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A PRELIMINARY EVALUATION OF THE THERMAL
EFFECTS OF THE BEN FRANKLIN DAM PROJECT
ON COLUMBIA RIVER TEMPERATURES
BELOW THE HANFORD PLANT

By

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November 1967

PACIFIC NORTHWEST LABORATORY
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R. T. Jaske

ABSTRACT

The planned construction of the Ben Franklin project below the Hanford production reactors poses the question of determining to what extent this project will affect the Columbia River temperatures. Using the plant operations record for the year 1966, and the weather record for the same period, a series of simulation runs was made to determine the effects of the dam on the temperature regime, and the extent to which density currents could be expected to develop. This information is to be used as background for the later evaluation of the modification of the existing radionuclide discharge. The digital simulation model COL HEAT, was used. This model has been previously developed under Atomic Energy Commission sponsorship for use in the regional evaluation of the effects of the Hanford plant. Operations with the model, using the data period indicated, showed that

- The existence of the proposed project would have nominal effect, tending towards a slight increase in downstream temperature for both the 385 and 400 ft pool elevations.
- Under some conditions, in critical temperature seasons (September), plant operations cause amplification of the temperature transients associated with stream regulations and plant load factor.
- The 385 ft pool can be considered as a channel flow case for estimating travel time. However, density currents could be expected to exist in the 400 ft pool for most of the summer months, causing decreased travel time and relatively adiabatic thermal conditions for the main flow system.

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R. T. Jaske

INTRODUCTION

As a consequence of renewed attention on the part of regulatory and conservation agencies towards stream temperature standards for the portion of the Columbia River affected by the Hanford plant, the Richland Operations Office directed the Pacific Northwest Laboratory to conduct a preliminary study to determine the effects of the Ben Franklin Dam on Columbia River temperatures, and to estimate radiation exposure from recreation at the reservoir.

By directive BNW-155, the study was to include:

1. Modeling the impoundment to determine changes in the downstream temperature regime;
2. Determining if the dam will cause unfavorable changes in the ability of the river to accommodate heat;
3. Determining if stratification will occur in the reservoir, and the resultant effects on the accumulation and concentration of radionuclides;
4. Estimating the physical deposition of radionuclides in the sediments and along the shore line;
5. Estimating the concentration of radionuclides in critical biota and estimating radiation exposure resulting from recreational activities at the reservoir.

By later correspondence, the scope of this request was modified to include only those features related to the thermal hydrodynamic regime; the radionuclide evaluations being deferred pending receipt of the thermal portion of the study.

This report summarizes the computation operations performed in response to the directive, and serves as ground work for the expected radionuclide study work which is planned to take place later.

Because of the limitation of time, a single year, 1966, is used as the basis for the conclusions of the study. However, the groundwork accomplished in this preliminary examination is of sufficient detail that additional cases could be handled with relative ease on short notice.

SUMMARY AND CONCLUSIONS

Based on the assumptions detailed in the discussion, and the weather and operations history of the Hanford plant for the year 1966, the following conclusions are appropriate:

1. The construction of the Ben Franklin project could be expected to have a slight, but measurable effect on the overall temperature regime of the Columbia River below the plant. The 385 ft. reservoir could be expected to increase the annual average temperature by 0.2 to 0.4 °C and decrease the expected maximum departure from the mean only slightly, resulting in the probability of a downstream regime similar to the present. The 400 ft reservoir could be expected to increase the annual average temperature by 0.4 to 0.6 °C and decrease the expected maximum departure from the mean a small amount, resulting in the probability of a downstream regime basically the same as present, but with the tendency to show slightly higher maximum temperatures.
2. The effects of flow from Priest Rapids Dam load factoring, and plant operating transients would tend to be amplified by both the proposed reservoir levels. While the specific effect for each level has a dynamic relationship to the actual conditions such that the relative effect alternates;

in general, the periods of highest heat stress, such as September and April, show amplifications of about 1 °C in the maximum daily averages as a result of the construction of either reservoir.

