.0	50	21	16.2	50	18	16.0
93	15	11.9	100	22	16.1	100	20	15.9
143	13	11.8	150	20	16.1	150	19	15.9
193	10	11.8	210	17	16.0	200	17	15.9
243	7	11.9	245	15	16.0	250	13	15.8
293	13	11.8	305	32	16.0	300	28	15.9
343	24	11.7	350	33	16.1	350	31	15.8
393	25	11.5	400	27	15.9	400	29	15.8
443	18	11.6	450	19	15.9	450	21	15.7
493	13	11.6	500	16	15.9	500	16	15.7
543	10	11.6	550	14	15.9	550	14	15.7
593	8	11.6	610	15	15.9	600	14	15.7
643	10	11.6	650	16	16.0	650	15	15.7
693	12	11.6	700	17	15.9	700	17	15.8
743	18	11.6	750	19	15.9	750	17	15.7
793	24	11.6	800	25	15.9	800	21	15.7
843	23	11.7	850	29	15.9	850	27	15.6
893	24	11.6	900	32	15.9	900	30	15.7
943	15	11.9	950	33	16.0	950	30	15.7
993	3	12.3	1000	31	16.0	1000	27	15.8
			1050	15	16.1	1050	10	15.9
			1100	1.5	16.8	1100	2	16.2

$$A_t = 44,100 \text{ ft}^2$$

$$T_m = 11.71^\circ \text{ C}$$

$$A_t = 70,300 \text{ ft}^2$$

$$T_m = 15.99^\circ \text{ C}$$

$$A_t = 66,400 \text{ ft}^2$$

$$T_m = 15.77^\circ \text{ C}$$

TABLE A-7
(Continued)

RIVER TEMPERATURE TRAVERSES - RICHLAND FERRY
River Mile: 340.9

Date: 8-30-63

Date: 8-30-63

Date: 10-10-63

Time: 1700

Time: 1800

Time:

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C
5	3	21.3	5	3	21.5	5	3	17.95
50	17	21.2	50	17	21.2	45	13	17.95
90	17	21.1	90	17	21.2	95	15	18.0
140	15	21.1	140	15	21.1	145	13	18.0
190	11	21.1	190	11	21.0	195	10	17.95
240	9	21.1	240	9	21.0	245	11	17.95
290	17	21.0	290	17	20.9	295	23	17.9
340	21	20.9	340	21	20.8	345	25	17.85
390	28	20.8	390	28	20.8	395	23	17.85
440	26	20.8	440	26	20.8	445	15	17.85
490	17	20.8	490	17	20.8	495	11	17.85
540	14	20.8	540	14	20.8	545	10	17.85
590	15	20.9	590	15	20.8	595	10	17.85
640	15	20.9	640	15	20.8	645	11	17.85
690	16	20.9	690	16	20.8	695	12	17.85
740	19	20.9	740	19	20.8	745	16	17.8
790	25	20.9	790	25	20.8	795	23	17.8
840	26	20.9	840	26	20.7	845	26	17.8
890	23	20.9	890	23	20.8	895	16	17.7
940	15	21.0	940	15	21.0	945	5	17.6
990	4	21.0	990	4	21.1			

$$A_t = 52,500 \text{ ft}^2$$

$$T_m = 20.93^\circ \text{ C}$$

$$A_t = 52,500 \text{ ft}^2$$

$$T_m = 20.91^\circ \text{ C}$$

$$A_t = 42,800 \text{ ft}^2$$

$$T_m = 17.86^\circ \text{ C}$$

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TABLE A-7
(Continued)

