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J. F. Honstead, R. T. Jaske

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1967 COLUMBIA RIVER TEMPERATURE ANALYSIS

J. F. Honstead, R. T. Jaske

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1967 COLUMBIA RIVER
TEMPERATURE ANALYSIS

J. F. Honstead, R. T. Jaske

Introduction

The Washington State Pollution Control Commission water quality standards for interstate and coastal waters were adopted in December of 1967. The temperature standard was identified as the most restrictive of these for the Hanford operations. This report compares the temperatures and thermal additions to the river from Hanford during 1967 with the limits specified by the Washington State Pollution Commission.

Two factors complicate the problem of evaluating Hanford operations that alter the temperatures in the river: (1) natural heating or cooling imposes temperature changes between the plant and downstream measuring locations, (2) wide flow fluctuations on a daily and weekly basis resulting from upstream dam regulation are reflected in similar temperature fluctuations. Using 1967 data this report identifies the Hanford temperature contribution at both 100-F and Richland. The effects of daily and weekly averaging as well as measurement location are presented.

Washington State Pollution Control Regulations

In the regulations adopted December 4, 1967, the State of Washington Water Pollution Control Commission established classifications for water quality and pertinent standards for each classification. (1) The Columbia River from the Washington-Oregon border to Grand Coulee Dam is classified Class A with the following special temperature conditions applicable from the Oregon border to Priest Rapids Dam:

"No measureable increases shall be permitted within the waters designated which result in water temperatures exceeding 68 °F nor shall the cumulative total of all such increases arising from nonnatural causes be permitted in excess of $t = 110 / (T - 15)$; for purposes hereof "t" represents the permissive increase and "T" represents the resulting water temperature."

The effect of this standard on the permitted temperature increase in this reach of the Columbia River is illustrated on the next page. The permitted temperature increase is greatest at low river temperatures and decreases to slightly more than 1.0 at 20 °C. While the standard is quoted in terms of degrees Fahrenheit this chart is constructed in terms of degrees Centigrade for consistency with most river temperature data. The temperature increase formula for temperatures measured in degrees Centigrade would be

$$t = \frac{33.95}{T + 9.44} .$$

(1) Water Pollution Control Commission, State of Washington, A Regulation Relating to Water Quality Standards for Interstate and Coastal Waters of the State of Washington and a Plan for Implementation and Enforcement of such Standards, December 4, 1967.

FIGURE 1. Washington State Water Quality Standards of 1967.

The Computer Model

The COL HEAT simulation model has been fully described in previous reports and publications⁽¹⁾ and has been extensively used both on the Columbia River and other tributary systems for the operational analysis of the effects of dams and industrial development. Using the assumption of complete mixing within a given limited reach, the model sets up a series of flow increments which effectively describe the transport of water or radionuclides in a manner which closely resembles the actual channel flow.

In addition to the basic accounting for water transport, the model includes analysis for the occurrence of density currents. Such currents occur in a turbulent stream only when reinforced by large surface heat inputs in impounded reaches. This feature is indispensable to the proper evaluation of large regional systems such as occur in the Wanapum Dam reach immediately above the Hanford plant.

The following data are required for operation of the temperature version of the model:

Water temperature at the inlet end (time increment, hours or larger)

Flow discharge at the lower or outlet end (side streams if significant)

Water temperature at the outlet (optional for statistical comparison)

Meteorological parameters (wind velocity, mean air temperature, dew point, sky cover in tenths, short wave radiation--all in the same time incrementation as the temperature data)

River or reservoir dimensions reduced to equivalent non-parallel trapezoidal cross sections

Heat input (megawatts per time incrementation)

Computations can be made for any incrementation time for which data are available down to one hour. All data rate must be in equivalent incrementation, although downward averaging is readily accomplished in sub-routines.

(1) Jaske, R. T. and J. L. Spurgeon, "Thermal Digital Simulation of Waste Heat Discharges," BNWL-SA-1631, February 19, 1968.

FIGURE 2. "COL HEAT" Computer Simulation Model of the Columbia River.