3. Although not specifically determined in this study, but as a result of other Atomic Energy Commission sponsored river temperature environmental research at Hanford, it could be expected that artificial temperature spikes resulting from transient operations of Priest Rapids project and the Hanford plant could be observed for a considerable distance downstream, perhaps as far as the outlet of the Bonneville project. However, the expected filling of the John Day reservoir in the spring of 1968 is expected to minimize the effects of severe transients emanating from Hanford operations or Priest Rapids load regulation below that project. The effects in the McNary reservoir could be expected to be noticeable during the critical temperature period of September.
4. No measurable effects from density current activity could be expected for the 385 ft pool. However, the 400 ft pool could be expected to develop density current activity regularly from April to November every year, during periods of rising air temperatures and clear skies with high solar radiation input. Under these conditions, the flow through most of the reservoir would be submerged and relatively adiabatic, resulting in little or no temperature differential through the lower project reach above the dam. It could be expected that this condition would decrease the theoretical transit time of water through the reservoir, and would create a condition where the extent of stratification would relate to the dilution of conservative and nonconservative contaminants in the plant effluent. Such conditions could potentially favor

recreational aspects of reservoir use by increasing surface temperatures desirable to bathers, and creating a surface layer with a relatively lower concentration of plant effluent. A detailed examination of data compiled from several years would be required to draw any meaningful conclusions.

5. The mean annual transport time of water through the reservoirs would be decreased measurably over the natural conditions. Based on statistical analysis of the 1966 history and the computed daily average temperatures below the reservoirs, the travel time for the 385 ft project would be increased approximately four days; for the 400 ft reservoir and increase of about nine days could be expected.

DISCUSSION

BACKGROUND

The proposed construction of a dam at Columbia River mile 348 has received extensive investigation regarding the effects of water levels on structural integrity, production capability and ground water contamination. (1-4 and contained references) None of these studies included an investigation of the reservoir itself below the Hanford operating areas, or an estimate of the thermal modification anticipated below the project as a result of the combined operations of the Hanford plant and the regulation of water flow imposed by the Priest Rapids project. Since long range planning for the release of project lands and the public access to the resulting reservoir are both closely related to expected joint operations upstream, the Richland Operations office authorized a preliminary investigation in order to determine a basis for this planning.

Prior to 1965, a basis for the prediction of the expected thermal hydrodynamic behavior of a river and reservoir system

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Page 4, the 5th conclusion should read as follows:

5. The mean annual transport time of water through the reservoirs would be increased measurably over the natural conditions. Based on statistical analysis of the 1966 history and the computed daily average temperatures below the reservoirs, the travel time for the 385 ft project would be increased approximately four days; for the 400 ft reservoir an increase of about nine days could be expected.

was not generally available. The development of the digital simulation system COL HEAT, under Atomic Energy Commission sponsorship for the purpose of evaluating the results of the annual Columbia River Cooling program, has been fully described⁽⁵⁾ and expanded in both scope and detail to permit the prediction of temperature conditions for both natural and advected heat additions from industrial activity, as well as the estimation of concentration for both conservative and nonconservative contaminants. This model provided an excellent basis for the examination of the proposed project for relatively little additional cost.

ASSUMPTIONS

In order to avoid classification of this report and to base the study on a record of observations which have been made available to the regulatory agencies and the public, the year 1966 was selected for this study. While the actual classified record of plant production for the year 1966 was used in the computer simulation runs, no classified output is generated by the program. The use of the public record eliminates the necessity of predicting future operations or requiring release of river temperature records prior to 1966 which are still considered sensitive to national defense by the Atomic Energy Commission.

An additional advantage of the period selected was the extended plant shutdown in 1966 during which it was possible to obtain excellent records of the extent of diurnality and the natural temperature rise through the plant reach. In effect, this study permits examination of the effects of the impoundment somewhat independently of the AEC operations, although this is in some degree an academic consideration.

The COL HEAT simulation system (Figure 1) requires the geometrical definition of the river dimensions into a series of sections nominally called reservoirs. (See Appendix A

FIGURE 1. Flow Diagram, Water Quality Simulation

for an outline of data submission requirements.) The actual computations are outlined in the flow sequence diagram accompanying the Appendix (Figure A-10). The existing limitation of the program is such that a maximum of 50 reservoir sections and 186 consecutive time periods can be handled within the core limits available in the Univac 1108 system. In addition, significant increases in processing time result from the density current check routine, somewhat in proportion to the number of reservoirs and the number of heat admission points to the system. It was thought desirable to retain as much fine structure of the diurnal character of the transients without the expense of going to hourly data; therefore, a time period of 6 hr was used as the basic incrementation time.