RIVER TEMPERATURE TRAVERSES - RICHLAND FERRY
River Mile 340.9 -

Date: 10-16-63

Date: 10-16-63

Date: 10-29-63

Time: 1715

Time: 1830

Time: 1445

<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds.</u>	<u>Depth feet</u>	<u>Temp. °C</u>
25	10	18.85	25	11	18.7	5	3	15.1
75	13	18.85	75	12	18.6	50	12	15.1
125	12	18.8	125	14	18.6	100	14	15.1
175	11	18.8	175	11	18.6	150	14	15.1
200	8	18.7	200	8	18.55	200	13	15.05
275	5	18.75	275	9	18.5	250	11	15.05
325	23	18.8	325	24	18.5	300	8	15.05
375	24	18.65	375	24	18.5	350	4	15.05
425	25	18.6	425	22	18.5	400	21	15.05
475	17	18.6	475	15	18.5	450	27	14.95
525	11	18.6	525	9	18.5	500	26	14.95
575	8	18.6	575	9	18.5	550	16	14.95
625	6	18.6	625	7	18.5	600	7	14.95
675	7	18.6	675	6	18.5	650	9	14.9
725	9	18.6	725	8	18.5	700	10	14.9
775	10	18.6	775	11	18.5	750	11	14.9
825	15	18.6	825	17	18.5	800	12	14.95
850	17	18.6	875	22	18.5	850	22	14.9
875	19	18.6	925	25	18.5	900	26	14.9
900	21	18.55	975	25	18.5	950	23	14.8
925	23	18.55	1025	22	18.4	1000	10	14.7
950	25	18.5				1020	3	14.8
975	25	18.5						
1025	24	18.6						

$$A_t = 43,300 \text{ ft}^2$$

$$T_m = 18.64^\circ \text{ C}$$

$$A_t = 43,700 \text{ ft}^2$$

$$T_m = 18.51^\circ \text{ C}$$

$$A_t = 44,300 \text{ ft}^2$$

$$T_m = 14.96^\circ \text{ C}$$

TABLE A-7
(Continued)

RIVER TEMPERATURE TRAVERSES - RICHLAND FERRY
River Mile: 340.9

Date: 10-29-63

Date: 12-16-63

Time: 1500

Time: 1020

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds.	Depth feet	Temp. °C
15	7	15.3	10	9	8.95
50	12	15.25	60	12	9.4
100	14	15.2	110	14	9.45
150	14	15.2	160	11	9.5
200	13	15.15	210	8	9.5
250	11	15.15	260	5	9.45
300	8	15.15	310	26	9.5
350	5	15.2	360	23	9.5
400	24	15.2	410	22	9.5
450	26	15.15	460	12	9.5
500	27	15.1	510	9	9.45
550	21	15.05	560	7.5	9.45
600	12	15.05	610	8	9.45
650	10	15.05	660	11	9.45
700	8	15.05	710	14	9.45
750	9	15.05	760	20	9.4
800	11	15.05	810	24	9.4
850	19	15.05	860	20	9.2
900	26	14.95	885	21	8.85
950	25	14.85	935	14	8.75
1020	3	14.85	955	5	8.5

$$A_t = 44,300 \text{ ft}^2$$

$$A_t = 41,000 \text{ ft}^2$$

$$T_m = 15.08^\circ \text{ C}$$

$$T_m = 9.37^\circ \text{ C}$$

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TABLE A-8

RIVER TEMPERATURE TRAVERSES - PASCO WATER PLANT

River Mile: 328.7

Date: 2-20-63

Date: 4-3-63

Date: 5-8-63

Time: 1620

Time: 1350

Time: 1350

<u>Distance from Plant Shore-yds</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds</u>	<u>Depth feet</u>	<u>Temp. °C</u>
5	7	5.8	3	2	7.4	3	3	10.6
50	30	5.5	50	22	7.4	50	23	10.5
95	39	5.4	95	38	7.0	95	38	9.9
145	46	5.4	145	40	6.6	145	43	10.0
190	48	5.2	195	48	6.5	195	48	9.6
235	60	5.4	245	56	6.4	245	53	9.4
290	53	5.1	295	55	6.4	300	54	9.6
350	38	5.1	345	55	6.4	350	44	9.6
390	31	5.2	395	41	6.7	395	38	9.6
415	5	5.8	445	32	6.5	445	35	9.6
			485	8	7.0	465	8	10.5

