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A Guide to Environmental Monitoring Data, 1945-1972

Hanford Environmental Dose Reconstruction Project

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March 1994

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March 2, 1994

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Dear Dr. Till and Mr. Donnelly:

A GUIDE TO ENVIRONMENTAL MONITORING DATA, 1945-1972

Enclosed for your review is the report, *A Guide to Environmental Monitoring Data* (PNWD-2226 HEDR). This report provides an overview of previously published Hanford Environmental Dose Reconstruction (HEDR) Project reports containing air, Columbia River, and ground-water pathway data. It also provides further information on radionuclides in Columbia River media. This report fulfills Milestone 0502C.

To make publicly available the entire results of the Environmental Monitoring Data Task work, the following reports will be published as diskettes. Diskettes rather than hard copies are being published because of the size of these documents and the type of information they contain. The diskettes are available from the HEDR Technical Steering Panel (c/o K. CharLee, Office of Nuclear Waste Management, Department of Ecology, Technical Support and Publication Information Section, P.O. Box 47651, Olympia, Washington 98504-7651).

- Duncan, J. P. 1994. *Overview of Vegetation Monitoring Data,* 1952-1983. PNWD-2235 HEDR, Battelle, Pacific Northwest Laboratories, Richland, Washington (approximately 200 pages).
- Hanf, R. W., and M. E. Thiede. 1994. *Environmental Radiological Monitoring of Air, Rain, and Snow on and near the Hanford Site,* 1945-1957. PNWD-2234 HEDR, Battelle, Pacific Northwest Laboratories, Richland, Washington (approximately 150 pages).
- Thiede, M. E., and J. P. Duncan. 1994. *Database of Radionuclide Measurements in Columbia River Water, Fish, Waterfowl, Gamebirds, and Shellfish Downstream of Hanford's Single-Pass Production Reactors, 1960-1970.* PNWD-2242 HEDR, Battelle, Pacific Northwest Laboratories, Richland, Washington (approximately 900 pages).

For us to incorporate the Technical Steering Panel comments and publish the final report prim to the end of *our* contract, we will need to receive the Technical Steering Panel comments by April 15,1994. Please let us know if this presents you with a problem.

Very truly yours,

Dillard B. Shipler, Manager
Hanford Environmental
Dose Reconstruction Project

DBS:prc

Enclosure

cc: MS Power (TSP)
RH Gray (BNW)
LB

Preface

In 1987 the U.S. Department of Energy (DOE) directed the Pacific Northwest Laboratory, which is operated by Battelle Memorial Institute, to conduct the Hanford Environmental Dose Reconstruction (HEDR) Project. The DOE directive to begin project work followed a 1986 recommendation by the Hanford Health Effects Review Panel (HHERP). The HHERP was formed to consider the potential health implications of past releases of radioactive materials from the Hanford Site near Richland, Washington.

Members of a Technical Steering Panel **(TSP)** were selected to direct the HEDR Project work. The TSP consists of experts in the various technical fields relevant to HEDR Project work and representatives from the states of Washington, Oregon, and Idaho; Native American Tribes; and the public. The technical members on the panel were selected by the vice presidents for research at major universities in Washington and Oregon. The state representatives were selected by the respective state governments. The Native American Tribes and public representatives were selected by the other panel members.

A December 1990 Memorandum of Understanding between the Secretaries of the DOE and the U.S. Department of Health and Human Services **(DHHS)** transferred responsibility for managing the **DOE's** dose reconstruction and exposure assessment studies to the DHHS. This transfer resulted in the current contract between Battelle, Pacific Northwest Laboratories (BNW) and the Centers for Disease Control and Prevention (CDC), an agency of the DHHS.

The purpose of the HEDR Project is to estimate the radiation dose that individuals could have received as a result of emissions since 1944 from the Hanford Site. The HEDR Project work is conducted under several technical and administrative tasks, among which is the Environmental Monitoring Data Task. Members of the Environmental Monitoring Data Task assembled, evaluated, and summarized key historical measurements of the concentrations of radionuclides in the environment around the Hanford Site for selected years from 1945 through 1972. The environmental media investigated included air, vegetation, foods, ground water, Columbia River water, fish, waterfowl, gamebirds, and shellfish.

This report is the culmination of work by the Environmental Monitoring Data Task. It follows the eight key HEDR environmental monitoring reports listed below. For a complete listing of previous environmental monitoring reports, please see Table S.1 at the end of the summary.

- **Denham** et al. **(1993a)** and Mart et al. **(1993),** which describe radionuclides in vegetation **(1945-1947),** water **(1963-1966),** and fish (phosphorus-32 and zinc-65, 1964-1966) and provide conversion and correction factors for iodine-131 in vegetation.

Hanf et al. (1993) and **Denham** et al. **(1993b),** which for 1948-1951 describe radionuclides in vegetation samples and provide conversion and correction factors for the period when the iodine extraction measurement method was developed and implemented.

- Duncan **(1994),** which describes historical documents available for vegetation samples from 1952-1983.
- Hanf et al. **(1992),** which describes historical documents available for Columbia River fish, waterfowl, and shellfish from 1945-1972.
- Hanf and Thiede **(1994),** which describes historical documents available for air samples from 1945-1957.
- **Freshley** and **Thorne (1992),** which describes ground-water contribution to dose from past Hanford operations from 1944-1990.

This report 1) provides an overview of previously published HEDR reports containing air, Columbia River, and ground-water pathway data, see Table S.1 and Section 4.0, and 2) provides further information on radionuclides in Columbia River media, see Section 5.0.

Only limited historical environmental data qualified for use in the calculation of dose. Therefore, computer models had to be developed. The historical data were used 1) directly in the dose calculations where possible, 2) in the development of regression equations and bioconcentration factors calculated to estimate the radionuclide concentrations, and 3) to validate the models.

This document fulfills HEDR Project Milestone **0502C.**

Summary

This report is a result of the Hanford Environmental Dose Reconstruction (HEDR) Project. The goal of the HEDR Project is to estimate the radiation dose that individuals could have received from radionuclide emissions since 1944 at the Hanford Site near Richland, Washington. The HEDR Project is conducted by Battelle, Pacific Northwest Laboratories.

Scope of Work

This report describes the activities of the Environmental Monitoring Data Task in recovering, evaluating, processing, and/or reconstructing the environmental monitoring data for .the period 1945-1972. This report ties together previous data collection work and subsequent efforts to collect more data related to the Columbia River pathway. Table S.1 is a guide to the suite of reports that have been or are in the process of being published on the historical environmental data evaluated by HEDR Project staff. The reports contain environmental monitoring information on vegetation, river media ground water, and air. New information in this report includes historical data for various environmental media affected by the Columbia River downstream of the Hanford single-pass production reactors. Summaries of radionuclide concentrations in Columbia River water (1960-1970), fish (1960-1967), salmon and steelhead trout (1960-1970), waterfowl (1960-1970), and gamebirds (1967-1970) are provided. Radionuclide concentrations in shellfish are summarized for coastal areas near the mouth of the Columbia River (1960-1970). In addition, the bioconcentration factors for Columbia River fish and waterfowl and the methods for computing them are described.

Technical Approach

To inventory and summarize the environmental monitoring data accumulated since the beginning of Hanford operations in December 1944, HEDR staff recovered and reviewed historical records and interviewed veteran Hanford employees familiar with the respective sampling and measuring techniques. During this study, more than 1000 documents were reviewed by HEDR staff. Once collected, the data were compiled in databases, one for each medium. For each measurement, the databases denote the location, date, historical radionuclide measurement, conversion of the historical measurement to standard measurement units, and the document number. The database entries were verified by a second person using a recognized statistical sampling plan.

Results

The results of the Environmental Monitoring Data Task are the accumulated databases of historical environmental data. The environmental monitoring databases contain all historical environmental data that could be located. Completeness of the databases was evaluated by the staff of the Environmental Monitoring Data Task as well as the staff members of those tasks whose work required the historical data. The conclusion was that enough environmental monitoring information

has been identified and/or reconstructed to satisfy the objectives of the HEDR Project. Finding new information later would not change any dose estimates by more than 5 percent.

Because only limited historical environmental data qualified for use in the calculation of dose, computer models had to be developed. Historical data are only used directly in the HEDR Project to estimate dose from the consumption of salmon and oysters for those dates when salmon and oyster data are available. Otherwise, the historical data are used in calculations to estimate the concentrations. In the case of oysters, a regression analysis establishes a representative concentration of radionuclides in oysters. For dose estimates from fish and waterfowl, bioconcentration factors were developed from the existing historical data. These bioconcentration factors are used to extrapolate data for the years when no data exist. All other types of historical monitoring data are too sparse in spatial and temporal coverage to provide direct input to the dose calculations. That input has been estimated by computer models. Selected sets of historical data have then been used for comparison with the concentrations estimated by the computer models. These comparisons indicate that the models adequately approximate the actual environmental contamination.

Table S.1. Overview of the HEDR Environmental Monitoring Reports

Report	I-131 in Vegetation	Radionuclides in Columbia River Water	Radionuclides in Columbia River Fish	Radionuclides in Waterfowl	Radionuclides in Upland Gamebirds	Radionuclides in Shellfish	Radionuclides in Ground Water	Radionuclides in Air
Denham et al. 1993a (PNWD-2145 HEDR)	1945-1947	1963-1966	1964-1966 (P-32, Zn-65)					
Mart et al. 1993 (PNWD-2133 HEDR)	1945-1947 (conv./corr. factors)							
Gilbert et al. 1994 (PNWD-1978 HEDR)	1945-1947 (uncer. & sens.)							
Hanf et al. 1993 (PNWD-2177 HEDR)	1948-1951							
Denham et al. 1993b (PNWD-2176 HEDR)	1948-1951 (conv./corr. factors)							
Duncan 1994 (PNWD-2235 HEDR)	1952-1983 (lit. summary)							
Thiede et al. 1994 (PNWD-2226 HEDR)		1960-1970 (sum. data)	1960-1967 (sum. data) all years (biocon. factors) 1960-1970 (Zn-65 in salmon & steelhead)	all years (biocon. factors)	1967-1970 (sum. data)	1960-1970 (sum. data)		
Thiede & Duncan 1994 (PNWD-2242 HEDR)		1960-1970	1960-1967	1960-1970	1967-1970	1960-1970		
Hanf et al. 1992 (PNWD-1986 HEDR)			1945-1972 (lit. summary)	1945-1972 (lit. summary)		1945-1972 (lit. summary)		
Freshley & Thorne 1992 (PNWD-1974 HEDR)							1944-1990	
Hanf & Thiede 1994 (PNWD-2234 HEDR)								1945-1957 (lit. summary)
Huesties 1992, 1993 (PNL-8063 HEDR) (PNWD-2119 HEDR)	(document databases)	(document databases)	(document databases)	(document databases)	(document databases)	(document databases)	(document databases)	(document databases)

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1.0 Introduction

This report is a guide to the work accomplished by the Environmental Monitoring Data Task, which is one of the tasks in the Hanford Environmental Dose Reconstruction (HEDR) Project. The objective of the Environmental Monitoring Data Task was to recover; evaluate, process, **and/or** reconstruct the environmental monitoring data for the period 1945-1972. The period of time for which environmental monitoring data were sought was determined by the start-up and shutdown dates of the Hanford facilities that emitted the majority of radionuclides to the two major pathways: air and the Columbia River. Radionuclide emissions to the air were mainly the result of the operation of the chemical separations plants from 1944-1972 (Heeb 1994). Radionuclide emissions to the Columbia River were mainly the result of the operation of the single-pass production reactors from 1944-1971 (Heeb and Bates 1994). Therefore, the historical environmental monitoring data sought were for the period 1945-1972.

Within the period of 1945-1972, specific periods of interest to the HEDR Project vary depending on the pathway. For example, 1945-1951 was the peak period for radionuclide emissions to the air and hence vegetation uptake of radionuclides, while 1956-1965 was the peak period for radionuclide emissions to the Columbia River and hence fish uptake of radionuclides. However, adequate historical data were not always available for the periods of interest. In the case of vegetation measurements, conversion and correction factors had to be developed to convert the historical measurements to modem standard measurements. See Table S.1 for the reports that explain these conversion and correction factors. In the case of Columbia River fish and waterfowl, **bioconcentration** factors were developed for use in any year where the river pathway data are insufficient.

Although 1956-1965 was the peak period for radionuclide emissions to the Columbia River, it was not until the 1960s that gamma spectrometry became the standard measuring technique and, thereby, adequate measurements of radionuclides could be made. Prior to the 1960s very few radionuclide-specific measurements were made of Columbia River media. Therefore, bioconcentration factors were developed from the data that were adequate for use in those years where the data were inadequate. This report provides **the** bioconcentration factors for Columbia River fish and waterfowl and a discussion of how the bioconcentration factors were developed.

Along with the bioconcentration factors, new data presented in this report are summary data (maximum, minimum, mean, and median) for Columbia River water **(1960-1970),** fish **(1960-1967)** including all data for zinc-65 in salmon and steelhead **(1960-1970),** upland gamebirds **(1967-1970),** and shellfish (1960-1970). Complete historical data for the Columbia River media measurements discussed in this report are published in **Thiede** and Duncan (1994). These databases are available on diskette from the HEDR Technical Steering Panel, **c/o** K. CharLee, **Office** of Nuclear Waste Management, Department of Ecology, Technical Support and Publication Information Section, P.O. Box 47651, Olympia, Washington **98504-7651.** For an overview of the contents of all environmental monitoring reports, see Table S.1.

2.0 Technical Approach

The pathways by which people could have been exposed to radionuclides were air, ground water, and the Columbia River. One of the first steps in calculating radiation dose was to search for historical documents containing environmental monitoring data measurements of media in those pathways.

Important historical environmental monitoring data reports were located, reviewed, and inventoried (Denham et al. 1993; Duncan 1994; Freshley and Thorne 1992; Hanf et al. 1992; Hanf et al. 1993; Hanf and Thiede 1994; Huesties 1992, 1993). Archived historical Hanford documents were the primary sources of environmental data. The pertinent documents were identified through searches of library card files, listings of historical logbooks, and files of historical serial and periodic documents about or from the Hanford Site. Reviews of summary document reference lists and extensive discussions with key former Hanford employees (Denham et al. 1988) produced further documentation. Physical copies of documents were obtained from historical files, the Hanford Technical Library, the Department of Energy (DOE) Records Holding Area (Building 712 in Richland, Washington), the state of Oregon, the U. S. Army Corps of Engineers, the U. S. Geologic Survey, and various universities. More than 1000 documents were reviewed by HEDR staff.

In the early stages of the HEDR Project, staff concentrated on identifying the sources of historical monitoring information, the environmental media collected, the radionuclides measured, and the offsite sampling locations. During the final stages of the HEDR Project, the Environmental Monitoring Data Task staff concentrated on determining the time periods during which sufficient offsite data were available to support validation of the computer models used to estimate dose.

As with the previously published environmental data, the new environmental data summarized in this report were collected and compiled into databases (Thiede and Duncan 1994). Each database was created by entering data in text format to keep the database simple and adaptable to multiple computer systems. Each measurement (e.g., radionuclide concentration in fish flesh) was identified by document number, collection location, and date. Quality assurance checks of the database entries against the historical records were made by a person different from the one who entered the original data. Because of the large number of entries in each database, each entry could not be verified. The entries were verified instead by using a recognized statistical sampling plan (Hoover and Baldwin 1984) to determine how many entries to randomly inspect against the original data and then how many entry errors would constitute a rejection of the database. Only one entry error was found.