Evaluation of Computed River Temperatures

Measured river temperatures are assumed to represent the bulk river temperature at a location at the time of measurement. The uncertainty in such measurements includes those arising from the technician's ability to read the measuring instruments and from the instrument's ability to report the bulk river temperature. The combined standard deviation for Priest Rapids temperature measurements is estimated to be $\pm 0.15^{\circ}\text{C}$. In the case of Richland temperature measurements the combined standard deviation is estimated to be $\pm 0.21^{\circ}\text{C}$. In calculating the temperature difference between Priest Rapids and Richland the overall uncertainty has an estimated standard deviation of $\pm 0.26^{\circ}\text{C}$. As is evident from the computed and observed temperature data illustrated for two representative months of 1967 (Figure 3) a small additional variance may be introduced when computed values are used. The absolute value of the difference between computed and measured temperatures for 1967 were analyzed and it was found that this difference was $< 0.35^{\circ}\text{C}$ 95% of the time. Thus, the computer program estimates the river temperature with an uncertainty only slightly larger than that present in the measured data and is therefore considered adequately representative for the analyses in this report. Other data needed for computing river temperatures are also shown in Figure 3.

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FIGURE 3. Hanford Operations Impact on the Columbia River - March-April 1967.

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1967 Columbia River Flows

The daily average flow of the Columbia River measured at Priest Rapids dam during 1967 is shown in Figure 4. The weekly fluctuation of flow resulting from dam regulation is clearly evident in this plot. The flow during 1967 varied from a high of 480,000 cu ft/sec on June 28 to a low of 38,000 cu ft/sec on May 7.

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FIGURE 4. 1967 Columbia River Flow (Daily Averages).

Daily Temperatures - Richland and 100-F

Figures 5 and 6 show the daily average temperatures of the Columbia River during 1967 at Priest Rapids, 100-F Area, and Richland. The 100-F and Richland temperatures are computed values. Also shown in these figures are the actual temperature differences between Priest Rapids and 100-F and between Priest Rapids and Richland compared to the allowed ΔT from the Washington State Pollution Commission formula. The weekly low water periods resulting from Priest Rapids dam regulation are clearly evident in the regular temperature peaks. On those days where the actual ΔT exceeds the Pollution Commission formula the Hanford plant would have been operating out of conformity with the standards if they had been in effect during 1967 and if the formula were implement on the basis of daily averages. At Richland there were 82 days (22.5% of the year) for which the actual ΔT would have exceeded the now adopted Pollution Commission standards. At 100-F the actual ΔT would have exceeded the Pollution Commission standards on 57 days (15.6% of the year). In the data presented in Figures 5 and 6 the points represent daily temperature averages at the locations shown.

FIGURE 5. Columbia River Temperatures, Daily Average °C, 1967.

FIGURE 6. Columbia River Temperatures, Daily Average °C, 1967.

7-Day Rolling Mean Temperatures - Richland and 100-F

A possible means of evaluating river temperatures that will eliminate day-to-day fluctuations resulting from short-term flow changes is to provide "rolling-mean-temperatures." Such rolling-mean temperatures calculated on a 7-day basis are shown in Figures 6 and 7. The 7-day rolling-mean temperature was selected to be sure that each mean temperature included weekends. Each point shown in these figures represents the average of the previous 7-day average temperatures. The effect of smoothing out weekend fluctuations is evident from these charts. The actual temperature differences between Richland and Priest Rapids and between 100-F and Priest Rapids derived from rolling-mean temperatures are plotted in the two lower curves. The allowed temperature differences from the WSPCC formula is also shown for each location. Using the rolling-mean concept the actual temperature difference exceeds the allowable on several occasions. At Richland the actual ΔT exceeds the allowable ΔT on 70 days (19.2% of the year). At 100-F the actual ΔT exceeds the allowable ΔT on 40 days (11.0% of the year).

FIGURE 7. Columbia River Temperature Rolling Mean °C, 1967.

FIGURE 8. Columbia River Temperature Rolling Mean $^{\circ}\text{C}$, 1967.

Weekly-Temperatures, Richland and 100-F

The average weekly temperatures for Richland and 100-F are shown as bar charts in Figures 9 and 10. The weekly averages were prepared for periods beginning at midnight Friday and extending through the following Friday. In the lower half of Figures 9 and 10 are shown comparisons of the actual ΔT 's and the ΔT allowed by the Washington State Pollution Control Commission (WSPCC) formula for both Richland and 100-F temperatures. When the actual ΔT values exceed the WSPCC allowable ΔT values, plant operation would have failed to meet State regulations, if such regulations had been adopted prior to 1967. In the case of Richland, the actual weekly average exceeded the standards on 11 weeks, or 21.2% of the time. At 100-F the actual ΔT exceeded the allowable on 7 weeks, or 13.5% of the time. The ΔT 's were calculated from weekly average temperatures at Priest Rapids and the respective downstream locations.