$$A_t = 50,800 \text{ ft}^2$$

$$T_m = 5.30^\circ \text{ C}$$

$$\begin{aligned} \text{Recorder} &= 5.6^\circ \text{ C} \\ \text{Temp.} \end{aligned}$$

$$A_t = 57,500 \text{ ft}^2$$

$$T_m = 6.71^\circ \text{ C}$$

$$\begin{aligned} \text{Recorder} &= 6.6^\circ \text{ C} \\ \text{Temp.} \end{aligned}$$

$$A_t = 61,800 \text{ ft}^2$$

$$T_m = 9.74^\circ \text{ C}$$

$$\begin{aligned} \text{Recorder} &= 10.0^\circ \text{ C} \\ \text{Temp.} \end{aligned}$$

TABLE A-8
(Continued)

RIVER TEMPERATURE TRAVERSES - PASCO WATER PLANT

River Mile: 328.7

Date: 5-16-63

Date: 6-13-63

Date: 6-18-63

Time: 1320

Time: 0950

Time: 1150

<u>Distance from Plant Shore-yds</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds</u>	<u>Depth feet</u>	<u>Temp. °C</u>	<u>Distance from Plant Shore-yds</u>	<u>Depth feet</u>	<u>Temp. °C</u>
5	4	13.0	5	3	15.3	2	2	16.2
50	23	13.0	50	25	15.5	50	28	16.2
95	40	12.5	100	37	15.3	100	45	16.1
145	42	12.2	150	45	15.0	150	50	16.0
195	47	12.3	200	49	14.9	200	50	16.0
245	50	12.1	250	55	14.9	250	56	15.9
295	52	12.1	300	55	14.8	300	56	15.9
345	42	12.1	350	48	14.7	350	52	15.9
395	38	12.1	400	38	14.9	408	42	15.7
445	33	12.3	450	38	15.1	450	38	15.8
495	26	12.5	500	10	15.4	500	20	16.2
515	20	12.5						

$$A_t = 58,300 \text{ ft}^2$$

$$T_m = 12.28^\circ \text{ C}$$

Recorder = 12.3° C
Temp.

$$A_t = 58,500 \text{ ft}^2$$

$$T_m = 14.97^\circ \text{ C}$$

Recorder = 14.7° C
Temp.

$$A_t = 64,300 \text{ ft}^2$$

$$T_m = 15.90^\circ \text{ C}$$

Recorder = 15.6° C
Temp.

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-74-

HW-80888

TABLE A-8
(Continued)

RIVER TEMPERATURE TRAVERSES - PASCO WATER PLANT

River Mile: 328.7

Date: 7-11-63

Date: 10-10-63

Date: 12-9-63

Time: 1100

Time: 1400

Time: 1400

Distance from Plant Shore-yds.	Depth feet	Temp. °C	Distance from Plant Shore-yds	Depth feet	Temp. °C	Distance from Plant Shore-yds	Depth feet	Temp. °C
5	8	16.6	5	5	18.4	10	10	8.35
100	37	16.3	50	25	18.4	25	23	8.45
200	49	16.05	105	38	18.45	50	24	8.4
300	55	15.95	155	42	18.45	75	25	8.4
400	38	15.9	205	50	18.5	95	38	8.9
500	38	16.0	265	56	18.45	120	48	8.9
535	10	16.25	305	55	18.45	145	52	8.9
			355	52	18.4	170	54	8.95
			405	38	18.35	195	52	9.0
			455	27	18.35	220	62	9.0
			505	7	18.35	245	66	9.0
						270	68	9.0
						295	58	9.0
						320	54	8.9
						345	47	8.9
						370	43	8.85
						395	40	8.8
						420	30	8.7
						445	22	8.5

$$A_t = 62,800 \text{ ft}^2$$

$$T_m = 16.08^\circ \text{ C}$$

Recorder = 16.4° C
Temp.

$$A_t = 57,400 \text{ ft}^2$$

$$T_m = 18.43^\circ \text{ C}$$

Recorder = 18.0° C
Temp.

$$A_t = 59,700 \text{ ft}^2$$

$$T_m = 13.88^\circ \text{ C}$$

Recorder = 8.6° C
Temp.