Data files were read and summarized using SAS statistical software (SAS Institute, Inc. 1989) on a VAX computer. SAS programs were written to standardize the database information because measurement units and terminology often differed among documents.

3.0 Data Quality Objectives

The data quality objectives for the Environmental Monitoring Data Task are defined in Shipler (1993). How the objectives for the Columbia River data were met is briefly described in the appropriate sections below. How the data quality objectives for the other environmental monitoring data were met is described in the respective reports.

3.1 Accuracy

The objective of accuracy was to verify reported concentrations or to reconstruct actual concentrations based on reported levels. By 1960, when radioactive releases were at their maximum in the Columbia River, gamma analysis techniques had been fully developed. Therefore, there was no need to reconstruct the historical measurements for the time period covered by this report. Accuracy of compiled databases was verified by direct comparisons of randomly selected database entries against original records.

3.2 Precision

The objective of precision was to quantify uncertainties in reported and reconstructed concentrations. The uncertainties have been quantified and will be reported in the Columbia River dosimetry report.

3.3 Completeness

The completeness objective required that reported values be averages and ranges of concentrations for each medium and location. These are presented in the appendixes as the maximum, minimum, means, and median. Also, all known and discoverable sources of environmental monitoring data related to the river were to be investigated. All known sources of environmental monitoring data (**i.e.,** water, fish, waterfowl, upland gamebirds and shellfish) were investigated. Completeness was evaluated by the staff of the Environmental Monitoring Data Task. The conclusion was that the pertinent environmental monitoring information has been identified and that finding new information later would not change any dose estimates by more than 5 percent.

Not all of the information in the historical documents was usable. This is because complete descriptions of the sampling process, the analysis method, and their unit conversions were not always clearly stated in the document. For example, the conversions of activity per unit weight from ash weight of a salmon sample to its corresponding tissue wet weight was not given. The variation about the means for groups of historical data described in this study is quite large and any new data found might provide more detail but would not change the dose calculations.

3.4 Representativeness

The representativeness objective was that concentrations developed represent ranges of actual concentrations that could have occurred in the environmental media. Representativeness should be ensured by generating concentrations using different methods and verified by uncertainty analyses and other source analyses (Napier et al. 1994).

3.5 Comparability

The comparability objective was that newly identified information be comparable (within a factor of two) to the previously identified information or that differences be technically explainable. Comparisons made between newly identified and previously identified data found that the new data would fit within a factor of two of the variations reported.

4.0 Overview of Previously Published Data

Radioactive emissions from the Hanford activities were released to three general pathways: the air pathway, the Columbia River pathway, and the ground-water pathway. Historical data for the air pathway are described in previously published HEDR documents listed in Sections 4.1 and 4.2. Previously reported information concerning the Columbia River pathway is in Section 4.3. Environmental data on the ground-water pathway are addressed in Section 4.4.

4.1 Air Measurements

Historical documents concerning air monitoring data for 1945 through 1957 were searched for, inventoried (Huesties 1992, 1993), and reviewed (Hanf and Thiede 1994). Historical sampling devices are described in Hanf and Thiede (1994), along with a brief statement about the problems associated with using historical air monitoring data collected with each device.

In general, historical measurements of air contamination cannot be used because the historical air sampling devices did not provide accurate measurements. The air sampling devices were difficult to maintain and calibrate, did not exclusively monitor the radionuclide found to be the major contributor of dose, iodine-131 (Napier 1992), and were used in only a few offsite locations. Therefore, the historical air monitoring data were not used by the HEDR Project because the data were not satisfactory in quality or number for dose calculations or validation of models.

4.2 Vegetation Measurements

Historical data (1945-1947) of iodine-131 (as total beta activity in 1-gram pellets) in vegetation are summarized in Denham et al. (1993a). Reconstructed conversion and correction factors for these pellets to correct the 1945-1947 vegetation data to today's best estimates of iodine-131 activity are described in Mart et al. (1993). Uncertainty and sensitivity of the conversion and correction factors for the 1945-1947 vegetation data are discussed in Gilbert et al. (1994). Historical vegetation data (1948-1951) are summarized in Hanf et al. (1993), and the conversion and correction factors for best estimates of activity for the 1948-1951 vegetation data are described in Denham et al. (1993b). A year-by-year overview (1952-1983) of historical documents available concerning vegetation and foods sampled near Hanford is in Duncan (1994). Databases of historical vegetation data have not been compiled beyond 1951 for the HEDR Project. Hanford's Surface Environmental Surveillance Project has compiled environmental media (including vegetation and foods) after 1971.[a]

4.3 River Measurements

(a) Unpublished report (project no. SESP-PDMS-001), *Project and Data Management System (PDMS) Users Guide Surface Environmental Surveillance Project*, by L. E. Bisping, 1990. Unpublished report (project no. SESP-PDMS-002), *Project and Data Management System (PDMS) Database Steward's Handbook*, by L. E. Bisping, 1990.

4.3 River Measurements

The Columbia River pathway is one of the exposure pathways for individuals living in the vicinity of the Hanford Site. Napier (1993) determined key radionuclides and parameters related to exposure from this pathway. Napier discussed the contributions to dose from external exposure to contaminated river water and ingestion of contaminated drinking water, resident fish, and waterfowl. Walters et al. (1992) reviewed data and literature on the river pathway. Denham et al. (1993a) discussed databases of historical data assimilated for summarizing radionuclide concentrations in Columbia River water (1963-1966) and fish (1964-1966). Hanf et al. (1992) summarized the historical documents available for determining radionuclide concentrations in fish, waterfowl, and shellfish for the years 1945-1972.

4.4 Ground-Water Measurements

The question addressed in the ground-water report (Freshley and Thorne 1992) is to what extent the ground-water pathway might have contributed to past radiation doses. Plume maps of important historical ground-water data are provided in this report as well as the estimated doses. Because Hanford Site ground water was largely inaccessible to the public and the estimated doses were small, it was recommended that no further work be performed on the ground-water pathway.

5.0 Columbia River Pathway Data and Bioconcentration Factors

The new information presented in this report summarizes recently compiled databases of historical data collected from 1960-1970 and provides bioconcentration factors. The period 1960-1970 represents the best historical Columbia River data available because routine monitoring of environmental samples for radionuclides using gamma spectrometry was practiced.

Provided in this report are summaries (maximum, minimum, mean, and median values) of the concentration data for five key radionuclides (Napier 1993) in Columbia River water from 1960 through 1970 (Appendix A) and in fish for 1960-1967 (Appendix B), bioconcentration factors for fish (Appendix C), concentration data for zinc-65 in salmon and steelhead trout from the Columbia River and Pacific Ocean for 1960-1970 (Appendix D), bioconcentration factors for waterfowl (Appendix E), summaries of the radionuclide concentrations in upland gamebirds for 1967-1970 (Appendix F) and shellfish sampled from the Pacific Ocean near the mouth of the Columbia River for 1960-1970 (Appendix G). A description of methods used to calculate bioconcentration factors from historical data for Columbia River fish is included in this report.

Not all of the information in the environmental monitoring databases is used in calculations. Some data sets were reserved for use in validating the computer models. Napier et al. (1993) identified the basis for the kinds of data and the time period reserved for river pathway validation efforts. Data reserved to validate the river model include the 1967 Columbia River water concentrations, the 1967 Columbia River fish concentrations, and the 1967 salmon and oyster concentrations. While these validation data sets are described in this report, the validation data are presented in Appendix D of Napier et al. (1994).

5.1 Radionuclide Concentrations in Columbia River Water, 1960-1970

Radionuclides with long enough half-lives or present in large enough quantities to be discharged from basins into the river were routinely sampled by Hanford's environmental monitoring group. Information published yearly by Hanford contractors was supplemented by such non-federal entities as the Oregon State Board of Health (Toombs and Culter 1968). Walters et al. (1992) summarized the locations where Columbia River water was sampled for the period 1950-1971 and also provided examples of radionuclides summarized for several locations along the river. Foster and Wilson (1963) found that 90 percent of the activity from reactor effluent radionuclides reaching the river consisted of sodium-24, silicon31, chromium-51, manganese-56, copper-64, arsenic-76, and neptunium-239. The minor components (8 percent of total radionuclide activity) consisted of phosphorus-32, zinc-65, zinc-69, gallium-72, yttrium-90192193, strontium-90191, niobium-97, iodine-133, and uranium-239. However, preliminary screening studies and dose calculations (Napier 1993; Napier and Brothers 1992) determined the key radionuclides with respect to exposure to the public. These studies indicated that the following radionuclides should be included in the HEDR dose modeling efforts: sodium-24, phosphorous-32, arsenic-76, zinc-65, and neptunium-239. The quantity of these radionuclides entering the river from each reactor are estimated by Heeb and Bates (1994).

The summary included in this report is for the five key radionuclides identified by Napier (1993) and does not describe all the radionuclides entered in the database. About 15,000 measurements of radionuclide concentrations in Columbia River water were entered from both government and **offsite** documents for the period 1960-1970. Nearly 6000 water measurements for the five key radionuclides identified by Napier (1993) are included in the river water summary in Appendix A. Of these 6000 measurements, phosphorus-32 and **zinc-65** were the most common ones made by Hanford personnel, accounting for 75 percent of the measurements.

The water database is summarized separately for grab samples **(Table** A.l) and for composite samples (Table A.2). Grab samples were taken by collecting a single sample of river water at one location. Composite samples were generally taken by a mechanical device over a period of one week at one location. Radionuclides with short half-lives **(e.g.,** arsenic-76, sodium-24, neptunium-239; see Table 5.1) were typically sampled using the grab sample method. The grab sample method tended to either overstate or understate general radionuclide conditions in the river because the radionuclides were not uniformly dispersed, and they varied with reactor discharges. Radionuclides with longer half-lives **(e.g.,** phosphorus-32 and zinc-65; see Table 5.1) were sometimes measured by both methods for comparison.

Table 5.1. Radiological Half-Lives of Key Radionuclides

Radionuclide	Radiological Half-life
Zinc-65	245 days
Phosphorus32	14.3 days
Neptunium-239	2.33 days
Arsenic-76	1.1 days
Sodium-24	15 hours

Historical water samples for short-lived radionuclides **(e.g.,** arsenic-76, sodium-24, and neptunium-239) were not taken from river sections downstream of Pasco. This is understandable because the travel time for water from the Hanford reactors is approximately one day to Pasco and six days to **McNary** Dam, the next measurement location just below Pasco (Walters et al. 1992). By the time the short-lived radionuclides reached **McNary** Dam, they would have decayed below instrument detection levels.

5.2 Radionuclide Concentrations in Columbia River Fish, 1960-1967

The following section describes the Columbia River fish database that was compiled from historical documents such as those described in **Hanf** et al. (1992) and Walters et al. (1992). **Radio**nuclides in fish samples **(zinc-65** and phosphorus-32) are described in **Denham** et al. **(1993a)** for the period 1964 through 1966. The fish database initially described in the **Denham** report has since been expanded to cover more years (1960-1967) and include more radionuclides (neptunium-239, arsenic-76, and sodium-24).

More than 20,000 radionuclide measurements of 25 fish species were obtained from historical documents and entered into a database. The database includes measurements of omnivore fish (bullhead, catfish, suckers, whitefish, chiselmouth, chub, minnows, shiners, and sturgeon), first-order predator fish (perch, crappie, punkinseed, and bluegill), and second-order predator fish (bass, trout, and squawfish).

The three groupings of fish refer to the feeding regimes of the fish. **Omnivore** fish tend to eat periphyton and macrophytes. First-order predators eat insect larvae, zooplankton, and herbivorous fish. Second-order predators eat **first-order** predator fish.

Two other fish groupings (salmon and steelhead trout) are discussed in Section 5.4. Hanf et al. (1992) suggested that salmon do not accumulate radionuclides because of short residence time in the Columbia River and because they generally do not eat during the spawning period.

Omnivore fish species constitute three-fourths of the database. First- and second-order predator fish each account for about 10 percent of the database entries. Steelhead and salmon account for only 2 percent of the database.

The five key radionuclides (zinc-65, phosphorus-32, neptunium-239, arsenic-76, and sodium-24) account for nearly 15,000 records in the fish database. Most of the fish were sampled from a limited number of locations: Hanford **(17%), Ringold (22%), Richland (13%), Burbank (29%),** Islandview **(4%), McNary** Dam **(4%),** and Hover (2%) and were not collected throughout the year. This limited number of locations caused difficulties in determining bioconcentration factors for fish (see Section 5.3).

Considerable variation in radionuclide concentrations in fish tissues is apparent in all historical fish data that were found. These variations arise from biological **as** well **as** environmental factors. When fish are collected, it is not known how long the fish resided in a particular area because of their mobility. Other factors that can influence fish radionuclide concentrations include the river's flow rate, radionuclide-laden sediment resuspension, water temperature, and biological uptake and retention of radionuclides. A seasonal variation was also noted in the concentrations of the radionuclides in fish. **Denham** et al. **(1993a)** show seasonal differences for phosphorus-32 and zinc-65 concentrations in Columbia River whitefish using 1964-1966 data. This variation appears to depend on the radionuclide type and the fish species, as well as the time of the year.

The concentration variations noted for fish in Table 5.2 may be partially attributed to the different goals of Hanford's sampling program during the **1960s.** Historically, the monitoring program was primarily interested in monitoring trends in radionuclide concentrations in fish downriver of the Hanford reactor operations. These data were not collected for the purpose of determining bioconcentration factors. For example, there was not full coverage of seasons and month, species catches were extremely variable, and not all radionuclides were measured. This made

Table 5.2. Example of Phosphorus-32 Concentration in Fish Taken from the Columbia River near Richland, Washington, in 1962

Fish Species	Number of Samples	Median (pCi/g)	5th Percentile	95th Percentile
Carp	10	45	14	270
Chiselmouth	23	160	12	1000
Perch	20	26	7	545
Squawfish	21	14	6	120
Sucker	23	230	100	1500
Whitefish	45	10	10	850

it difficult to come up with bioconcentration factors by species and month. Historical data show inconsistencies in the sampling of fish species for determining detailed seasonal, annual, and location-dependent variation.

Concentrations of key radionuclides in fish are summarized in Appendix B. These tables reflect the biological and environmental influences described above.

5.3 Bioconcentration Factors in Columbia River Fish

While there are many historical records for fish available for the time period 1960-1966 (see Section 5.2), historical data before 1958 are less useful because only gross beta was analyzed then. To calculate the concentrations of radionuclides in fish for times when little data were available, bioconcentration factors were computed for periods when the greatest amount of historical data are available. Those factors are then used in conjunction with the radionuclide concentrations in water to estimate the radionuclide concentrations in fish. However, whenever possible, the use of actual measurements is preferred over the use of factors gleaned from the literature and determined under different conditions.