All input weather cards were prepared from daily average weather and river data using a statistical expansion process for those variables related to periodicity. For those variables which vary at random, such as cloud cover, wind speed, etc., the average for the 24 hr period was used as the average for the individual 6 hr period. This procedure leads to a masking out of a portion of the diurnal effect; however, absolute simulation of diurnality was beyond the scope of the study and, therefore, significant savings in clerical and computer time were possible. The diurnality of the input and output water temperature record was also statistically expanded in order to preserve this minor, but interesting effect. Since the conclusions of the study are based on a statistical treatment of the entire 365 day record, the individual variations introduced by this procedure were thought to be minor.

In addition, as indicated above, to minimize operating time, the plant record of heat additions to the river was introduced entirely at the location of the 100 K area outfall. This procedure can be rigorously defended in a classified

discussion only, but is mentioned for the purpose of clearly indicating any computational assumptions which reflect on the end result. Figure 2⁽⁶⁾ shows that the effect of introducing a temperature change in the river yields a relatively long lasting result from a spacial consideration; therefore, the extent of distortion involved in concentrating the heat additions to a single point is considered minor, or beyond the accuracy of the basic computation. A short section of the test computations simulating the natural river for the period before and after the start-up of plant operations in August, 1966, is shown in Figure 3. The deviations from ideal modeling are somewhat greater than for impounded sections of the river because of the sensitivity of the conduction coefficient to current and wind speed. However, for the reconnaissance purposes intended, the overall result appears acceptable.

River profiles used in the development of cross sections for the computations were derived from data⁽⁵⁾ supplied by the U.S. Corps of Engineers, Seattle District Office, and were identical to those used by other investigators.⁽⁴⁾ On the basis of these profiles, the following reservoir and river volumes were used for the cases detailed:

TABLE I. *Reservoir Volumes for Various Flows*

	<u>75,000 ft³/sec</u>	<u>150,000 ft³/sec</u>
Normal River	135,000 AF	178,000 AF
385 ft Dam	379,000 AF	428,000 AF
400 ft Dam	596,000 AF	672,000 AF

Contours were derived from U.S. Geological Survey maps of the Hanford plant area. The details of these reservoir sections remain in punch card form, useful for future cases or other detailed examination.

FIGURE 2. Loss or Gain of Imposed Artificial Temperature Differential--Real Time Basis

FIGURE 3. Natural River Test; Digital Simulation Model; Columbia River Mile 394 to 336.

COMPUTATIONS

The program for the actual computer runs included a series of stepwise sub-cases in which the reservoir volumes were adjusted for the river flow volumes under consideration as the seasons progressed. Figures 4, 5, 6, 7 and 8 summarize the results of the generated output. The diurnal effects have been eliminated in the computations in order to simplify the presentation. The results are self explanatory, but can be summarized to the extent that the following observations are pertinent.

1. Temperatures below the dam, measured at the Richland Ferry site, can be expected to be slightly higher for all but the highest flow conditions during which lower temperatures could be expected to prevail.
2. Temperature transients introduced by the combination of flow regulation and Hanford plant load factor are somewhat amplified by the presence of the reservoirs, especially when density currents could be expected to exist on the 400 ft reservoir during April through October. Figures 5 and 7 show periods of time when transients are especially noted. The Labor Day weekend combined with low river flow from Priest Rapids regulation produces a relatively large effect, even more pronounced than that currently experienced without the dam. These spike transients could be expected to be measurable for considerable distances downstream, and would be of special significance if downstream water temperature standards were used as a basis for regulation of integrated heat input to the Columbia River.
3. Each of the Figures 4 through 8, has indications of the extent of increased travel time through the impounded areas. Since the flows change considerably during a

FIGURE 4. Thermal Effect of Ben Franklin Dam Superimposed on 1966 Plant Operations Record; January 5, to February 10, 1966.

FIGURE 5. Thermal Effect of Ben Franklin Dam Superimposed on 1966 Plant Operations Record; March 26, to April 30, 1966.

FIGURE 6. Thermal Effect of Ben Franklin Dam Superimposed on 1966 Plant Operations Record; June 16, to July 22, 1966.

FIGURE 7. Thermal Effect of Ben Franklin Dam Superimposed on 1966 Plant Operations Record; August 17, to September 20, 1966.

FIGURE 8. Thermal Effect of Ben Franklin Dam Superimposed on 1966 Plant Operations Record; September 20, to October 21, 1966.

transit through the reservoir, it is difficult to illustrate a travel time except on an average basis over an extended time period.