TABLE A-8
(Continued)

RIVER TEMPERATURE TRAVERSES - PASCO WATER PLANT
River Mile: 328.7

Date: 12-13-63

Time: 1330

<u>Distance from Plant Shore-yds</u>	<u>Depth feet</u>	<u>Temp. °C</u>
5	6	7.75
25	13	7.8
50	24	7.85
75	33	8.05
95	40	8.25
120	46	8.45
145	50	8.45
170	53	8.45
195	52	8.55
220	55	8.55
245	60	8.55
270	60	8.5
295	61	8.5
320	60	8.5
345	55	8.5
370	47	8.45
395	39	8.4
420	27	8.15
445	18	8.15
470	20	8.1

$$A_t = 59,800 \text{ ft}^2$$

$$T_m = 8.41^\circ \text{ C}$$

$$\text{Recorder} = 8.0^\circ \text{ C}$$

Temp.

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TABLE A-9HEAT LOSS IN 107-F RETENTION BASIN

(Temperatures in °C)

<u>Date</u>	<u>Reactor Outlet Temperature</u>	<u>Basin Outlet Temperature</u>	<u>Basin ΔT</u>	<u>Reactor ΔT</u>	<u>Basin - % Loss</u>
12-16-63	89.9	84	6	80.9	7 1/2
12-17	90.0	85	5	81.1	6
12-18	89.6	83 1/2	6	81.1	7 1/2
12-19	89.8	84 1/2	5 1/2	81.7	6 1/2
12-20	91.0	85	6	82.0	7 1/2
12-24	86.1	83	3	78.2	4
12-25	90.6	86 1/2	4	81.2	5
12-26	90.0	85 1/2	4 1/2	81.0	5 1/2
12-27	91.0	85 1/2	5 1/2	82.2	6 1/2
12-28	91.2	86	5	82.4	6
12-29	91.0	86 1/2	4 1/2	82.6	5 1/2
12-30	91.0	85	6	83.2	7
12-31	91.0	86 1/2	4 1/2	83.2	5 1/2

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TABLE A-10

F-AREA SEWER TEMPERATURES

<u>Date</u>	<u>Average Raw Water Temp. -°C</u>	<u>Weighted Average Sewer Temp. -°C</u>
8-29-63	20.0	24
8-30	20.3	24.5
8-31	20.7	25
9-1	20.6	24.5
9-2	20.1	24.5
9-3	20.3	25.5
9-4	20.0	25
9-5	20.7	26
9-6	20.7	25
9-7	21.0	25
9-8	21.2	25.5
9-13	20.9	26
9-14	20.7	25
9-15	20.5	24
9-16	20.0	24
9-17	20.2	24
9-18	20.3	24
9-19	19.7	23
9-20	19.9	25.5
9-21	20.3	23.5
9-25	20.4	24
9-26	20.6	24
9-27	20.8	24
9-30	21.0	24
10-1	20.6	24
10-2	20.0	24.5
10-3	20.0	25
10-4	19.9	22.5
10-5	19.8	22.5
10-6	20.4	22.5
10-7	20.3	23
10-11	19.2	24
10-12	19.1	21.5
10-15	18.9	21.5
10-16	18.8	22
10-17	18.5	22
10-18	18.3	22
10-19	18.8	22
10-20	18.8	22.5

TABLE A-10
(Continued)

F-AREA SEWER TEMPERATURES

<u>Date</u>	<u>Average Raw Water Temp.-°C</u>	<u>Weighted Average Sewer Temp.-°C</u>
10-21-63	18.5	22
10-22	17.8	21
10-23	17.5	20.5
10-24	17.3	20.5
10-25	17.0	19.5
10-26	16.5	19.5
10-27	17.0	19.5
10-28	16.5	19.5
10-29	15.8	19
10-30	15.5	19
10-31	15.1	18.5
11-1	15.1	18
11-2	15.0	17.5
11-3	15.3	17.5