Development of bioconcentration factors for food fish harvested from the Columbia River are discussed in Denham *et* al. (1993a) and Walters *et* al. (1992). This work provides additional information that was used to compute the bioconcentration factors for Columbia River fish and waterfowl. As directed by the HEDR Technical Steering Panel, the bioconcentration factors developed for second-order predator fish will also be used for salmon. The salmon data were too sparse to develop bioconcentration factors. The bioconcentration factors are determined by the following equation:

$$BCF_n = F_n/W_n \quad (1)$$

where BCF_n = bioconcentration factor in **(L/kg)** for radionuclide (n)
F_n = concentration of the radionuclide (n) in fish **(pCi/kg)**
W_n = concentration of the radionuclide (n) in water **(pCi/L).**

Fish bioconcentration factors vary greatly depending on the site-specific locations of an aquatic system, as noted by summaries of factors in Vanderploeg et al. (1975) and **Poston** and Klopfer (1988). The bioconcentration factors developed for this study apply only for conditions characteristic of **the** Columbia River.

The initial analysis of historical data was designed to preserve maximum detail in terms of species and season for the Columbia River. Determining bioconcentration factors required that fish and water data match by location and month. When matching fish data to water data, HEDR staff found a number of years and locations where the data were inadequate. Table 5.3 shows the available fish and water data by year and location.

Table 53. Available Fish and Water Data Grouped by Location and Year

Location	1961	1962	1963	1964	1965	1966
Hanford	x[(a)]	x	x		x	
Ringold					x	x
Richland/300 Area			x	x	x	x
Pasco/Burbank	x	x	x	x	x	
McNary/Umatilla				x	x	x

(a) x = Locations and years when both fish and water data are available.

Only the years 1961-1967 had sufficient monthly fish and water data for comparisons. Data from the year 1967 were omitted from the comparison because these data were reserved for model validation (Napier et al. 1994). Finding data on samples from matching locations presented greater problems. Many times fish were sampled at one location and water was sampled at another. Sometimes fish were sampled for a radionuclide during one year, but the water for the same site was sampled during a different year. Near **Ringold,** fish were sampled on the Hanford reactor side of the river, but water was sampled on the public access side, which is opposite the reactors. While the side of the river would be less important further downriver **(e.g.,** Pasco), the **Ringold** site was only a few miles downstream of the reactors where mixing of the reactor plume would have been incomplete. Other locations had similar problems. Many of the historical fish samples were taken from **Burbank,** downriver of the confluence of the Snake and Columbia Rivers. Radionuclide concentrations would have been diluted by water from the Snake River but may not have been evenly dispersed. No water samples were taken at Burbank. However, water samples were commonly taken at Pasco, upriver of the confluence of the Snake and Columbia rivers. Matching data sets from two such locations could lead to biased bioconcentration factors. Combinations of some river segments were examined to try to increase the matches of fish and water by time and location. However, combining river segments was not satisfactory because the differences in water concentrations in the segments were too significant.

Because of problems in matching the historical fish data with the historical data water to obtain the best estimate of bioconcentration factors, it was concluded that historical fish data would be better matched to computer modeled water concentrations. Estimated water concentrations would provide a match for every fish sample. The following subsection describes the results of that matching.

5.3.1 Use of Modeled Water Concentrations

Monthly average radionuclide concentrations in water were estimated by the Surface-Water Transport Subtask staff using the WSU-CHARIMA model (Holley et al. 1993; Walters et al. 1994). WSU-CHARIMA is an unsteady flow model for river systems. The radionuclide concentrations in the Columbia River water were estimated based on the estimated releases of radionuclides from the eight single-pass production reactors (Heeb and Bates 1994).

The WSU-CHARIMA files contain data for the five key radionuclides (sodium-24, phosphorus-32, zinc-65, arsenic-76, neptunium-239) as well as chromium-51 for use in validation. Of the twelve Columbia River locations modeled by WSU-CHARIMA, four are of use for matching river water locations to fish sampling locations: Ringold, Richland, the Snake and Walla Walla rivers, and Umatilla and Boardman. There were not enough fish data for the other eight segments. The resulting fish and water matches used to compute bioconcentration factors are as shown in Table 5.4.

Table 5.4. Locations Where Fish Data Are Used with WSU-CHARIMA Modeled Water Data to Compute Bioconcentration Factors

Fish	River Segment in WSU-CHARIMA
Hanford to Ringold	Ringold
Richland	Richland
Burbank	Snake River to Walla Walla River[(a)]
McNary	Umatilla to Boardman[(a)]

(a) Concentrations calculated at the midpoint between the two sites.

In the model that is used to calculate dose from the Columbia River pathway **(Farris 1993),** bioconcentration factors are assumed to be the same for all locations and years. Therefore, with the bioconcentration factors for Columbia River fish developed from historical data and the **WSU-CHARIMA** modeled water concentrations (Walters et al. **1994),** the radionuclide concentration in fish can be determined when historical fish sample data are lacking. Equation (1) can be rewritten **as** follows:

$$F_n(L) = BCF_n \cdot W_n(L) \tag{2}$$

where $F_n(L)$ = concentration of the radionuclide (n) in fish at location (L)
BCF, = bioconcentration factor in **L/kg** for radionuclide (n)
$W_n(L)$ = concentration of the radionuclide (n) in water at location (L) as determined by the WSU-CHARIMA computer model.

5.3.2 Calculation of Bioconcentration Factors

Using modeled river estimates, all historical fish concentration measurements were matched with river concentration estimates by location and month. Table 5.5 shows the median bioconcentration factors calculated for arsenic-76, chromium-51, neptunium-239, sodium-24, phosphorus-32, and zinc-65.

In addition, the resulting calculated bioconcentration factors for each radionuclide were statistically analyzed to examine if certain groupings of the data should be treated separately; **i.e.,** if the bioconcentration factors appeared to be significantly different for variables such as fish feeding groups (defined in Section 5.2) and seasons. Analysis of variance methods were used, followed by means separations tests. These analyses were evaluated and included in determinations of which subpopulations needed to be defined. Bioconcentrations were collapsed into bigger groups if there were no significant differences. For example, seasons were collapsed into cool season **(December-**May) and warm season (June-November) for phosphorus-32 and **zinc-65.**

5.3.2.1 Phosphorus-32

The bioconcentration factor for phosphorus-32 was found to be sensitive to time and location. Differences noted in the bioconcentration factors led to grouping these factors into two seasons: the cool season (December-May) and the warm season (June-November). However, monthly differences within the seasons were not considered large enough to maintain separate bioconcentration factors. Section 5.3 discussed the problems of location in matching historical water data with historical fish data. The bioconcentration factors were different at **Ringold** and **Burbank** when determined by matching WSU-CHARIMA modeled water data for those locations with historical fish data. This may be due to a number of variables such **as** those described earlier concerning fish movements and sample locationdependent factors. Bioconcentration factors for omnivore fish were significantly different from either first- or second-order predator fish. Therefore, the bioconcentration factors are given for each category (Table 5.5). Predator fish were grouped together because there were no significant differences between the first- and second-order predator fish.

Table 5.5. Median Bioconcentration Factors for Columbia River Fish Using Historical Fish Data and WSU-CHARIMA Modeled Water Concentrations

Radionuclide	Fish Feeding Class	Season	Median Bioconcentration Factor[a] (L/kg)
Phosphorus-32	omnivores	cool[b]	420
Phosphorus-32	omnivores	warm[c]	1500
Phosphorus-32	predators	cool	76
Phosphorus-32	predators	warm	980
Zinc-65	omnivores	cool	130
Zinc-65	omnivores	warm	220
Zinc-65	first-order predators	cool	97
Zinc-65	first-order predators	warm	250
Zinc-65	second-order predators	cool	67
Zinc-65	second-order predators	warm	110
Sodium-24	omnivores	all[d]	8.0
Sodium-24	predators	all	2.1
Arsenic-76	all	all	240
Neptunium-239	all	all	21
Chromium-51	all	all	1.7

(a) Median bioconcentration factors are rounded to two significant digits.
(b) Cool season is December-May.
(c) Warm season is June-November.
(d) "All" refers to combining the variables pertinent to the particular column.

5.3.2.2 Zinc-65

Monthly differences for zinc were similar to those of phosphorus. The data were also collapsed to two seasons. Omnivore, first-order predator, and second-order predator class differences were all significant. Therefore, different bioconcentration factors were provided. Median values for six resulting bioconcentration factors are provided for zinc-65 in Table 5.5.

5.3.2.3 Sodium-24

There are fewer historical data for sodium-24 in fish than for phosphorus-32 or zinc-65. Data for sodium-24 in fish are available only for omnivores and second-order predators. No data were available for first-order predators. The bioconcentration factors for second-order predators are used for **first-order** predators. Because season was not a significant variable, only two bioconcentration factors were developed for sodium-24 (Table 5.5).

5.3.2.4 Arsenic-76

Only one bioconcentration factor is provided for arsenic-76 (Table 5.5). Season and feeding class were not significant variables. Location appears to be an important variable at the level of significance tested but was not included because of the general lack of historical data.

5.3.2.5 Neptunium-239

The finding of no difference for neptunium-239 by season or feeding class permitted just one number for the bioconcentration factor (Table 5.5).

5.3.2.6 Chromiumdl

The bioconcentration factor was computed for chromium-51. Although chromium was not included as one of the key radionuclides for this study, there were sufficient historical data in the database to compute a bioconcentration factor to test our procedures. The low median **bioconcentration** factor of 1.7 **L/kg** (Table 5.5) agrees with published literature (Walters et al. **1992),** which suggests that chromium does not accumulate in fish. The data **confirm** that season, feeding class, and location are not important variables for chromium-51.

5.4 Zinc-65 Concentrations in Salmon and Steelhead, 1960-1970

Anadromous species (fish that live part of their lives in freshwater and part in saltwater) such as chinook salmon, sockeye salmon, coho salmon, and steelhead trout travel up the Columbia River to spawn. Walters et al. (1992, Figure 4.5) summarized the time periods when these species are found in the Columbia River. According to Foerster **(1968),** sockeye, in common with other Pacific salmon species, do not feed once they enter fresh water. The evidence for lack of feeding is by stomach content analysis, decreased fat and protein content, and atrophy of digestive organs. Because feeding usually ceases prior to spawning (Brown 1957; Foerster 1968; Meehan **1991),** fish must rely on the reserves of fats and proteins stored within their bodies during the period of ocean residence to reach their natal spawning area to reproduce. Withler (1966) found that stomach samples of summer **steelhead** from the Coquihalla River in British Columbia, Canada, were largely empty, again suggesting that little feeding occurs in fresh water. The average length of residence in fresh water for anadromous species is given in Table 5.6 (Oregon Department of Fish and Wildlife and Washington Department of Fisheries 1993).

Table 5.6. Average Length of Residence in the Columbia River for Salmon and Steelhead

Type	Juvenile (months)	Spawning Adult (months)
Fall Chinook	3-6	3-4
Spring Chinook	12-24	2-5
Steelhead	12-24	3-9

Juvenile salmon and steelhead feed as they migrate downstream and spend 3-24 months in the river (Oregon Department of Fish and Wildlife and Washington Department of Fisheries 1993). Because juveniles are feeding as they travel downstream, the bioconcentration factors for juveniles are the same as for resident second-order predators (Table 5.5).

Because spawning adult anadromous species such as salmon and steelhead generally do not eat as they enter fresh water, any radionuclides assimilated would have been while feeding on organisms in the ocean. There is some speculation but no historical data to show that radionuclides might be assimilated from the water either through the mouth or gills of the fish. Should such assimilation occur, these radionuclides would be in addition the those gained from feeding in the ocean.

Appendix D shows zinc-65 concentrations in salmon and steelhead for both the Columbia River and the Pacific Ocean. Of 47 historical samples of Columbia River salmon, the data show that concentrations of zinc-65 were at or below the minimum detection level for 31 samples, and the rest of the samples varied from just above detection to a maximum concentration of 13 picocuries per gram. The highest concentrations were from salmon near the Hanford Site. On the other hand, 23 samples of ocean salmon vary from 0 to 0.38 picocuries per gram. However, the detection limit for the ocean-sampled salmon was not given. There are many reasons these data sets should not be compared. The river data included only spring chinook while the ocean samples were from fall run sockeye, silver, chinook, and chum salmon. Also some of the sample data were monthly means, yearly means, or daily means. The only conclusion that can be made from these limited historical data is that radionuclide activities in anadromous fish appear one to three orders of magnitude lower than in fish that reside in the Columbia River their entire life cycle.

Because of the relative scarcity of data, bioconcentration factors could not be calculated for salmon. At the suggestion of the Technical Steering Panel at the October 7-8, 1993 public meetings, the dose from ingestion of salmon will be modeled using two different approaches to bound the possible range of dose. In the first approach, all salmon will be assumed to be contaminated to a level of 1.0 pCi/g, regardless of source. This contamination level exceeds the average and median of the measurements by a minor safety factor. This approach will provide a lower-bound dose estimate. In the second approach, the bioconcentration factors for second-order predators will be used in the model. This is because the predator species (trout, bass, and squawfish) have similar feeding habits to those of the anadromous fish if the anadromous fish were feeding. Table 5.5 lists the median bioconcentration factors for **zinc-65** for second-order predator fish. The bioconcentration factor for phosphorus32 is the same for first- and second-order fish because statistical differences between the two groups are not apparent.

5.5 Bioconcentration Factors for Waterfowl

Historical data concerning radionuclides in waterfowl were documented as early as 1946 (Hanf et al. 1992). Historical documents for waterfowl samples are described in Hanf et al. (1992) for the period 1946 through 1972. Waterfowl data were entered into a database. That database file contains approximately 7300 measurements of radionuclides in waterfowl. Of the radionuclides of interest for the dose model, 59 percent of these measurements were for phosphorus-32 in waterfowl and 20 percent for **zinc-65.** Two general types of ducks include diver ducks (those that eat small fish and invertebrates) and puddle ducks (those that eat near-surface water plants and grain crops). A third category, geese, which feed in a similar manner to puddle ducks, was included in this summary because historical data were available. Approximately 72 percent of the measurements were for puddle ducks **(e.g.,** mallards, **gadwall, pintail,** shovelers, widgeon, and woodduck), 17 percent were for diver ducks **(e.g.,** goldeneye, bufflehead, canvasback, merganser, coot, scaup, and ruddyduck), and 11 percent were for geese.

These historical measurements provide a basis for calculating the Columbia River **bioconcen-**tration factors for waterfowl. WSU-CHARIMA modeled river concentrations (Walters et al. 1994) were used in the bioconcentration factor computations for diver ducks, puddle ducks, and geese (Table 5.7). Bioconcentration factors for diver ducks and puddle ducks combined are also given. WSU-CHARIMA modeled data were available for 1960-1970. The waterfowl data for the year 1967 were reserved for model validation. Therefore, the bioconcentration factors were developed from historical waterfowl measurements from 1960-1970, excluding 1967.

Table 5.7. Median Bioconcentration Factors for Columbia River Waterfowl

Radionuclide	Waterfowl	Median Bioconcentration **Factor[a] (L/kg)**
Phosphorus-32	**geese**	240
Phosphorus-32	diver ducks	620
Phosphorus-32	puddle ducks	290
Phosphorus-32	diver and puddle ducks	340
Zinc-65	**geese**	22
Zinc45	diver ducks	53
Zinc-65	puddle ducks	44
Zinc-65	diver and puddle ducks	44

(a) **Median bioconcentration factors are rounded to two significant digits.**

Analysis of the data show that diver ducks had significantly higher bioconcentration factors for phosphorus-32 than either puddle ducks or geese. The bioconcentration factors for puddle ducks were not significantly different from those for geese.

