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PROGRESS REPORT ON COLUMBIA RIVER STUDIES
July - December 1969

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PROGRESS REPORT ON COLUMBIA RIVER STUDIES
July - December 1969

by

R. F. Foster

J. F. Honstead

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ENVIRONMENTAL AND LIFE SCIENCES DIVISION

Pacific Northwest Laboratory
Battelle Memorial Institute
Richland, Washington

January 13, 1970

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PROGRESS REPORT ON COLUMBIA RIVER STUDIES

July - December 1969

P R E F A C E

The studies reported in this document are a continuation of ones formerly included in the O2 Research and Development Program under Mission 14 - Columbia River Studies. The funding for Fiscal Year 1970 is being provided via Douglas United Nuclear, Inc. rather than directly from AEC to Battelle-Northwest.

As in past years, two sub-programs are included in this report. The "Mechanisms of Environmental Exposure" studies constitute an invaluable complementary program to the more routine environmental surveillance program because they provide new or improved knowledge of how radionuclides in the environment reach people and contribute to dose. From this information, rational modifications are made of the assumptions used of the intake of foods of special interest, the time spent by people on or near the river, and other parameters necessary for dose calculations.

The "Effects of Reactor Effluent on the Quality of Columbia River Water" has been concerned dominantly with the flux of heat in the river and, to a lesser extent, with the dispersion and transport of toxic chemicals, radionuclides, and dissolved gases. Through a combination of field measurement and mathematical modeling, a capability has been developed and is being refined for predicting the effects downstream of a variety of acute and chronic releases. This work includes conditions both in the immediate vicinity of the outfall and at long distances and, also, the interaction of dams and flow regulations.

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PROJECT TITLE Mechanisms of Environmental Exposure
PRINCIPAL INVESTIGATOR J. F. Honstead, Radiological Physics Section
REPORTING PERIOD July 1, 1969 through December 31, 1969

	<u>FY-1969</u> <u>BUDGET</u>	<u>FY-1969</u> <u>ACTUAL</u>	<u>FY-1970</u> <u>BUDGET</u>	<u>JULY-DEC '69</u> <u>EXPERIENCE</u>	<u>FY-1970</u> <u>ESTIMATE</u>
COSTS (THOUSANDS)	75	75	100	46.1	100
SCIENTIFIC MANPOWER (MAN YEARS)	1.0	1.0	1.0	--	1.0

I. SCOPE AND OBJECTIVES

Members of the population living in the vicinity of the Hanford Plant may become exposed to radiation resulting from Plant operation through a variety of mechanisms, or pathways. This may include external exposure to radiation from radioactivity introduced into the environs with low-level radioactive effluents and radiation exposure from internally deposited radionuclides ingested with various food sources. This project investigates the pathways of exposure of members of the public to permit quantitative evaluation of the magnitude of exposure from various pathways and their summation. The study, for example, will try to evaluate the effect of effluents released to the Columbia River and the atmosphere. The resulting estimates of exposure require evaluation of how the members of the public utilize various parts of their environment, such as the Columbia River, for recreation, as a source of sanitary water, and for food production.

These investigations will provide improved estimates of exposure levels experienced by local residents and strengthen confidence in effluent control provisions. The resulting dose estimates will contain fewer uncertainties with regard to the validity of the population sample examined and the pathway parameters used to compute human exposure.

II. PRIOR WORK

1. A 12-month study designed to permit a statistical evaluation of fishing pressure on the Columbia River below the Hanford Project was completed in early 1967. One Washington State Game Department biologist was occupied

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full time with interviews of over 2,100 fishermen. The results of the interviews were coded, key-punched and entered into a computer program in mid-1967 for statistical extrapolation of the data into characterization of the entire population of local fishermen.

2. Special studies were conducted to investigate the uptake and retention of radionuclides in certain locally-produced foodstuffs. Studies of fish consumption, seafood consumption and other foods were conducted and reported. The results provided estimates of some of the parameters required for calculating exposure from the consumption of these foods. The experiments included whole-body counting measurements and excreta analyses to establish uptake and retention data.

3. Dietary and whole-body counting data were obtained from local residents including segments of the local population of particular interest. Hanford Plant employees measured in the Hanford whole-body counting facility as part of a routine examination provided most of the adult data. Special dietary and whole-body counting surveys of the local elementary schools gave similar data for the children population. In addition, special whole-body counting surveys were performed among special population groups, such as local fishermen. A mobile whole-body counter in a van-type truck was used for these surveys.

4. Data obtained in special population surveys were entered on magnetic tape files for use in a digital computer. Programs were prepared to permit correlation of dietary and whole-body counting data and to permit individual dose calculations. The computer was used to prepare tabulations and averages for publication of these results.