FIGURE 9. Columbia River Temperature Weekly Average, 1967.

FIGURE 10. Columbia River Temperature Weekly Average, 1967.

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Interpretation of Data

Evaluation of various river temperature averages and different measuring locations must include more than simply the number of days or weeks during which the actual temperature increase exceeded the WSPCC standards. In addition to the frequency of excess ΔT , it is necessary to determine the extent to which the actual temperature difference exceeds the standards. For this purpose the data analyzed for 1967 were examined to determine the MW-days production that would have been lost if the plant had operated entirely within the allowable ΔT . In the case of daily averaging it was found that with a measuring station at Richland 353,000 MW-days would have been lost. This represents fractional reductions for 82 days, during which the greatest reduction required would have been 15,300 MW on August 17. If the measuring station had been located at 100-F it would have been necessary to reduce production 195,000 MW-days to remain within the WSPCC standards. This represents fractional power reduction during 57 days, with a maximum of 10,100 MW on April 2. If weekly temperature averaging had been practiced during 1967 and the measuring station located at Richland, it would have been necessary to reduce production for 260,000 MW-days to remain within State regulations. This would represent fractional power reduction during 11 weeks with a maximum of 55,100 MW-days during the week ending August 18. With weekly temperature averages and a measuring location at 100-F the production loss necessary to remain within State regulations would have amounted to 107,000 MW-days. This would have represented a fractional reduction of power during 7 weeks with a maximum of 27,600 MW-days during the week ending August 18.

If the 7-day rolling-mean averaging method had been used during 1967 and if the measuring station were located at Richland, the production loss necessary to operate within the State regulations would have been 233,000 MW-days. This would have represented fractional reduction of power levels during 70 days with a maximum of 9500 MW on August 21. If the 7-day rolling-mean averaging method were applied to temperature measurements at 100-F during 1967 it would have been necessary to reduce production by 96,700 MW-days to remain within the proposed Pollution Control standards. This would have represented fractional power reductions during 40 days with a maximum of 6600 MW on August 20.

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SUMMARY TABLE

	Daily Average	Weekly Average	7-Day Rolling-Mean
	Richland		
Amount of Time with Excess ΔT	82 Days (22.5%)	11 Weeks (21.2%)	70 Days (19.2%)
Excess Production MW-Days	353,000	260,000	233,000
	100-F		
Amount of Time with Excess ΔT	57 Days (15.6%)	7 Weeks (13.5%)	40 Days (11.0%)
Excess Production MW-Days	195,000	107,000	96,700

If 1967 is used as a basis for judgement it becomes evident that the greatest advantage to Hanford is accrued if measurements are made at 100-F and a 7-day rolling-mean or weekly average is applied. It is clear that the impact on Hanford production if the plant operates within the State temperature standards is quite sensitive to both measurement location and means of averaging.

In each of the cases it was found that a rather short period of time contributed heavily toward this total production loss. For example, a 7-day period in August contributed 23% of the total MW-day excess power in the case of daily averages for 100-F temperatures, and 36% of the total in the case of the 7-day rolling-mean at 100-F.

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Conclusions

Based on the foregoing analysis of 1967 river temperatures and flows and Hanford operations data the following conclusions may be drawn:

1. The evaluation of river temperature data to establish conformance with State regulations is sensitive to the measurement location chosen and temperature averaging method.
2. Temperatures measured at 100-F are more advantageous to Hanford than those measured at Richland.
3. Weekly temperature averages or 7-day rolling-mean temperatures are less restrictive to Hanford operation than are daily averages.
4. This study indicates the usefulness of analyses of this type for guiding decisions on future reactor operations and river regulations in order that the standards are always met.
5. Future evaluations for guiding plant and river operation schedules should be based not on the 1967 data, as were used here, but rather on expected normal, warm and cool river temperatures and reactor operation forecast for the future.

Acknowledgement

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