Much of the waterfowl data were from head samples (30 percent) rather than from muscle samples. Comparison of data using head samples to compute bioconcentration factors with data using muscle samples shows no significant differences. Therefore, both type of samples were grouped together. River location for the waterfowl samples was not an important variable. Time also appeared not to be significant, but then waterfowl were sampled only during the winter months, which is the usual harvest period by hunters. Forty-two percent of approximately 1200 waterfowl measurements for phosphorus-32 were lower than the historical detection limit. Twelve percent of the 516 measurements for zinc45 were at the historical detection limit. Amounts lower than detectable levels were included in the calculation of bioconcentration factors.

A model for estimating concentrations in ducks is described in Napier (1993, p. 43) and Baker and Soldat (1992, p. 5). Given this model and the bioconcentration factors in Table 5.7, which were developed from historical data and the WSU-CHARIMA modeled water concentrations (Walters et al. 1994), the concentration of radionuclides in waterfowl can be computed for years in which historical data are lacking.

5.6 Radionuclide Concentrations in Upland Gamebirds, 1967-1970

Historical samples of radionuclides in upland gamebirds (pheasants and quail) were lacking in Hanford documents until about 1967. A database was compiled for the years 1967-1970, which is summarized in Appendix F. Nearly 30 percent of the measurements were taken from the head only which had been collected from hunters. Unlike the waterfowl, the radionuclides in upland gamebird head and muscle were significantly different. Therefore, the measurements from gamebird heads were deleted in this summary, and measurements only from muscle samples were used. Only muscle sample measurements were used because the muscle is the edible part.

Nearly all of the upland gamebird samples were listed as either from Hanford or White Bluffs (across the river from the single-pass production reactors). Historically, upland gamebirds were sampled only during October and December. Phosphorus-32 in pheasants was significantly less than in quail. Because zinc45 concentrations in pheasant and quail were not significantly different, the two sets of data were combined. The median concentrations of phosphorus-32 and zinc-65 in upland gamebirds are given in Table 5.8.

5.7 Radionuclide Concentrations in Shellfish, 1960-1970

Zinc-65 and phosphorus-32 were monitored near the mouth of the Columbia River as early as 1959. Walters et al. (1992) summarized average radionuclide concentrations found in Willapa Bay water for 1959-1977. Hanf et al. (1992) describe sources for historical information on radionuclides in shellfish. After the last reactor was shut down in early 1971, the concentrations measured in shellfish dropped below detection levels within a year.

Table 5.8. Median Concentrations of Radionuclide in Gamebirds near the Hanford Site

Radionuclide	Upland **Gamebird**	Median **Concentration**[a] (pCi\g)	Number of Samples
Phosphorus-32	pheasant	2.4	46
Phosphorus-32	quail	4.1	98
Zinc-65	pheasant and quail combined	4.8	144
(a) **Median concentration values are rounded to two significant digits.**			

A database was created from documents listed by **Hanf** et al. (1992). The summary statistics of this database for phosphorus-32 and **zinc-65** are listed in Appendix G for such locations as Willapa Bay, **Astoria,** Cannon Beach, Coos Bay, Seaside Beach, **Tillamook** Bay, and Agate Beach (see sampling location map in Figure 4.5 of Hanf et al. 1992). This study is primarily interested in **zinc-65** concentrations in oysters at Willapa Bay because oysters generally contain higher concentrations of **zinc-65** than other marine organisms (Wilson and Foster 1964). Willapa Bay was chosen because many of the commercial oysters came from that area.

The total reactor output by year (Heeb and Bates 1994) is compared to the average **zinc-65** in oysters at Willapa Bay (Figure 5.1). A general linear model (SAS Institute, Inc. 1989) was used to determine the regression coefficient for comparing **zinc-65** in oysters with reactor production. The **coefficient** is 0.0019. Using this information, it is possible to calculate the concentration of radioactivity of **zinc-65** in oysters for years in which there are little or no historical data (1944-1959). The reactor output by year was regressed against the concentration of zinc-65 in oysters by year for Willapa Bay. The resulting regression was significant with $R^2 = 0.83$. The following equation describes the conversion of reactor production to radioactivity in oysters.

$$\text{WBO (pCi/g zinc–65)} = 1.9 \times 10^{-3}\ C \qquad (3)$$

where WBO = radioactivity of **zinc-65** in Willapa Bay oysters
1.9×10^{-3} = regression coefficient
C = total **Ci/year** from the single-pass production reactors at Hanford as given in Heeb and Bates (1994).

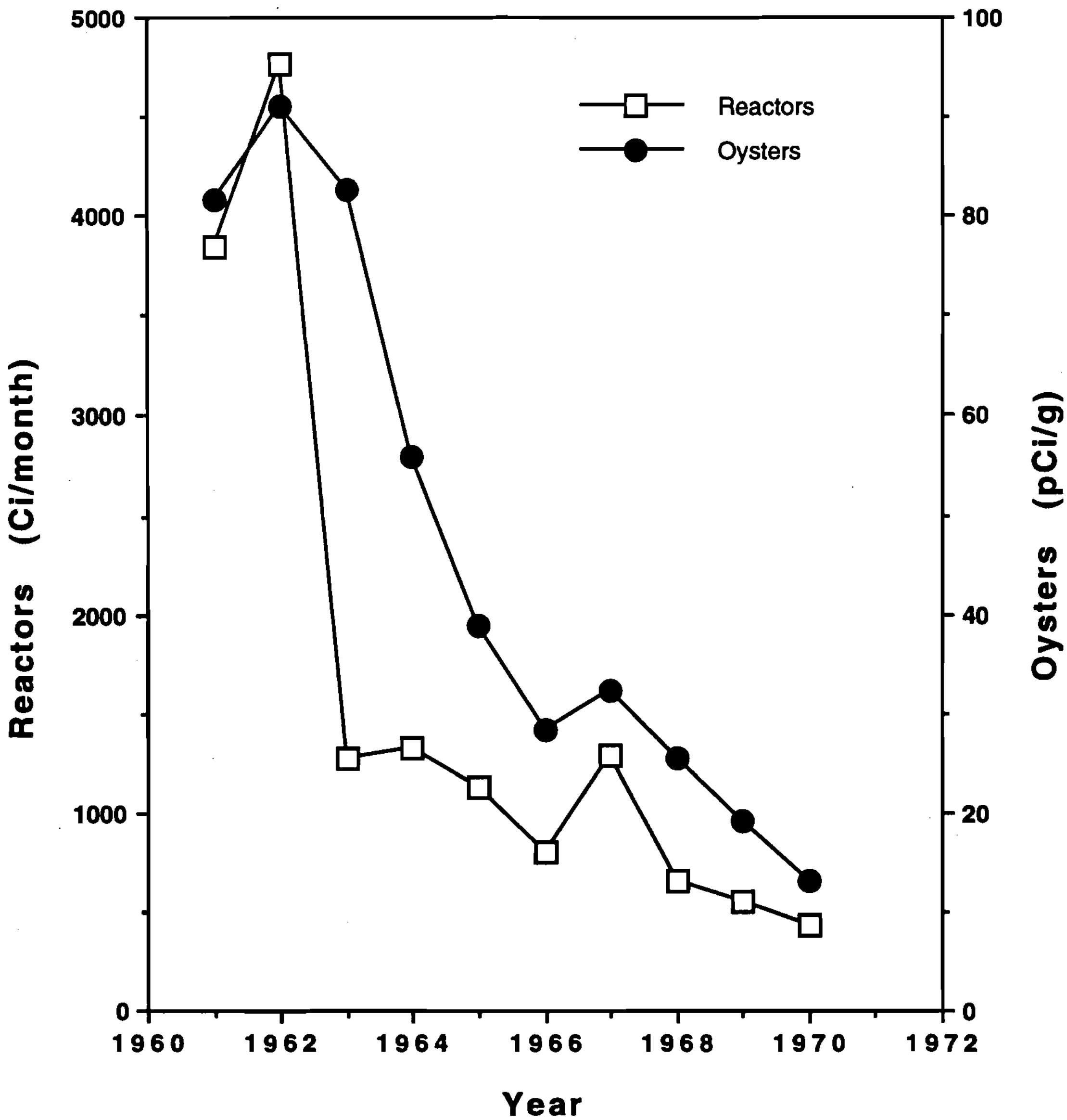

Figure 5.1. Zinc-65 in Willapa Bay Oysters Compared with Hanford's Production Reactor Output

6.0 Results

The results of the Environmental Monitoring Data Task are the accumulated databases of historical environmental data. The environmental monitoring databases contain all historical environmental data that could be located. Completeness of the databases was evaluated by the staff of the Environmental Monitoring Data Task as well as the staff members of those tasks whose work required the historical data. The conclusion was that enough environmental monitoring information has been identified and/or reconstructed to satisfy the objectives of the HEDR Project. Finding new information later would not change any dose estimates by more than 5 percent.

Because only limited historical environmental data qualified for use in the calculation of dose, computer models had to be developed. Historical data are only used directly in the HEDR Project to estimate dose from the consumption of salmon and oysters for those dates when salmon and oyster data are available. Otherwise, the historical data are used in calculations to estimate the concentrations. In the case of oysters, a regression analysis establishes a representative concentration of radionuclides in oysters. For dose estimates from fish and waterfowl, bioconcentration factors were developed from the existing historical data. These bioconcentration factors are used to extrapolate data for the years when no data exist. All other types of historical monitoring data are too sparse in spatial and temporal coverage to provide direct input to the dose calculations. That input has been estimated by computer models. Selected sets of historical data have then been used for comparison with the concentrations estimated by the computer models. These comparisons indicate that the models adequately approximate the actual environmental contamination.

7.0 References

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Appendix A

Summary Radionuclide Concentrations in Columbia River Water, 1960-1970

Appendix A

Summary Radionuclide Concentrations in Columbia River Water, 1960-1970

The following tables summarize the Columbia River Water Database that was collected and provided to the Surface-Water Transport **Subtask** and the Environmental Pathways and Dose Estimates **Subtask** Group to support dose calculations. This water database is summarized separately for grab samples (Table A.l) and for composite samples (Table A.2).

About **15,000** measurements of radionuclide concentrations in river water were entered from documents for the period 1960-1970. Of the **15,000** measurements in the Columbia River water database, nearly 6000 water measurements for the five key radionuclides (phosphorus-32, **zinc-65,** neptunium-239, arsenic-76, and sodium-24) were included in the river water summary table. Phosphorus32 and **zinc-65** measurements were the most common measurements taken by **Hanford** personnel, accounting for 75 percent of the measurements. The summary is sorted by nuclide, location, and year.

The water database is summarized separately for grab samples (Table A.1) and for composite samples (Table A.2). Grab samples were taken by collecting a sample volume of river water at one location at one moment in time. Composite samples were generally taken by a mechanical device over a period of one week at one location. Radionuclides with short half-lives **(e.g.,** neptunium-239, arsenic-76, and sodium-24) were typically measured from grab samples. Radionuclides with longer half-lives **(e.g.,** phosphorus32 and zinc-65) were measured by both methods. Summary statistics for various locations and radionuclides are included in this file.

The column headings are described below:

OBS = Line number (not part of the data)
Nuclide = Radionuclide; standard abbreviations for the element and the isotope number
Location = Location where the sample was collected
Year = Year sample collected
N = Number of samples collected
Mean = Average in picocuries per gram **(pCi/g)**
STD = Standard deviation of the mean
Max = Maximum measurement
Median = Middle measurement
Min = Minimum measurement
P95 = Ninety-fifth percentile
P5 = Fifth percentile

Table A.1. Radionuclide Concentrations in Columbia River Water Grab Samples (pCi/g)

OBS	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
1	as76	300area	64	10	1471.00	657.51	2500	1450.0	400.0	2500	400.0
2	as76	hanford	62	24	1541.25	888.30	4800	1200.0	620.0	2700	730.0
3	as76	hanford	63	15	2274.00	1432.16	5000	2000.0	650.0	5000	650.0
4	as76	hanford	65	9	380.00	226.77	910	330.0	150.0	910	150.0
5	as76	hanfordferry	60	25	4814.80	2791.16	11000	4900.0	470.0	9000	1000.0
6	as76	hanfordferry	61	26	3675.77	3542.69	14000	2300.0	380.0	13000	460.0
7	as76	pasco	60	51	1483.53	675.56	3300	1400.0	320.0	2800	410.0
8	as76	pasco	61	52	1219.62	1040.92	5100	790.0	210.0	3400	300.0
9	as76	pasco	62	27	467.04	164.43	870	450.0	180.0	770	220.0
10	as76	pasco	63	24	754.58	421.19	1700	645.0	180.0	1400	260.0
11	as76	pasco	64	16	659.38	304.40	1200	655.0	180.0	1200	180.0
12	as76	richland	63	8	1236.25	560.46	1800	1450.0	540.0	1800	540.0
13	as76	richland	64	17	1250.59	725.56	2400	1100.0	300.0	2400	300.0
14	as76	richland	65	11	1040.91	739.13	2900	1000.0	170.0	2900	170.0
15	as76	richland	66	12	421.75	299.95	900	415.5	5.0	900	5.0
16	as76	richland	67	12	397.50	195.83	700	350.0	130.0	700	130.0
17	as76	richland	68	12	324.42	188.29	590	340.0	73.0	590	73.0
18	as76	richland	69	12	310.00	131.84	560	275.0	110.0	560	110.0
19	as76	richland	70	5	129.60	50.80	180	140.0	48.0	180	48.0
20	as76	ringold	65	9	373.99	353.33	1100	310.0	4.9	1100	4.9
21	as76	ringold	66	12	322.42	204.81	610	355.0	5.0	610	5.0
22	as76	ringold	67	11	277.09	138.19	480	320.0	88.0	480	88.0
23	as76	ringold	68	3	383.33	61.10	450	370.0	330.0	450	330.0
24	na24	300area	64	10	4680.00	1534.64	6500	4950.0	1900.0	6500	1900.0
25	na24	hanford	62	24	6112.92	2836.53	11000	6350.0	610.0	10000	1100.0
26	na24	hanford	63	15	7586.67	3399.34	13000	6800.0	3200.0	13000	3200.0
27	na24	hanford	65	9	1661.11	513.43	2300	1700.0	750.0	2300	750.0
28	na24	hanfordferry	60	25	6772.00	3627.39	14000	5800.0	2800.0	14000	2800.0
29	na24	hanfordferry	61	26	9465.38	3913.66	16000	9600.0	2300.0	16000	2500.0
30	na24	pasco	60	51	1502.75	561.68	3000	1500.0	390.0	2400	700.0
31	na24	pasco	61	52	1840.38	693.62	3200	1850.0	620.0	2900	690.0
32	na24	pasco	62	27	1554.07	523.53	2400	1600.0	170.0	2300	690.0

Table A.1. (contd)