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TABLE A-11

TEMPERATURES IN EFFLUENT BUBBLES AND FLUMES

<u>Outfall Location</u>	<u>Depth feet</u>	<u>Date</u>	<u>Time</u>	<u>Maximum Temp. -°C</u>	<u>Upstream Temp. -°C</u>	<u>Maximum Temp. @100 yds Downstream</u>
B	1	11/26/63	1230-	17.2	10.6	-
	4		1330	17.7	10.6	14.1
	8			16.3	10.6	-
	15			19.5	10.6	-
C	3	11/26/63	1330	19.5	-	14.4
	10			17.6	-	-
D	1	11/26	1430	28.1		
	10'			22.3	13.8	16.9
F	1	10/16/63	0800	26.1	18.0	-
	1	12/3/63	1330	23.8	10.8	-
	5			20.3	-	
H	1	12/3/63	1130	16.7	11.0	-
K (shore) (main bubble)	3	11/26/63	1400	17.9	11.3	12.9
	3			21.7		12.8
	15			23.7		

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TABLE A-12

EQUILIBRIUM DYE CONCENTRATIONS

10-29-63 1904-H River Mile 372.6

Reactor Flow Rate - 84,700 gpm
C₀ = 29 ppb

Average River Flow Rate - 75,000 cfs
C_m = 0.081 ppb

<u>Location</u>	<u>River Mile</u>	<u>L-mi.</u>	<u>R_{max}-units</u>	<u>C_{max}-ppb</u>	<u>$\frac{C_{max}}{C_m}$</u>	<u>$\frac{C_{max}}{C_0}$</u>
Above 181-F	369.3	3.3	3	0.048	0.56	0.0017
Hanford	361.0	11.6	2-1/2	0.040	0.49	0.0014
Ringold	354.4	18.2	1-1/2	0.024	0.30	0.0008
Power Line Crossing	350.5	22.1	1	0.016	0.20	0.0006
Above 300 Area	345.0	27.6	1-1/2	0.024	0.30	0.0008
Richland Ferry	340.9	31.7	1	0.016	0.20	0.0006

10-31-63 1904-F River Mile 369.0

Reactor Flow Rate - 89,700 gpm
C₀ = 21 ppb

Average River Flow Rate - 65,000 cfs
C_m = 0.065 ppb

50 yds. below	369.0	< 0.1	25-1/2	0.41	6.3	0.020
Hanford	361.0	8.0	6-1/2	0.105	1.6	0.0050
Ringold	354.4	14.6	3	0.048	0.75	0.0023
Power Line Crossing	350.5	18.5	2-1/2	0.040	0.6	0.0019
Above 300 Area	345.0	24.0	1-1/2	0.024	0.4	0.0012
Richland Ferry	340.9	28.1	1	0.016	0.25	0.0008

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FIGURE 1

Traverse Locations - Temperature Studies

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FIGURE 2

The Heat Budget

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FIGURE 3

Effects of Reactor Heat on River Temperatures

FIGURE 4

Temperature Increment - Priest Rapids to 300 Area, 1962-63

FIGURE 5

Temperature Cross-Sections at Hanford

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FIGURE 6
Temperature Cross-Sections Above 300 Area

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FIGURE 7

Temperature Cross-Sections at Pasco

G-102-711

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FIGURE 8

River Gauge Station - PRTR Intake

FIGURE 9

Resistance Thermometer Used for Temperature Traverses :

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KECCE RICHLAND, WASH.

FIGURE 10

Dye Measurement in River Samples with Fluorophotometer

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FIGURE 11

Dye Detection Equipment in Use in Boat

FIGURE 12
Portable Meteorological Station on Test

FIGURE 13
Recording Instruments at Portable Meteorological Station

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