III. PROGRESS DURING REPORTING PERIOD

1. A study was conducted at the high school and one junior high school in Richland to obtain dietary and whole-body counting data for the teenage population. A total of 428 sets of data were obtained in this survey. In addition, the students were questioned concerning their use of the Columbia River for swimming and other recreation. It was found that this group estimated their exposure time in and on the Columbia River to average 115 hours per year. This is somewhat higher than had been previously estimated. Individuals among the students questioned estimated exposure times as great as 1,000 hours in some cases. These estimates are probably exaggerated, but 38 teenagers estimated more than 300 hours per year. The 1967 annual dose estimated for the typical Richland resident included a 2 mR external exposure from time spent along the river. These 38 young people who estimated exposure times in excess of 300 hours would have received exposures ranging from 10 to 70 mR as a result of this experience. A reasonable extrapolation of these data to the total Richland population results in an exposure increment not widely different from the 2 mR used in the 1967 environmental dose summation.

2. Students in high school and junior high school home economics classes cooperated in performing a survey of the size of servings taken by members

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of their families during normal meals. The students were provided with "handbooks" containing photographs of weighed servings of various foods to assist in the survey. Some of the dietary data obtained in the course of population surveys is reported in "servings" or in "meals per week," which must be converted to grams. This study of serving sizes was designed to provide the needed weight conversions. A total of 385 people were included in the survey conducted by students. The results are tabulated by sex and weight of the person surveyed and will be used in computations of dose.

3. A special survey was conducted of the body burdens and diets of fishermen located at two popular fishing spots on the Columbia River. The survey was made during a period of several days, including the Labor Day weekend. Recent poor fishing success along the Columbia reduced the fishing pressure, and only 40 fishermen were surveyed. None were found to have body burdens of radionuclides from Hanford in excess of those normally measured in Tri-Cities residents. These results will be combined with previous surveys of fishermen for analysis.

4. A month-long special study was conducted of the diets and body burdens of members of farm families living in the rural suburban Riverview district near Pasco. This area is furnished irrigation water directly from the Columbia River, providing numerous exposure pathways initiated through irrigated gardens and pastures. Seven 4-H clubs in the area assisted with the survey by contacting families and scheduling their visits to the mobile whole-body counter. The whole-body counter truck was parked for this purpose adjacent to a fire station near the center of the district. A total of 344 people, ranging from 2 years to more than 80 years of age, was included in the survey. The survey provided diet estimates and also direct river exposure time estimates as well as whole-body counting data. None of those examined showed unusually high body burdens of radionuclides. A total of 23 people was found to exhibit ^{65}Zn body burdens in excess of 10 nCi, with a maximum detected of 23 nCi. The diet information obtained from this population group will be used to compute individual dose estimates to permit evaluation of probable dose distributions among the group.

IV. EVALUATION OF EFFORT

This study is beginning to provide data that are extremely important for evaluating the significance of various environmental pathways. It will soon be possible to identify the dose contribution from various pathways and radionuclides for a variety of selected population groups and age groups. The whole-body counting data provides an independent evaluation of the validity of diet models used in environmental dose estimates. The results of this study should make a fundamental contribution to environmental evaluation techniques in a variety of situations, as well as providing confirmation of the dietary and exposure bases for Hanford environmental dose estimates.

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V. FUTURE WORK

1. Plans have been initiated to conduct a dietary and whole-body counting survey among residents of a seafood-production area along the Pacific coast. Tentatively, it is proposed to conduct this study in Tillamook County, Oregon, where sizable quantities of oysters, crab meat, and shrimp are produced commercially. The area has been included in the Oregon State Board of Health's radiological surveillance program for a number of years, providing a good background of analytical data. The survey would be conducted in cooperation with the Oregon State Board of Health. The survey will probably include students in a local school and the families of employees of the local seafood packing companies.
2. It would be desirable to extend the survey of coastal communities to include an area adjacent to Willapa Bay, Washington. This region produces additional kinds of seafood and is located closer to the mouth of the Columbia River.
3. The 15,000 entries in the environmental data file provide a unique opportunity to study the components of environmental dose. It is planned to devise computational programs to examine these data from the viewpoint of environmental dose in greater depth than has heretofore been possible.
4. An opportunity is available to examine downstream communities along the Columbia River using already developed techniques and equipment. These communities can be chosen to permit examination of selected exposure pathways without the confusion arising from a multiplicity of pathways.

VI. TOPICAL REPORTS ISSUED

1. Honstead, J. F., "Mechanisms of Transfer of Radionuclides to Man in the Vicinity of a Nuclear Facility," Environmental Contamination by Radioactive Materials, IAEA, Vienna, Austria, 1969.
2. Honstead, J. F., Recreational Use of the Columbia River - Evaluation of Environmental Exposure, BNWL-CC-2299, October, 1969.