OBS	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
33	na24	pasco	63	25	1630.00	560.69	3100	1600.0	750.0	2500	850.0
34	na24	pasco	64	16	1466.88	638.14	2600	1250.0	680.0	2600	680.0
35	na24	richland	63	8	3400.00	781.94	4600	3550.0	2300.0	4600	2300.0
36	na24	richland	64	17	3541.18	1669.23	5600	4300.0	1100.0	5600	1100.0
37	na24	richland	65	9	3062.22	1427.18	5100	3000.0	860.0	5100	860.0
38	na24	richland	66	12	2564.17	1747.02	5500	2750.0	35.0	5500	35.0
39	na24	richland	67	12	2641.67	1175.86	5200	2450.0	1000.0	5200	1000.0
40	na24	richland	68	12	2216.67	1168.40	3900	2050.0	700.0	3900	700.0
41	na24	richland	69	13	1654.62	874.27	3100	1700.0	210.0	3100	210.0
42	na24	richland	70	23	1013.04	536.10	2300	830.0	60.0	2300	590.0
43	na24	ringold	65	9	1456.11	1184.73	3700	1600.0	35.0	3700	35.0
44	na24	ringold	66	12	2733.33	1698.34	4900	3100.0	35.0	4900	35.0
45	na24	ringold	67	11	2236.36	1209.36	4800	2200.0	600.0	4800	600.0
46	na24	ringold	68	3	2466.67	305.51	2800	2400.0	2200.0	2800	2200.0
47	np239	300area	64	10	2401.00	914.70	3800	2350.0	910.0	3800	910.0
48	np239	hanford	62	24	2085.42	867.87	3900	2000.0	690.0	3600	890.0
49	np239	hanford	63	15	3077.33	1510.44	6400	3000.0	860.0	6400	860.0
50	np239	hanford	65	9	630.00	392.91	1500	610.0	320.0	1500	320.0
51	np239	hanfordfeny	60	25	7052.00	4037.65	16000	7100.0	1700.0	13000	1800.0
52	np239	hanfordfeny	61	27	5054.44	4188.06	17000	3300.0	700.0	13000	870.0
53	np239	pasco	60	51	3311.37	2016.63	11000	3400.0	670.0	6500	770.0
54	np239	pasco	61	52	2364.81	2005.92	9800	1600.0	360.0	6900	520.0
55	np239	pasco	62	27	980.74	411.28	1900	880.0	340.0	1700	380.0
56	np239	pasco	63	25	1608.80	1144.68	6300	1400.0	530.0	2300	600.0
57	np239	pasco	64	16	1355.00	628.90	2300	1400.0	310.0	2300	310.0
58	np239	richland	63	8	2237.50	1076.95	3700	1850.0	1000.0	3700	1000.0
59	np239	richland	64	17	2625.29	1451.74	5600	2800.0	640.0	5600	640.0
60	np239	richland	65	10	1655.00	804.643	2700	1750.0	320.0	2700	320.0
61	np239	richland	66	12	769.17	527.420	1700	755.0	10.0	1700	10.0
62	np239	richland	67	12	1099.17	591.968	2600	895.0	450.0	2600	450.0
63	np239	richland	68	12	1013.33	517.658	2000	960.0	330.0	2000	330.0
64	np239	richland	69	12	1090.00	525.686	2100	1060.0	350.0	2100	350.0
65	np239	richland	70	5	582.00	459.696	1400	380.0	320.0	1400	320.0
66	np239	ringold	65	9	620.56	680.754	2200	460.0	15.0	2200	15.0

Table A.1. (contd)

OBS	Nuclide	ion	Year	N	Mean	STD	Max	Median	Min	P95	P5
67	np239	ringold	66	12	464.17	302.488	1100	480.0	10.0	1100	10.0
68	np239	ringold	67	11	662.73	334.457	1400	740.0	200.0	1400	200.0
69	np239	ringold	68	3	886.67	265.016	1100	970.0	590.0	1100	590.0
70	np239	vancouver	60	22	135.18	106.153	480	115.0	23.0	280	25.0
71	np239	vancouver	61	21	109.95	76.575	330	110.0	28.0	230	30.0
72	np239	vancouver	62	19	56.84	53.224	180	50.0	0.0	180	0.0
73	np239	vancouver	63	12	82.17	71.985	190	92.0	0.0	190	0.0
74	np239	vancouver	64	3	25.43	22.958	47	28.0	1.3	47	1.3
75	p32	300area	64	9	272.89	150.516	500	300.0	66.0	500	66.0
76	p32	astoria	65	11	18.00	10.431	45	17.0	5.0	45	5.0
77	p32	astoria	66	12	12.17	9.880	33	10.0	2.0	33	2.0
78	p32	astoria	67	12	14.33	6.329	24	14.5	2.0	24	2.0
79	p32	astoria	68	12	8.25	4.372	17	8.0	3.0	17	3.0
80	p32	astoria	69	11	7.45	4.719	19	8.0	2.0	19	2.0
81	p32	astoria	70	12	3.25	2.261	9	3.0	1.0	9	1.0
82	p32	beaverarmy	65	11	35.82	22.225	83	22.0	12.0	83	12.0
83	p32	beaverarmy	66	13	14.85	10.808	34	11.0	2.0	34	2.0
84	p32	beaverarmy	67	12	20.17	13.717	45	11.5	3.0	45	3.0
85	p32	beaverarmy	68	12	14.33	9.198	31	11.0	3.0	31	3.0
86	p32	beaverarmy	69	11	10.18	4.400	19	11.0	3.0	19	3.0
87	p32	beaverarmy	70	12	3.50	2.195	8	3.0	1.0	8	1.0
88	p32	gable	65	11	34.55	20.825	74	22.0	14.0	74	14.0
89	p32	gable	66	14	16.07	10.866	30	11.0	1.0	30	1.0
90	p32	gable	67	12	21.33	14.386	53	11.5	2.0	53	2.0
91	p32	gable	68	12	13.17	9.340	30	8.5	4.0	30	4.0
92	p32	gable	69	11	8.36	4.007	13	8.0	2.0	13	2.0
93	p32	gable	70	12	3.67	2.605	9	3.0	1.0	9	1.0
94	p32	hanford	62	24	260.63	120.125	600	260.0	86.0	430	99.0
95	p32	hanford	63	15	332.00	164.716	650	290.0	130.0	650	130.0
96	p32	hanford	65	9	89.11	42.818	160	71.0	42.0	160	42.0
97	p32	hanfordferry	60	25	384.08	234.884	850	390.0	84.0	800	94.0
98	p32	hanfordferry	61	27	404.74	326.113	1300	380.0	12.0	950	44.0
99	p32	pasco	60	51	210.27	141.931	580	200.0	21.0	570	35.0
100	p32	pasco	61	52	264.37	199.556	890	225.0	24.0	670	36.0

Table A.1. (contd)

OBS	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
101	p32	pasco	62	27	176.00	106.834	590	170.0	50.0	330	57.0
102	p32	pasco	63	25	193.72	107.366	430	180.0	54.0	350	58.0
103	p32	pasco	64	16	208.38	135.260	400	225.0	39.0	400	39.0
104	p32	richland	63	8	276.38	175.000	490	210.0	71.0	490	71.0
105	p32	richland	64	16	285.31	188.863	630	310.0	60.0	630	60.0
106	p32	richland	65	9	304.78	188.826	560	220.0	43.0	560	43.0
107	p32	richland	66	12	195.92	122.835	370	220.0	6.0	370	6.0
108	p32	richland	67	12	194.75	127.765	480	185.0	54.0	480	54.0
109	p32	richland	68	6	203.00	133.709	410	180.0	38.0	410	38.0
110	p32	ringold	65	9	82.92	74.698	230	78.0	6.0	230	6.0
111	p32	ringold	66	12	123.42	91.119	280	115.5	6.0	280	6.0
112	p32	ringold	67	11	87.09	59.495	180	74.0	12.0	180	12.0
113	p32	ringold	68	3	81.33	39.716	110	98.0	36.0	110	36.0
114	p32	roosterrock	65	10	32.40	28.489	100	27.0	2.0	100	2.0
115	p32	roosterrock	66	12	37.25	27.893	92	32.5	1.0	92	1.0
116	p32	roosterrock	67	12	35.17	26.354	82	24.0	2.0	82	2.0
117	p32	roosterrock	68	12	21.42	14.532	45	19.0	3.0	45	3.0
118	p32	roosterrock	69	9	14.78	7.934	26	15.0	3.0	26	3.0
119	p32	roosterrock	70	9	4.111	1.965	8.00	4.00	2.00	8.00	2.00
120	p32	thedallesdam	65	2	111.500	6.364	116.00	111.50	107.00	116.00	107.00
121	p32	thedallesdam	66	5	47.200	22.027	80.00	42.00	20.00	80.00	20.00
122	p32	thedallesdam	67	3	62.000	21.656	82.00	65.00	39.00	82.00	39.00
123	p32	thedallesdam	68	2	39.000	32.527	62.00	39.00	16.00	62.00	16.00
124	p32	thedallesdam	69	4	19.500	15.264	42.00	14.00	8.00	42.00	8.00
125	p32	thedallesdam	70	3	4.333	2.517	7.00	4.00	2.00	7.00	2.00
126	p32	umatilla	65	14	29.517	26.924	101.12	17.50	3.24	101.12	3.24
127	p32	umatilla	66	12	39.998	20.526	85.37	38.85	12.70	85.37	12.70
128	p32	umatilla	69	1	9.000	.	9.00	9.00	9.00	9.00	9.00
129	p32	umatilla	70	2	22.000	11.314	30.00	22.00	14.00	30.00	14.00
130	p32	vancouver	60	22	40.545	23.599	86.00	33.00	11.00	85.00	16.00
131	p32	vancouver	61	23	68.000	55.383	190.00	48.00	11.00	180.00	18.00
132	p32	vancouver	62	19	37.853	28.835	110.00	30.00	8.40	110.00	8.40
133	p32	vancouver	63	21	32.367	25.243	93.00	23.00	5.00	73.00	8.30
134	p32	vancouver	64	6	50.333	11.656	61.00	54.00	31.00	61.00	31.00

Table A.1. (contd)

OBS	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
135	n65	300area	64	10	251.600	125.774	460.00	265.00	93.00	460.00	93.00
136	zn65	arlington	'63	1	35.000	.	35.00	35.00	35.00	35.00	35.00
137	n65	arlington	64	2	148.500	12.021	157.00	148.50	140.00	157.00	140.00
138	zn65	astoria	63	11	35.000	0.000	35.00	35.00	35.00	35.00	35.00
139	zn65	astoria	64	11	35.182	0.603	37.00	35.00	35.00	37.00	35.00
140	zn65	astoria	65	12	35.000	0.000	35.00	35.00	35.00	35.00	35.00
141	zn65	astoria	66	12	33.333	9.717	57.00	35.00	21.00	57.00	21.00
142	zn65	astoria	67	10	29.400	12.972	60.00	23.50	21.00	60.00	21.00
143	zn65	astoria	68	12	31.667	11.015	49.00	28.50	21.00	49.00	21.00
144	zn65	astoria	69	12	26.750	9.517	49.00	21.00	21.00	49.00	21.00
145	zn65	astoria	70	12	21.000	0.000	21.00	21.00	21.00	21.00	21.00
146	zn65	beaverarmyt	62	2	39.000	5.657	43.00	39.00	35.00	43.00	35.00
147	zn65	beaverarmyt	63	10	55.900	30.031	131.00	47.00	35.00	131.00	35.00
148	zn65	beaverarmyt	64	11	41.364	14.834	81.00	35.00	35.00	81.00	35.00
149	zn65	beaverarmyt	65	12	39.250	8.966	64.00	35.00	35.00	64.00	35.00
150	zn65	beaverarmyt	66	14	39.214	19.526	97.00	35.00	21.00	97.00	21.00
151	zn65	beaverarmyt	67	10	32.200	24.439	100.00	21.00	21.00	100.00	21.00
152	zn65	beaverarmyt	68	12	43.833	32.962	119.00	24.00	21.00	119.00	21.00
153	n65	beaverarmyt	69	11	33.273	15.304	63.00	25.00	21.00	63.00	21.00
154	zn65	beaverarmyt	70	12	22.250	3.279	32.00	21.00	21.00	32.00	21.00
155	zn65	ftstevensstpk	63	1	35.000	.	35.00	35.00	35.00	35.00	35.00
156	zn65	gable	63	10	35.000	0.000	35.00	35.00	35.00	35.00	35.00
157	zn65	gable	64	11	36.273	2.867	43.00	35.00	35.00	43.00	35.00
158	zn65	gable	65	12	37.667	4.849	51.00	35.00	35.00	51.00	35.00
159	n65	gable	66	14	34.357	10.035	62.00	35.00	21.00	62.00	21.00
160	zn65	gable	67	10	33.000	18.135	78.00	25.50	21.00	78.00	21.00
161	zn65	gable	68	12	49.167	30.771	102.00	38.50	21.00	102.00	21.00
162	n65	gable	69	12	24.000	6.339	39.00	21.00	18.00	39.00	18.00
163	zn65	gable	70	12	22.167	4.041	35.00	21.00	21.00	35.00	21.00
164	n65	hanford	62	24	417.917	324.372	1800.00	350.00	150.00	630.00	160.00
165	zn65	hanford	63	15	534.667	273.283	950.00	500.00	180.00	950.00	180.00
166	zn65	hanfordferry	60	25	564.000	254.951	930.00	610.00	180.00	920.00	180.00
167	zn65	hanfordferry	61	27	599.630	366.611	1300.00	510.00	150.00	1300.00	170.00
168	zn65	hoodriver	64	12	46.227	17.910	76.30	50.57	11.93	76.30	11.93

Table A.1. (contd)

OBS	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
169	zn65	johndaydam	62	2	45.500	9.192	52.00	45.50	39.00	52.00	39.00
170	zn65	johndaydam	63	5	47.200	19.980	81.00	35.00	35.00	81.00	35.00
171	zn65	pasco	60	51	297.706	124.693	540.00	300.00	81.00	530.00	110.00
172	zn65	pasco	61	52	342.942	215.021	800.00	265.00	63.00	730.00	76.00
173	zn65	pasco	62	27	224.074	115.368	510.00	190.00	110.00	450.00	110.00
174	zn65	pasco	63	25	218.160	113.107	540.00	190.00	87.00	450.00	89.00
175	zn65	pasco	64	16	197.250	141.997	610.00	185.00	30.00	610.00	30.00
176	zn65	richland	63	8	411.250	346.964	1200.00	325.00	130.00	1200.00	130.00
177	zn65	richland	64	17	441.706	445.774	1800.00	256.00	63.00	1800.00	63.00
178	zn65	richland	65	11	178.636	99.185	390.0	170.000	66.00	390.0	66.00
179	zn65	richland	66	12	135.000	98.330	340.0	115.000	20.00	340.0	20.00
180	zn65	richland	67	12	198.667	111.092	470.0	160.000	74.00	470.0	74.00
181	zn65	richland	68	12	130.583	95.351	380.0	125.000	30.00	380.0	30.00
182	zn65	richland	69	5	354.000	318.088	890.0	180.000	120.00	890.0	120.00
183	zn65	richland	70	3	360.000	182.483	570.0	270.000	240.00	570.0	240.00
184	zn65	ringold	67	7	87.286	45.485	180.0	78.000	44.00	180.0	44.00
185	zn65	ringold	68	3	81.667	10.693	94.0	76.000	75.00	94.0	75.00
186	zn65	roosterrock	63	9	45.111	16.366	74.0	35.000	35.00	74.0	35.00
187	zn65	roosterrock	64	13	48.846	12.935	75.0	49.000	35.00	75.0	35.00
188	zn65	roosterrock	65	13	90.231	100.568	407.0	54.000	35.00	407.0	35.00
189	zn65	roosterrock	66	16	42.500	17.588	96.0	35.000	21.00	96.0	21.00
190	zn65	roosterrock	67	10	51.800	21.202	84.0	49.500	21.00	84.0	21.00
191	zn65	roostemk	68	12	47.667	25.360	94.0	50.000	21.00	94.0	21.00
192	zn65	roostemk	69	10	42.900	28.661	83.0	21.000	21.00	83.0	21.00
193	zn65	roosterrock	70	12	23.083	4.274	33.0	21.000	21.00	33.0	21.00
194	zn65	thedallesdam	65	2	84.500	40.305	113.0	84.500	56.00	113.0	56.00
195	zn65	thedallesdam	66	5	61.600	18.078	79.0	59.000	35.00	79.0	35.00
196	m65	thedallesdam	67	3	131.667	37.072	161.0	144.000	90.00	161.0	90.00
197	zn65	thedallesdam	68	2	109.500	125.158	198.0	109.500	21.00	198.0	21.00
198	zn65	thedallesdam	69	4	47.250	33.866	92.0	38.000	21.00	92.0	21.00
199	zn65	thedallesdam	70	3	23.667	4.619	29.0	21.000	21.00	29.0	21.00
200	zn65	tillamookbay	62	3	35.000	0.000	35.0	35.000	35.00	35.0	35.00
201	zn65	tillamookbay	63	12	35.000	0.000	35.0	35.000	35.00	35.0	35.00
202	zn65	tillamookbay	64	9	35.000	0.000	35.0	35.000	35.00	35.0	35.00