In order to summarize the results of the computation in a form which is readily used, all output temperature computations for the entire year were key punched and analyzed on the same least squares fitted functional model using the LEARN routine developed at Battelle-Northwest.⁽⁸⁾ Illustrations of the direct output from the plotting routine of this program are shown in Figures 9, 10 and 11. These figures show the computed output for the two different reservoir elevations and the actual record of 1966 measurements at the Richland Ferry site.

TABLE II. *Comparative Results of Predictive Calculations*

Functions fitted to the general model

$$T = A + B \sin(Cd + D),$$

where

T = Computed Temp for Day, (d), °C
 A = Annual Average of Model, °C
 B = Computed Extremes, °C
 C = Daily Functional Movement, RAD/DA
 d = Number of days under Consideration
 D = Displacement of $T_{\max}$ from
 Arbitrary Zero (D = 0.0173 x Days
 Displaced)

Richland Actual, 1966	$T = 12.04 + 6.24 \sin(0.0163d + 4.04)$
385 ft Dam	$T = 12.34 + 5.95 \sin(0.0163d + 3.97)$
400 ft Dam	$T = 12.57 + 5.86 \sin(0.0163d + 3.91)$

The values for the individual terms described above, summarize the expected trends from the construction of the reservoirs, and are quite typical of the result of other projects upstream, with the exception that in the case of the other upstream dams

FIGURE 9. Least Squares Model Fit; $T = 12.04 + 6.24 \sin(0.0163d + 4.04)$; Richland (CY 1966 Data).

FIGURE 10. Least Squares Model Fit; $T = 12.34 + 5.95 \sin(0.0163d + 3.97)$; Ben Franklin (CY 1966 Data) 385 ft Elevation.

FIGURE 11. Least Squares Model Fit; $T = 12.57 + 5.86 \sin(0.0163d + 3.91)$; Ben Franklin (CY 1966 Data) 400 ft Elevation.

cited in Reference 7, over a long period of time, the net effect was a slight cooling trend. The heating trend for the Ben Franklin project is related to the combination of flow regulation and reactor plant load factoring. Table III illustrates values for other Columbia River projects subjected to the same analysis procedure for calendar year, 1966.

TABLE III. Actual Results for Selected Points for CY 1966

Richland	$T = 12.04 + 6.24 \sin(0.0163d + 4.04)$
Priest Rapids	$T = 10.65 + 6.63 \sin(0.0166d + 3.95)$
Rocky Reach	$T = 10.44 + 6.53 \sin(0.0163d + 3.80)$
Grand Coulee	$T = 10.40 + 6.49 \sin(0.0165d + 3.67)$
International Border*	$T = 9.29 + 6.26 \sin(0.0165d + 4.16)$
Bonneville Dam	$T = 11.93 + 7.20 \sin(0.0164d + 4.17)$
McNary Dam	$T = 12.21 + 7.16 \sin(0.0165d + 4.09)$

** The anomalous value for the International Border for CY 1966 needs further investigation and explanation. Part of the data used are of doubtful accuracy.*

A complete report of the analysis of the temperature trends for all available Columbia River dam projects temperature data is being prepared. The values in Table III show the tendency for large impoundments to delay the timing of the natural temperature peak; while the lower, less significant reservoirs act more like the natural river and produce a tendency to return the peak to the more normal time period. At Bonneville, the arrival of peak temperature for 1966, coincides with the timing for the International Border for the 1966 season. The departures from the mean also show the tendency to return to the larger values associated with natural streams.

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APPENDIX A

DIGITAL SIMULATION SYSTEM LOGIC DIAGRAMS

(Figure A-1 Through A-9)

AND

WEATHER CONDITIONS

FOR CRITICAL TEMPERATURE MONTHS, 1966

(Figure A-10)

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FIGURE A-1. Digital Simulation System Logic Diagram

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FIGURE A-3. Digital Simulation System Logic Diagram

FIGURE A-4. Digital Simulation System Logic Diagram

FIGURE A-5. Digital Simulation System Logic Diagram

FIGURE A-6. Digital Simulation System Logic Diagram

FIGURE A-7. Digital Simulation System Logic Diagram

FIGURE A-8. Digital Simulation System Logic Diagram

FIGURE A-9. Digital Simulation System Logic Diagram

FIGURE A-10. Weather Conditions for Critical Temperature Months-- 1966

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