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PROJECT TITLE Effect of Reactor Effluent on the Quality of
 Columbia River Water

PRINCIPAL INVESTIGATOR R. T. Jaske, Water Resources Systems Section

REPORTING PERIOD July 1, 1969 through December 31, 1969

	<u>FY-1969</u> <u>BUDGET</u>	<u>FY-1969</u> <u>ACTUAL</u>	<u>FY-1970</u> <u>BUDGET</u>	<u>JULY-DEC '69</u> <u>EXPERIENCE</u>	<u>FY-1970</u> <u>ESTIMATE</u>
COSTS (THOUSANDS)	75	75	100	54	100
SCIENTIFIC MANPOWER (MAN YEARS)	1.5	1.5	2	--	2

I. SCOPE AND OBJECTIVES

This study is concerned with defining the extent to which Hanford reactor effluents alter the physical and chemical characteristics of the Columbia River. Emphasis has been placed on the dispersion of the effluents in the river, the heat load placed on the river by the reactors, and the persistence of heat and chemicals added by the reactors at points downstream. Basic data obtained in the field are now being used to perfect mathematical models so that extrapolation to different river and operating conditions is possible and to better define the residual effects of the reactors at greater distances downstream. The results of this program have direct and immediate application in the evaluation of both chronic and unusual releases to the river and in the appraisal of the real and postulated status of the river in relation to existing federal guides and state standards.

II. PRIOR WORK

1. The extent to which reactor power levels can be estimated from river temperatures was determined and verified. A wide range of mathematical models, both statistical and of the input-output type, was used to correlate and predict the effect of reactor heat on Columbia River temperatures.
2. Routine temperature and chemical monitoring sites were established in locations where these single point measurements are reasonably representative of average conditions throughout the cross section of the river. The individual locations were moved and optimized to provide the best available information for the stated purposes of the program.

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3. Continuous dye tests of effluent dispersion were completed for all reactors for at least three river flow rates. These releases provided approximate dilution factors as far downstream as the 300 Area over the range of river flow from 40,000 to 140,000 cfs. Short duration dye additions were completed at each reactor outfall for at least two river flow rates, providing approximate time of flow data as far as the 300 Area over the range of river flow from 40,000 to 100,000 cfs.
4. Temperature probing of all effluent plumes of the older operating reactors was completed and the data reduced to a mathematical model which describes the dimensions and temperature of the plumes over a river flow range of 40,000 to 200,000 cfs and for travel times up to 1,500 seconds below the outfall. Exploratory data in the region immediately below the discharges were taken.
5. Dissolved oxygen measurements made during temperature probing and in special cases failed to reveal any significant interaction between the thermal discharges and the concentration of dissolved oxygen in the Columbia River.
6. The input-output digital simulation model, originally developed for assessment of the effects of the Columbia River cooling program was modified and improved to incorporate the effects of tributary streams and meteorological conditions on a regional basis. Additional modifications were made to permit modeling of radionuclide and chemical effluent discharges from any point on the Columbia or Snake River with resultant estimates of concentration and travel time as far downstream as Astoria, Oregon.
7. Special measurements taken during the program at many points have illustrated that normal routine temperature records are not a sufficient basis for the study of the trends in river temperatures and the assessments of the modifications from specific plant activities. As a result additional stations have been installed and monitored very carefully in order to ascertain the calibration accuracy on a continuous basis. A notable drift of accuracy occurs in the measurements published for Bonneville Dam to the extent that the actual conditions at that point are not known with any certainty since 1963. Instruments installed as part of this program are now operating at Northport, Chief Joseph, Grand Coulee, Rocky Reach, Priest Rapids, Richland, Pasco, Umatilla, Oregon, and below John Day Dam. The past record of this installation comprises the best single network of temperature data in the United States.
8. Temperature effects from the operation of the Hanford Plant were evaluated with respect to other sources of thermal modification of the Columbia as far downstream as Astoria, Oregon (River Mile 17). The quantitative fraction of heat remaining in the river from AEC operation was determined both seasonally and on a point by point basis as far downstream as Bonneville Dam (River Mile 146.2). Generally, a fraction of from 0.2 to 0.3 of the original heat as measured at Richland remains at Mile 146. Heat input from the Snake River is a major factor in warming of the McNary Reservoir in the critical summer months.