Table A.1. (contd)

OBS	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
203	zn65	tillarnookbay	65	12	35.000	0.000	35.0	35.000	35.00	35.0	35.00
204	zn65	tillamookbay	66	12	31.500	6.332	35.0	35.000	21.00	35.0	21.00
205	*n65*	tillamookbay	67	7	21.000	0.000	21.0	21.000	21.00	21.0	21.00
206	zn65	umatilla	63	1	86.000	.	86.0	86.000	86.00	86.0	86.00
207	*n65*	umatilla	65	16	21.664	14.167	49.6	20.665	0.74	49.6	0.74
208	zn65	umatilla	66	30	39.977	20.236	78.1	40.160	15.92	76.8	16.15
209	zn65	umatilla	69	1	60.000	.	60.0	60.000	60.00	60.0	60.00
210	zn65	umatilla	70	2	90.000	79.196	146.0	90.000	34.00	146.0	34.00
211	zn65	vancouver	60	22	74.727	45.115	150.0	64.500	12.00	150.0	13.00
212	zn65	vancouver	61	23	83.348	53.619	170.0	100.000	11.00	160.0	17.00
213	zn65	vancouver	62	19	63.789	36.465	140.0	70.000	15.00	140.0	15.00
214	zn65	vancouver	63	22	62.591	47.713	220.0	55.500	17.00	110.0	17.00
215	*n65*	vancouver	64	6	55.833	12.057	75.0	50.500	43.00	75.0	43.00
216	*n65*	willapabay	63	10	9.280	1.902	11.1	9.800	6.20	11.1	6.20

Table **A.2.** Radionuclide Concentrations in Columbia River Water Composite Samples **(pCi/g)**

OBS	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
1	np239	mcnarydam	64	25	335.800	190.425	660.00	320.00	70.00	600.00	85.00
2	np239	richland	70	4	113.500	31.554	154.00	110.00	80.00	154.00	80.00
3	p32	300area	64	32	195.750	134.005	440.00	195.00	13.00	430.00	17.00
4	p32	bonnevilledam	64	59	16.725	7.121	36.00	15.00	4.40	30.00	7.10
5	p32	bonnevilledam	65	82	21.754	12.320	50.00	20.00	3.00	41.00	5.50
6	p32	bonnevilledam	66	71	23.332	12.289	45.00	23.00	6.00	44.00	6.00
7	p32	bonnevilledam	67	52	25.038	14.276	67.00	18.00	9.00	60.00	10.00
8	p32	bonnevilledam	68	23	15.378	7.471	39.00	14.00	6.00	27.00	7.80
9	p32	bonnevilledam	69	26	13.835	6.657	32.00	12.00	6.00	24.00	6.30
10	p32	bonnevilledam	70	21	6.624	1.447	11.00	6.00	6.00	10.00	6.00
11	p32	mcnarydam	64	91	70.505	47.070	190.00	65.00	8.10	160.00	9.50
12	p32	mcnarydam	65	103	52.318	43.518	240.00	40.00	8.10	120.00	9.80
13	p32	mcnarydam	66	109	83.807	116.014	714.00	61.00	6.00	240.00	6.00
14	p32	mcnarydam	67	51	49.490	29.629	180.00	44.00	6.00	96.00	10.00
15	p32	mcnarydam	68	46	39.217	19.745	83.00	39.50	6.00	74.00	6.00
16	p32	mcnarydam	69	26	33.046	17.910	72.00	29.50	6.00	69.00	9.20
17	p32	pasco	64	34	85.618	59.836	270.00	69.00	17.00	230.00	23.00
18	p32	pasco	65	51	86.392	56.522	200.00	70.00	5.00	190.00	16.00
19	p32	richland	64	28	126.000	76.200	280.00	100.00	28.00	270.00	42.00
20	p32	richland	65	51	126.525	89.219	420.00	100.00	4.40	300.00	18.00
21	p32	richland	66	51	136.961	79.616	300.00	150.00	6.00	260.00	6.00
22	p32	richland	67	52	128.346	77.597	380.00	120.00	21.00	270.00	26.00
23	p32	richland	68	52	92.192	54.925	250.00	89.00	12.00	220.00	18.00
24	p32	richland	69	51	72.745	37.842	200.00	68.00	10.00	150.00	21.00
25	p32	richland	70	43	31.537	18.623	93.00	28.00	6.00	65.00	9.10
26	p32	thedallesdam	64	60	32.467	17.584	78.00	29.50	10.00	62.00	11.00
27	p32	thedallesdam	65	100	30.892	23.396	88.00	22.50	4.90	85.00	6.00
28	zn65	300area	64	32	263.469	158.243	900.00	270.00	68.00	530.00	68.00
29	zn65	bonnevilledam	64	66	65.939	46.758	190.00	44.50	17.00	170.00	23.00
30	zn65	bonnevilledam	65	90	59.844	44.667	230.00	42.00	14.00	150.00	20.00
31	zn65	bonnevilledam	66	76	45.934	36.686	164.00	28.50	20.00	122.00	20.00
32	zn65	bonnevilledam	67	52	61.462	51.122	290.00	46.50	20.00	160.00	20.00

Table A.2. (contd)

OBS	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
33	m65	bonnevilledam	68	23	30.130	9.915	46.00	29.00	20.00	45.00	20.00
34	m65	bonnevilledam	69	26	29.038	10.686	55.00	24.50	20.00	49.00	20.00
35	zn65	bonnevilledam	70	25	20.360	1.254	25.00	20.00	20.00	24.00	20.00
36	zn65	mcnarydam	64	99	76.646	42.566	190.00	65.00	16.00	150.00	22.00
37	zn65	mcnarydam	65	102	69.039	47.139	200.00	46.00	20.00	170.00	21.00
38	m65	mcnarydam	66	105	62.876	32.296	121.00	67.00	20.00	120.00	20.00
39	zn65	mcnarydam	67	52	82.212	49.161	220.00	64.50	20.00	160.00	24.00
40	zn65	mcnarydam	68	46	51.109	19.105	110.00	48.50	20.00	89.00	27.00
41	m65	mcnarydam	69	26	44.231	23.097	140.00	40.50	20.00	64.00	20.00
42	zn65	pasco	64	37	143.784	90.796	460.00	120.00	27.00	280.00	39.00
43	zn65	pasco	65	52	160.750	95.657	440.00	120.00	63.00	340.00	65.00
44	zn65	richland	64	28	205.464	118.189	570.00	160.00	70.00	380.00	83.00
45	zn65	richland	65	51	232.549	139.898	650.00	160.00	70.00	500.00	100.00
46	zn65	richland	66	51	196.471	134.186	680.00	170.00	20.00	450.00	21.00
47	zn65	richland	67	52	270.365	395.426	2800.00	195.00	37.00	640.00	86.00
48	zn65	richland	68	53	85.340	34.108	170.00	85.00	29.00	150.00	32.00
49	zn65	richland	69	51	71.431	30.276	210.00	66.00	25.00	120.00	32.00
50	zn65	richland	70	51	35.078	18.244	99.00	31.00	20.00	76.00	20.00
51	zn65	thedallesdam	64	68	73.941	53.001	310.00	62.00	14.00	140.00	19.00
52	zn65	thedallesdam	65	88	54.818	35.092	170.00	44.00	20.00	110.00	20.00
53	zn65	umatilla	66	5	14.512	5.886	22.21	14.34	8.24	22.21	8.24

Appendix B

Summary Radionuclide Concentrations in Columbia River Fish, 1960-1967

Appendix B

Summary Radionuclide Concentrations in Columbia River Fish, 1960-1967

Table B.1 summarizes the five radionuclides in fish from the Columbia River that are pertinent to the HEDR Project. The summary is sorted by the fish feeding regime, radionuclide, sample location, and year. The column heading "class" designates one of the three feeding classifications. Omnivore fish tend to eat periphyton and macrophytes. First-order predators eat insect larvae, zooplankton, and herbivorous fish, while second-order predators eat first-order predator fish. The database summarizes measurements of omnivore fish (bullhead, catfish, suckers, whitefish, chiselmouth, chub, minnows, shiners, and sturgeon), first-order predator fish (perch, crappie, punkinseed, and bluegill), and second-order predator fish (bass, trout, and squawfish).

The column headings are described below:

OBS = Line number (not part of the data)
Class = Omnivore (omni), first-order predator (pre1), second-order predator (pre2)
Nuclide = Radionuclide; standard abbreviations for the element and isotope number
Location = Location where the sample was collected.
Year = Year sample collected
N = Number of samples collected
Mean = Average in wet weight
STD = Standard deviation of the mean
Max = Maximum measurement
Median = Middle measurement
Min = Minimum measurement
P95 = Ninety-fifth percentile
P5 = Fifth percentile.

Table B.1. Radionuclide Concentrations in Fish in the Columbia River, 1960-1967 **(pCi/g** Wet Weight)

OBS	Class	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
1	omni	as76	burbank	61	53	471.70	704.11	2600.0	100.00	100.00	2300.00	100.00
2	omni	as76	hanford	61	142	258.45	364.49	2100.0	100.00	100.00	1100.00	100.00
3	omni	as76	mcnary	61	3	100.00	0.00	100.0	100.00	100.00	100.00	100.00
4	omni	as76	priestrapids	61	96	312.50	1016.24	9100.0	100.00	100.00	570.00	100.00
5	omni	as76	richland	61	62	2782.26	5515.00	28000.0	100.00	100.00	12000.00	100.00
6	omni	as76	ringold	61	61	1033.28	2913.15	14000.0	100.00	100.00	8700.00	100.00
7	omni	na24	100dringold	68	10	57.94	18.11	85.9	53.95	22.30	85.90	22.30
8	omni	na24	100fringold	67	20	33.13	40.83	115.0	1.95	0.00	102.35	0.00
9	omni	na24	burbank	64	200	0.02	0.25	3.3	0.00	0.00	0.00	0.00
10	omni	na24	burbank	65	161	0.58	1.88	12.0	0.00	0.00	4.00	0.00
11	omni	na24	hanford	65	101	28.26	18.60	78.0	25.00	0.00	66.00	5.00
12	omni	na24	hanfordringold	67	11	107.51	26.10	149.0	98.70	75.10	149.00	75.10
13	omni	na24	rchlandsacajawea	67	5	18.14	18.73	43.0	18.30	0.00	43.00	0.00
14	omni	na24	richland	64	100	7.83	11.32	52.0	1.35	0.00	34.50	0.00
15	omni	na24	richland	65	140	34.58	28.77	145.0	29.00	0.00	93.50	2.00
16	omni	na24	richland	66	30	24.40	20.40	100.0	17.50	5.00	66.00	5.00
17	omni	na24	richland	68	10	9.09	10.26	30.2	5.10	0.00	30.20	0.00
18	omni	na24	ringold	65	72	27.89	21.68	90.0	22.50	0.00	68.00	0.00
19	omni	na24	ringold	66	98	39.18	23.46	120.0	35.50	0.00	98.00	11.00
20	omni	na24	ringold	67	253	40.55	23.11	164.0	37.80	1.00	77.40	7.95
21	omni	na24	ringold	68	138	36.10	22.69	139.0	32.45	2.09	76.60	5.96
22	omni	na24	ringoldrichland	67	9	67.68	34.58	117.0	74.20	11.60	117.00	11.60
23	omni	np239	burbank	61	83	35.14	45.52	260.0	10.00	10.00	130.00	10.00
24	omni	np239	hanford	61	140	59.81	95.46	580.0	22.00	10.00	230.00	10.00
25	omni	np239	mcnary	61	6	13.83	6.65	27.0	11.00	10.00	27.00	10.00
26	omni	np239	priestrapids	61	98	90.19	489.52	4800.0	10.00	10.00	230.00	10.00
27	omni	np239	richland	61	67	133.21	227.53	810.0	20.00	10.00	660.00	10.00
28	omni	np239	ringold	61	61	97.54	154.95	810.0	41.00	10.00	480.00	10.00
29	omni	p32	burbank	60	3	1116.67	828.15	1900.0	1200.00	250.00	1900.00	250.00
30	omni	p32	burbank	61	99	243.57	499.84	3400.0	69.00	2.00	1300.00	2.00
31	omni	p32	burbank	62	160	94.14	239.21	1900.0	24.00	2.00	365.00	3.00
32	omni	p32	burbank	63	128	104.49	134.14	860.0	57.50	2.00	360.00	4.00

Table B.1. (contd)

OBS	Class	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
33	omni	p32	burbank	64	164	42.28	59.60	400.0	17.00	2.00	150.00	3.00
34	omni	p32	burbank	65	143	58.92	66.95	330.0	36.00	1.00	230.00	2.00
35	omni	p32	burbank	66	141	19.35	28.83	200.0	8.00	1.00	62.00	2.00
36	omni	p32	burbank	67	139	42.78	76.99	517.0	8.00	1.00	212.00	1.00
37	omni	p32	coyoterapids	62	2	3.00	1.41	4.0	3.00	2.00	4.00	2.00
38	omni	p32	hanford	60	11	9769.09	10394.65	31000.0	5200.00	390.00	31000.00	390.00
39	omni	p32	hanford	61	128	484.56	941.30	6800.0	135.00	2.00	2400.00	7.80
40	omni	p32	hanford	62	147	327.65	568.37	3700.0	130.00	7.00	1400.00	16.00
41	omni	p32	hanford	63	104	224.21	327.44	2200.0	110.00	10.00	740.00	16.00
42	omni	p32	hanford	64	130	269.11	282.96	1600.0	185.00	4.00	770.00	9.00
43	omni	p32	hanford	65	211	235.23	383.12	2800.0	110.00	2.00	730.00	11.00
44	omni	p32	hanford	66	120	67.21	73.58	370.0	39.50	1.00	230.00	7.50
45	omni	p32	hover	67	60	18.87	28.90	158.0	7.50	1.00	68.00	1.00
46	omni	p32	isla	64	10	8.20	14.09	48.0	3.00	2.00	48.00	2.00
47	omni	p32	isla	66	40	54.43	81.13	350.0	17.00	1.00	250.00	1.50
48	omni	p32	islaudview	67	133	66.56	167.58	1380.0	3.00	1.00	385.00	1.00
49	omni	p32	mcnary	60	13	673.62	899.34	3200.0	280.00	79.00	3200.00	79.00
50	omni	p32	mcnary	61	6	129.50	147.17	380.0	50.00	17.00	380.00	17.00
51	omni	p32	mcnary	62	90	189.41	288.83	2200.0	92.00	2.00	610.00	5.00
52	omni	p32	mcnary	63	40	186.95	167.48	780.0	135.00	4.00	505.00	7.50
53	omni	p32	mcnary	64	40	59.83	53.60	280.0	51.00	3.00	160.00	5.00
54	omni	p32	mcnary	65	35	36.83	39.20	140.0	18.00	1.00	130.00	1.00
55	omni	p32	mcnary	66	10	27.80	32.64	110.0	16.00	3.00	110.00	3.00
56	omni	p32	nearreactors	60	9	10856.67	15035.83	47000.0	5800.00	210.00	47000.00	210.00
57	omni	p32	priestrapids	60	12	184.57	226.75	770.0	140.00	6.80	770.00	6.80
58	omni	p32	priestrapids	61	129	312.23	1373.86	14000.0	2.50	2.00	1500.00	2.00
59	omni	p32	priestrapids	62	118	74.27	154.47	790.0	8.00	2.00	480.00	2.00
60	omni	p32	priestrapids	63	8	202.50	212.30	500	130.00	3.0	500.0	3.00
61	omni	p32	priestrapids	64	103	76.87	138.45	1100	35.00	2.0	280.0	7.00
62	omni	p32	priestrapids	65	54	79.87	213.26	1300	8.00	1.0	560.0	1.00
63	omni	p32	priestrapids	66	15	54.40	65.91	220	29.00	2.0	220.0	2.00
64	omni	p32	priestrapids	67	18	157.11	326.57	990	1.50	1.0	990.0	1.00
65	omni	p32	richland	60	12	3316.58	3689.68	12000	2050.00	19.0	12000.0	19.00
66	omni	p32	richland	61	71	759.27	812.65	2800	330.00	2.0	2400.0	6.20

Table B.1. (contd)

OBS	Class	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
67	omni	p32	richland	62	104	330.55	414.11	2200	175.00	3.0	1000.0	12.00
68	omni	p32	richland	63	28	179.86	232.89	840	68.50	4.0	830.0	8.00
69	omni	p32	richland	64	78	134.73	244.48	1400	45.50	2.0	550.0	8.00
70	omni	p32	richland	65	163	303.39	425.17	1800	140.00	3.0	1400.0	11.00
71	omni	p32	richland	66	48	91.65	116.25	460	50.00	1.0	400.0	13.00
72	omni	p32	ringold	60	11	3300.91	3653.12	13000	2900.00	320.0	13000.0	320.00
73	omni	p32	ringold	61	68	643.30	1089.28	5200	230.00	2.0	3900.0	2.90
74	omni	p32	ringold	62	156	477.30	479.84	2300	340.00	8.0	1700.0	45.00
75	omni	p32	ringold	63	67	742.79	641.77	2800	630.00	2.0	1900.0	31.00
76	omni	p32	ringold	64	128	594.41	676.13	4900	405.00	7.0	1800.0	20.00
77	omni	p32	ringold	65	113	318.33	317.72	1200	190.00	4.0	1000.0	10.00
78	omni	p32	ringold	66	267	99.82	133.86	830	42.00	2.0	390.0	8.00
79	omni	p32	ringold	67	261	244.03	291.20	1600	150.00	1.0	880.0	4.00
80	omni	zn65	burbank	61	99	66.41	58.84	360	44.00	5.0	180.0	11.00
81	omni	zn65	burbank	62	168	54.15	44.11	200	40.00	5.0	130.0	7.00
82	omni	zn65	burbank	63	175	28.56	21.01	110	20.00	0.0	70.0	8.00
83	omni	zn65	burbank	64	198	19.88	11.14	64	15.00	6.0	45.0	9.00
84	omni	zn65	burbank	65	215	17.95	14.23	100	13.00	2.7	51.0	5.10
85	omni	zn65	burbank	66	158	18.31	16.15	110	12.00	0.4	49.0	3.40
86	omni	zn65	burbank	67	140	11.00	9.92	70	7.65	1.1	28.0	2.75
87	omni	zn65	coyoterapids	62	1	5.00	.	5	5.00	5.0	5.0	5.00
88	omni	zn65	hanford	61	162	109.63	175.22	1400	63.00	5.0	380.0	10.00
89	omni	zn65	hanford	62	182	65.33	47.49	400	55.00	5.0	140.0	20.00
90	omni	zn65	hanford	63	102	37.74	20.19	130	30.00	5.0	80.0	10.00
91	omni	zn65	hanford	64	127	33.91	19.68	190	31.00	7.0	61.0	13.00
92	omni	zn65	hanford	65	211	24.41	14.33	90	21.00	1.2	52.0	5.00
93	omni	zn65	hanford	66	120	23.04	11.51	85	22.00	3.6	39.5	7.40
94	omni	zn65	hover	67	60	8.46	5.91	31	6.90	2.1	23.5	3.45
95	omni	zn65	isla	64	22	10.00	6.32	28	7.00	5.0	22.0	5.00
96	omni	zn65	isla	66	48	11.16	16.67	72	5.95	0.9	66.0	1.10
97	omni	zn65	islandview	67	136	6.69	9.20	74	4.30	0.3	19.0	0.80
98	omni	zn65	mcnary	61	6	98.83	36.98	150	105.00	51.0	150.0	51.00
99	omni	zn65	mcnary	62	90	50.54	28.98	140	40.00	9.0	100.0	20.00
100	omni	zn65	mcnary	63	40	22.35	11.23	70	20.00	6.0	40.0	9.00

Table B.1. (contd)

OBS	Class	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
101	omni	zn65	mcnary	≤4	37	20.41	8.30	37	20.00	5.0	37.0	6.00
102	omni	zn65	mcnary	≤5	36	15.51	10.53	52	13.50	0.3	38.0	2.10
103	omni	zn65	mcnary	≤6	10	5.76	2.35	10	4.70	3.0	10.0	3.00
104	omni	zn65	priestrapids	≤1	113	44.91	101.94	1000	14.00	5.0	130.0	5.00
105	omni	zn65	priestrapids	≤2	122	29.28	32.09	130	8.00	5.0	90.0	5.00
106	omni	zn65	priestrapids	≤3	10	30.00	21.47	60	30.00	5.0	60.0	5.00
107	omni	zn65	priestrapids	≤4	114	35.75	20.49	94	34.50	5.0	75.0	7.00
108	omni	zn65	priestrapids	≤5	55	11.77	13.36	66	6.00	0.3	38.0	0.50
109	omni	zn65	priestrapids	≤6	16	9.93	8.64	26	9.00	0.3	26.0	0.30
110	omni	zn65	priestrapids	≤7	18	8.64	14.00	42	1.85	0.3	42.0	0.30
111	omni	zn65	richland	≤1	71	137.28	259.75	1700	81.00	5.0	230.0	11.00
112	omni	zn65	richland	≤2	128	69.25	55.07	330	60.00	5.0	200.0	10.00
113	omni	zn65	richland	≤3	33	33.94	23.64	90	30.00	5.0	90.0	5.00
114	omni	zn65	richland	≤4	85	21.56	20.76	130	14.00	4.0	62.0	5.00
115	omni	zn65	richland	≤5	164	29.79	20.72	200	27.00	0.4	66.0	6.00
116	omni	zn65	richland	≤6	48	29.21	18.84	82	28.50	0.8	63.0	4.40
117	omni	zn65	ringold	≤1	68	118.63	368.58	3000	63.00	5.0	180.0	5.00
118	omni	zn65	ringold	≤2	183	65.38	34.96	200	60.00	5.0	130.0	20.00
119	omni	zn65	ringold	≤3	68	51.84	25.700	120.0	50.00	5.0	90.0	8.0
120	omni	zn65	ringold	≤4	135	39.08	18.259	100.0	39.00	5.0	72.0	8.0
121	omni	zn65	ringold	≤5	114	30.51	17.825	74.0	29.00	0.8	65.0	4.9
122	omni	zn65	ringold	≤6	269	20.01	11.243	70.0	19.00	1.7	41.0	4.8
123	omni	zn65	ringold	≤7	261	19.87	11.315	70.0	19.00	0.4	41.0	3.3
124	omni	zn65	woodyisland	≤7	1	1.00	.	1.0	1.00	1.0	1.0	1.0
125	pre1	as76	burbank	≤1	11	100.00	0.000	100.0	100.00	100.0	100.0	100.0
126	pre1	na24	burbank	≤4	136	0.00	0.000	0.0	0.00	0.0	0.0	0.0
127	pre1	na24	burbank	≤5	87	0.64	2.147	16.0	0.00	0.0	4.0	0.0
128	pre1	na24	hanford	≤5	3	14.33	6.351	18.0	18.00	7.0	18.0	7.0
129	pre1	na24	richland	≤4	23	0.00	0.000	0.0	0.00	0.0	0.0	0.0
130	pre1	na24	richland	≤5	2	0.00	0.000	0.0	0.00	0.0	0.0	0.0
131	pre1	na24	richland	≤6	1	10.00	.	10.0	10.00	10.0	10.0	10.0
132	pre1	np239	burbank	≤1	20	16.65	12.253	51.0	10.00	10.0	48.0	10.0
133	pre1	p32	burbank	≤1	30	109.35	219.743	920.0	4.10	2.0	670.0	2.0
134	pre1	p32	burbank	≤2	34	67.41	77.285	320.0	40.50	6.0	260.0	7.0

Table B.1. (contd)

OBS	Class	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
135	prel	p32	burbank	63	64	171.41	195.043	970.0	105.00	4.0	620.0	7.0
136	prel	p32	burbank	64	122	34.14	60.514	400.0	14.00	2.0	180.0	3.0
137	prel	p32	burbank	65	60	63.50	62.079	280.0	46.50	0.0	210.0	2.0
138	prel	p32	burbank	66	94	16.59	25.985	190.0	8.50	1.0	67.0	1.0
139	prel	p32	burbank	67	138	34.51	81.454	503.0	1.50	1.0	218.0	1.0
140	prel	p32	hanford	60	1	1600.00	.	1600.0	1600.00	1600.0	1600.0	1600.0
141	prel	p32	hanford	62	4	110.00	160.225	350.0	33.00	24.0	350.0	24.0
142	prel	p32	hanford	63	17	918.24	540.199	1900.0	870.00	140.0	1900.0	140.0
143	prel	p32	hanford	64	2	1350.00	494.975	1700.0	1350.00	1000.0	1700.0	1000.0
144	prel	p32	hanford	65	3	71.67	41.259	110.0	77.00	28.0	110.0	28.0
145	prel	p32	hanford	66	6	41.17	32.981	100.0	39.00	6.0	100.0	6.0
146	prel	p32	hover	67	96	29.53	43.335	269.0	7.00	1.0	94.0	1.0
147	prel	p32	isla	66	3	49.67	38.682	86.0	54.00	9.0	86.0	9.0
148	prel	p32	islandview	67	103	34.97	70.357	348.0	4.00	1.0	174.0	1.0
149	prel	p32	mcnary	60	1	220.00	.	220.0	220.00	220.0	220.0	220.0
150	prel	p32	mcnary	62	1	55.00	.	55.0	55.00	55.0	55.0	55.0
151	prel	p32	richland	62	22	113.59	168.925	680.0	26.00	7.0	410.0	8.0
152	prel	p32	richland	63	50	233.14	395.701	2300.0	99.00	7.0	1000.0	8.0
153	prel	p32	richland	64	13	35.31	68.387	250.0	12.00	3.0	250.0	3.0
154	prel	p32	richland	65	2	57.50	47.376	91.0	57.50	24.0	91.0	24.0
155	prel	p32	richland	66	2	168.00	214.960	320.0	168.00	16.0	320.0	16.0
156	prel	p32	ringold	60	1	470.00	.	470.0	470.00	470.0	470.0	470.0
157	prel	p32	ringold	62	2	462.00	619.426	900.0	462.00	24.0	900.0	24.0
158	prel	m65	burbank	61	31	40.69	40.171	210.0	28.00	5.0	120.0	6.3
159	prel	zn65	burbank	62	36	33.06	19.686	90.0	30.00	10.0	80.0	10.0
160	prel	m65	burbank	63	95	25.65	10.329	50.0	30.00	8.0	50.0	10.0
161	prel	zn65	burbank	64	136	14.94	4.380	32.0	14.00	6.0	22.0	10.0
162	prel	zn65	burbank	65	93	12.38	5.454	27.0	11.00	1.1	23.0	5.6
163	prel	zn65	burbank	66	106	11.93	8.620	89.0	11.00	0.4	21.0	6.8
164	prel	zn65	burbank	67	139	8.96	5.193	36.0	7.70	2.1	20.0	4.2
165	prel	zn65	hanford	62	6	20.00	30.000	80.0	5.00	5.0	80.0	5.0
166	prel	zn65	hanford	63	17	56.47	25.725	90.0	50.00	10.0	90.0	10.0
167	prel	zn65	hanford	64	2	25.00	5.657	29.0	25.00	21.0	29.0	21.0
168	prel	zn65	hanford	65	3	24.77	15.351	40.0	25.00	9.3	40.0	9.3

Table B.1. (contd)