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III. PROGRESS DURING REPORTING PERIOD

1. Additional progress in the verification of the basic transport mechanics of the COL HEAT simulation model was obtained using dye releases previously made during previous phases of this program. The simulated curves compare favorably with measurements taken in the reach between 1904 B and the ACRMS at 300 Area. This indicates that the COL HEAT transport system is a reasonable approximation of water transport in the Hanford reach of the river. This work was supplemented by a statistical transport model derived from multiple simultaneous fitting of a number of releases with respect to time using the LEARN-LIKELY code. This model produces integrated mixing coefficients which are of value in assessment of the turbulence characteristics of the Columbia and streams in general.
2. Much progress was made in the development of mixing and transport models for the estimation of the downstream thermal effects of specific releases at 100 K. Previous work was verified and extended, and new remote sensing developments using both photomultiplier dye enhancement and infrared were employed. A great deal of new information pertinent to effluent modeling was generated which is of vital interest not only to this operation but to other AEC programs as well.
3. Temperature and current measurements were made in Wanapum Reservoir from July through September in order to evaluate the density current regimen of the computer simulation model. Continued poor and unusually cold weather defeated rational study of the data collected in relation to more normal years. Temperature transverses were also taken at the Oregon-Washington border on McNary Reservoir in order to provide input to studies of the residual effects of the thermal modification in the Plant reach.
4. The basic concepts for modeling the increase in dissolved nitrogen and oxygen concentration in water passing through the Hanford reach are now well developed. The presence of supersaturation can be explained as a combination of absorption below the spillway and very slow equilibration of the mean sample as it is exposed to the surface in the flowing river. Supersaturation represents the concentration of saturated water at the mean depth of the stream. A computer model for relating these effects to dam operations practices and effluent releases is being developed.
5. A start was made on the determination of costs of alternate modes of river operation to decrease transient concentrations of temperature or radionuclides resulting from peaking operations at Priest Rapids Dam. Data on costs are being accumulated and a linear programming model used to apportion cost factors in relation to constraints of interest to the Hanford operation.

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IV. EVALUATION OF EFFORT

The comprehensive program concerned with temperature changes in the Columbia River and the relative significance of the Hanford reactors to the temperatures of the Columbia River at points far removed from the Plant boundaries has permitted the development of a level of technical achievement which is state of the art. This includes the erection and calibration of a system of thermal measurement stations which have been installed and maintained in support of the development of a truly factual position unexcelled anywhere in the conterminous United States.

The ability of the Plant staff to use the resulting mathematical tools to effectively conduct self-analysis of effluent effects to a higher degree of sophistication than the associated regulatory agencies permitted hasty action to be forestalled and a moderate position developed in regulatory activity.

New knowledge concerning the thermal influence of relatively remote physical developments of the river both above and below the Plant permitted insight into historical temperature trends in relation to fisheries resources. A factual basis for study of temperature trends in relation to various contributing sources of fluctuations in fisheries was established.

With assistance provided by new classification interpretations, a detailed description of the mixing processes in the immediate vicinity of the Plant outfalls was made available for public study, and ancillary mathematical models for describing a wide range of fisheries and other pollutional aspects were established.

V. FUTURE WORK

Fiscal 1970

1. Continued primary emphasis will be placed on the publication and refinement of plume dispersion models currently under development. The maximum advantage of infrared and photomultiplier imagery is being used to develop improved methods of determining mixing coefficients and new approaches. The research plan includes verification of the probability of fish involuntarily entering the mixing zone.
2. The chemical and radiation version of the basic COL HEAT model will be developed to improve the longitudinal dispersion capability so that the computer system can recreate measured downstream concentrations as a function of time and space within standard deviation of the instrument errors.
3. Work will continue and a report will be published summarizing the development of non-linear regression models for temperature, flow and heat flux fitted to annual data sets for the Columbia River in order to explain trends in regional temperature effects which can be associated with global phenomenon which had previously been associated with the activities of the Hanford Plant.

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4. Reports summarizing studies on the McNary Reservoir, the simulation of effects of John Day and the dissolved gas transport model are planned for issue before July 1, 1970.

VI. TOPICAL REPORTS ISSUED

None

OTHER RELATED PRESENTATIONS

1. BNWL-SA-2880, "On the Use of Advanced Methods for Studies of Environmental Impact of Industrial Operations," International Water Conference of the Engineers' Society of Western Pennsylvania, Pittsburg, Nov. 1969 (In press).
2. BNWL-SA-2737, "Improved Methods for Planning of Thermal Discharges before Site Acquisition," American Nuclear Society Winter Meeting, Nov. 30, 1969, San Francisco, California (In press).
3. BNWL-SA-2972, "Comments Pertinent to the Use and Abuse of Energy in the American Economy," AAAS Meeting, Boston, Mass., Dec. 1969 (In press).
4. BNWL-SA-2603, "Methods for Evaluating Effects of Transient Conditions in Heavily Loaded and Extensively Regulated Streams," Stream Pollution Abatement Conference, Rutgers University, New Brunswick, N. J., June 10, 1969 (In press).

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