OBS	Class	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
169	pre1	zn65	hanford	≤6	7	9.70	7.221	19.0	10.00	0.2	19.0	0.2
170	pre1	zn65	hover	≤7	96	10.60	6.282	42.0	9.55	1.2	22.0	4.4
171	pre1	zn65	isla	≤6	3	5.30	3.559	9.4	3.50	3.0	9.4	3.0
172	pre1	zn65	islandview	≤7	103	8.36	5.617	29.0	6.60	0.9	20.0	2.0
173	pre1	zn65	mcnary	≤2	1	40.00	.	40.0	40.00	40.0	40.0	40.0
174	pre1	zn65	richland	≤2	45	29.40	25.822	100.0	20.00	5.0	80.0	5.0
175	pre1	zn65	richland	≤3	58	32.43	24.898	120.0	30.00	5.0	80.0	5.0
176	pre1	zn65	richland	≤4	23	26.78	13.823	58.0	24.00	5.0	52.0	5.0
177	pre1	zn65	richland	≤5	2	14.50	4.950	18.0	14.50	11.0	18.0	11.0
178	pre1	zn65	richland	≤6	2	24.50	4.95	28	24.5	21.0	28.	21.0
179	pre1	zn65	ringold	≤2	5	24.00	42.49	100	5.0	5.0	100	5.0
180	pre2	as76	burbank	≤1	13	100.00	0.00	100	100.0	100.0	100	100.0
181	pre2	as76	hanford	≤1	33	195.15	170.88	700	100.0	100.0	570	100.0
182	pre2	as76	priestrapids	≤1	15	116.00	59.26	330	100.0	100.0	330	100.0
183	pre2	as76	richland	≤1	9	1522.22	3294.61	9900	100.0	100.0	9900	100.0
184	pre2	as76	ringold	≤1	17	1024.71	2081.38	8600	100.0	100.0	8600	100.0
185	pre2	na24	100fringold	≤7	1	44.00	.	44	44.0	44.0	44	44.0
186	pre2	na24	burbank	≤4	7	0.00	0.00	0	0.0	0.0	0	0.0
187	pre2	na24	burbank	≤5	7	0.00	0.00	0	0.0	0.0	0	0.0
188	pre2	na24	hanford	≤5	10	11.70	9.14	26	7.5	0.0	26	0.0
189	pre2	na24	hanfordringold	≤7	1	130.00	.	130	130.0	130.0	130	130.0
190	pre2	na24	richland	≤4	3	0.00	0.00	0	0.0	0.0	0	0.0
191	pre2	na24	richland	≤5	14	11.36	9.48	27	11.5	0.0	27	0.0
192	pre2	na24	richland	≤6	2	8.00	1.41	9	8.0	7.0	9	7.0
193	pre2	na24	ringold	≤5	18	28.44	64.04	260	6.0	1.0	260	1.0
194	pre2	na24	ringold	≤6	11	14.00	16.36	47	8.0	0.0	47	0.0
195	pre2	np239	burbank	≤1	17	10.88	2.55	19	10.0	10.0	19	10.0
196	pre2	np239	hanford	≤1	32	21.31	20.96	110	10.0	10.0	54	10.0
197	pre2	np239	priestrapids	≤1	12	14.25	6.85	29	10.0	10.0	29	10.0
198	pre2	np239	richland	≤1	9	158.89	315.26	900	10.0	10.0	900	10.0
199	pre2	np239	ringold	≤1	16	119.19	292.07	1200	20.0	10.0	1200	10.0
200	pre2	p32	burbank	≤1	21	39.59	73.11	290	6.6	2.0	160	2.0
201	pre2	p32	burbank	≤2	19	27.42	43.30	190	11.0	3.0	190	3.0
202	pre2	p32	burbank	≤3	2	11.00	11.31	19	11.0	3.0	19	3.0

Table B.1. (contd)

OBS	Class	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
203	pre2	p32	burbank	64	6	47.50	61.08	150	14.5	4.0	150	4.0
204	pre2	p32	burbank	65	3	77.33	38.55	120	67.0	45.0	120	45.0
205	pre2	p32	burbank	66	4	3.25	1.71	5	3.5	1.0	5	1.0
206	pre2	p32	burbank	67	25	21.24	61.32	280	1.0	1.0	147	1.0
207	pre2	p32	coyoterapids	62	1	74.00	.	74	74.0	74.0	74	74.0
208	pre2	p32	hanford	60	10	3323.00	4415.43	15000	1500.0	310.0	15000	310.0
209	pre2	p32	hanford	61	34	202.65	359.34	1500	45.0	2.0	1400	2.7
210	pre2	p32	hanford	62	29	119.31	128.35	490	56.0	5.0	380	5.0
211	pre2	p32	hanford	63	20	437.80	480.38	1400	235.0	2.0	1300	3.5
212	pre2	p32	hanford	64	17	415.00	460.22	1630	290.0	17.0	1630	17.0
213	pre2	p32	hanford	65	7	75.14	132.44	370	23.0	4.0	370	4.0
214	pre2	p32	hanford	66	7	35.00	32.83	86	22.0	10.0	86	10.0
215	pre2	p32	hover	67	14	2.43	2.90	12	1.5	1.0	12	1.0
216	pre2	p32	isla	66	1	17.00	.	17	17.0	17.0	17	17.0
217	pre2	p32	islandview	67	57	12.18	26.17	131	1.0	1.0	80	1.0
218	pre2	p32	mcnary	60	1	180.00	.	180	180.0	180.0	180	180.0
219	pre2	p32	mcnary	62	38	41.50	57.66	230	15.5	5.0	200	5.0
220	pre2	p32	mcnary	63	5	188.00	73.96	310	160.0	120.0	310	120.0
221	pre2	p32	mcnary	64	2	10.50	3.54	13	10.5	8.0	13	8.0
222	pre2	p32	priestrapids	60	1	15.00	.	15	15.0	15.0	15	15.0
223	pre2	p32	priestrapids	61	26	7.68	19.13	96	2.0	2.0	35	2.0
224	pre2	p32	priestrapids	62	39	15.74	30.23	130	6.0	2.0	120	2.0
225	pre2	p32	priestrapids	64	1	11.00	.	11	11.0	11.0	11	11.0
226	pre2	p32	priestrapids	65	3	11.67	10.02	23	8.0	4.0	23	4.0
227	pre2	p32	priestrapids	67	6	11.33	20.04	52	3.0	1.0	52	1.0
228	pre2	p32	richland	60	3	3900.00	3903.84	7900	3700.0	100.0	7900	100.0
229	pre2	p32	richland	61	15	380.56	697.34	2600	45.0	2.2	2600	2.2
230	pre2	p32	richland	62	29	131.55	186.42	670	28.0	5.0	520	6.0
231	pre2	p32	richland	63	3	286.67	150.44	460	210.0	190.0	460	190.0
232	pre2	p32	richland	64	3	22.33	8.74	32	20.0	15.0	32	15.0
233	pre2	p32	richland	65	18	243.39	151.00	500	230.0	5.0	500	5.0
234	pre2	p32	richland	66	2	59.50	47.38	93	59.5	26.0	93	26.0
235	pre2	p32	ringold	60	3	1473.33	2188.98	4000	270.0	150.0	4000	150.0
236	pre2	p32	ringold	61	24	102.68	266.50	1300	12.5	3.5	240	3.6

Table B.1. (contd)

OBS	Class	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
237	pre2	p32	ringold	62	49	157.347	296.748	1600.0	28.00	5.0	770.0	6.0
238	pre2	p32	ringold	63	13	30.462	30.385	120.0	27.00	2.0	120.0	2.0
239	pre2	p32	ringold	64	40	55.675	234.553	1500.0	15.00	5.0	52.0	6.0
240	pre2	p32	ringold	65	21	170.571	266.481	820.0	19.00	6.0	740.0	6.0
241	pre2	p32	ringold	66	19	107.789	95.462	350.0	96.00	3.0	350.0	3.0
242	pre2	zn65	burbank	61	23	23.948	13.390	46.0	25.00	5.0	42.0	5.0
243	pre2	zn65	burbank	62	20	21.600	9.577	40.0	20.00	5.0	40.0	6.0
244	pre2	zn65	burbank	63	1	6.000	.	6.0	6.00	6.0	6.0	6.0
245	pre2	zn65	burbank	64	7	16.429	5.350	28.0	15.00	13.0	28.0	13.0
246	pre2	zn65	burbank	65	7	9.714	2.582	13.0	8.70	7.2	13.0	7.2
247	pre2	zn65	burbank	66	4	10.175	1.912	13.0	9.35	9.0	13.0	9.0
248	pre2	zn65	burbank	67	25	6.284	2.981	15.0	5.40	1.2	12.0	2.3
249	pre2	zn65	coyoterapids	62	1	30.000	.	30.0	30.00	30.0	30.0	30.0
250	pre2	zn65	hanford	61	39	53.279	29.187	150.0	50.00	6.9	120.0	20.0
251	pre2	zn65	hanford	62	35	57.143	26.298	120.0	50.00	20.0	100.0	20.0
252	pre2	zn65	hanford	63	20	27.000	13.416	50.0	20.00	10.0	50.0	10.0
253	pre2	zn65	hanford	64	17	37.529	20.221	100.0	32.00	24.0	100.0	24.0
254	pre2	zn65	hanford	65	10	19.960	23.421	85.0	12.00	4.9	85.0	4.9
255	pre2	zn65	hanford	66	7	15.429	3.359	20.0	15.00	11.0	20.0	11.0
256	pre2	zn65	hover	67	14	5.350	1.726	7.7	5.65	2.7	7.7	2.7
257	pre2	zn65	isla	66	1	2.400	.	2.4	2.40	2.4	2.4	2.4
258	pre2	zn65	islandview	67	57	4.665	4.532	17.0	2.60	0.4	14.0	0.4
259	pre2	zn65	mcnary	62	39	28.308	15.643	60.0	20.00	5.0	60.0	5.0
260	pre2	zn65	mcnary	63	5	18.000	8.367	30.0	20.00	10.0	30.0	10.0
261	pre2	zn65	mcnary	64	2	14.500	0.707	15.0	14.50	14.0	15.0	14.0
262	pre2	zn65	mcnary	65	1	6.200	.	6.2	6.20	6.2	6.2	6.2
263	pre2	zn65	priestrapids	61	24	8.417	8.631	36.0	5.00	5.0	34.0	5.0
264	pre2	zn65	priestrapids	62	40	12.325	18.155	70.0	5.00	5.0	65.0	5.0
265	pre2	zn65	priestrapids	64	1	13.000	.	13.0	13.00	13.0	13.0	13.0
266	pre2	zn65	priestrapids	65	4	13.750	20.118	43.0	5.75	0.5	43.0	0.5
267	pre2	zn65	priestrapids	67	6	1.200	0.735	2.2	1.20	0.4	2.2	0.4
268	pre2	zn65	richland	61	16	58.875	89.452	350.0	31.00	14.0	350.0	14.0
269	pre2	zn65	richland	62	34	35.882	20.169	100.0	30.00	10.0	80.0	10.0
270	pre2	zn65	richland	63	3	30.000	0.000	30.0	30.00	30.0	30.0	30.0

Table B.1. (contd)

OBS	Class	Nuclide	Location	Year	N	Mean	STD	Max	Median	Min	P95	P5
271	pre2	zn65	richland	64	2	39.500	33.234	63.0	39.50	16.0	63.0	16.0
272	pre2	zn65	richland	65	19	17.100	4.529	26.0	17.00	9.9	26.0	9.9
273	pre2	zn65	richland	66	2	11.450	5.020	15.0	11.45	7.9	15.0	7.9
274	pre2	zn65	ringold	61	24	44.233	37.635	170.0	32.00	5.0	120.0	8.6
275	pre2	zn65	ringold	62	52	35.096	27.839	170.0	30.00	5.0	80.0	5.0
276	pre2	zn65	ringold	63	18	17.778	5.483	30.0	20.00	10.0	30.0	10.0
277	pre2	zn65	ringold	64	40	24.650	5.736	42.0	25.00	12.0	32.5	14.5
278	pre2	zn65	ringold	65	23	25.561	23.268	87.0	15.00	8.6	81.0	9.3
279	pre2	zn65	ringold	66	24	36.042	26.389	92.0	24.50	11.0	90.0	11.0
280	shad	na24	burbank	65	2	0.000	0.000	0.0	0.00	0.0	0.0	0.0
281	shad	p32	islandview	67	2	66.500	45.962	99.0	66.50	34.0	99.0	34.0
282	shad	zn65	islandview	67	2	5.000	4.101	7.9	5.00	2.1	7.9	2.1

Appendix C

Bioconcentration Factors for Columbia River Fish

Appendix C

Bioconcentration Factors for Columbia River Fish

Using WSU-CHARIMA modeled river concentrations (Holley et al. 1993; Walters et al. 1994), all historical fish concentration measurements were matched with river concentration values by location and month. Table C.1 shows the bioconcentration factors for arsenic-76, chromium-51, neptunium-239, sodium-24, phosphorus-32, and zinc-65.

The column headings are described below:

Nuclide = Radionuclide; standard abbreviations for the element and isotope number
Class = Omnivore (omni), first-order predator (pre1), second-order predator (pre2), both first-order predator and second-order predator @re), all fish combined (all)
Season = Cool season from December-May, warm season from June-November, and "all" denotes the two seasons combined.
N = Number of samples collected
Mean = Average in liter/kilogram (L/kg)
STD = Standard deviation of the mean
Max = Maximum measurement
Median = Middle measurement
Min = Minimum measurement
P95 = Ninety-fifth percentile
P5 = Fifth percentile

Table C.1. Bioconcentration Factors (L/kg) Derived from Fish Data and WSU-CHARIMA Modeled Water

Nuclide	Class	Season	N	Mean	STD	Max	Median	Min	P95	P5
as-76	all	all	189	1726.43	3617.55	27455.29	244.42	54.0871	8922.97	54.087
cr-51	all	all	318	4.29	6.06	68.04	1.71	0.5720	11.99	0.690
np-239	all	all	378	49.81	126.35	1704.22	21.04	2.6563	236.19	4.631
na-24	omni	all	442	9.95	8.26	69.68	8.00	0.1848	24.19	0.999
na-24	pre2	all	55	4.71	7.71	47.92	2.10	0.0954	21.12	0.095
p-32	omni	cool	1221	974.75	1897.49	31633.31	420.22	5.2578	3346.66	24.282
p-32	omni	Warm	1966	3293.74	5941.59	119942.20	1502.15	21.5471	11879.42	134.409
p-32	pre	cool	367	186.20	395.16	3613.62	76.38	0.0000	584.65	14.380
p-32	pre	Warm	611	2056.31	3286.84	29973.18	978.63	44.2122	7214.49	91.426
zn-65	omni	cool	1468	175.11	174.71	2759.76	132.33	2.7071	444.74	32.811
zn-65	omni	Warm	2034	367.52	480.80	6441.98	217.19	0.0000	1158.98	33.376
zn-65	pre1	cool	274	117.68	106.18	1401.57	97.36	2.1699	246.40	6.603
zn-65	pre1	Warm	394	313.12	272.17	1497.75	251.95	3.6283	891.46	30.331
zn-65	pre2	cool	222	102.54	118.74	752.03	67.13	6.3475	289.85	17.405
zn-65	pre2	Warm	272	165.55	162.87	1081.61	105.17	7.2023	501.00	21.770

Appendix D

Zinc-65 Concentrations in Salmon and Steelhead Trout from the Columbia River and Pacific Ocean, 1960-1970

Appendix D

Zinc-65 Concentrations in Salmon and Steelhead Trout from the Columbia River and Pacific Ocean, 1960-1970

Table D.1 shows historical data on zinc-65 concentrations in salmon and steelhead trout muscle tissue from both the Columbia River and the Pacific Ocean. Radionuclide measurements in salmon from migration routes along the Alaskan Coast are given for comparison with Pacific Ocean salmon near the mouth of the Columbia River.

An explanation of the column headings follows:

Group	=	General location where the sample was collected: Columbia River or Pacific Ocean
Type	=	Salmon or steelhead trout
Location	=	Location where the sample was collected
Year	=	Year sample collected
Month	=	Month sample collected with January represented by 1 and December by 12
Time Period	=	Designates whether the sample was an individual sample (daily = d), monthly mean (m) of several samples, or annual (a) mean of samples
Document	=	Publication number of document in which the data were found
Original Units	=	Units of sample in picocuries per gram (pCi/g) as listed in the historical document
Sample	=	Type of fish (e.g., chinook, king) sampled
Less than	=	Concentrations of zinc-65 below minimum detection
Convert	=	New value after units are standardized (pCi/g wet weight)
New Unit	=	Unit of picocuries per gram (pCi/g) after the conversion factor

Table D.1. Zinc-65 Concentrations in Muscle Tissue of Salmon and Steelhead Trout from the Columbia River and Pacific Ocean, 1960-1970

Group	Type	Location	Year	Month	Time Period	Document	Original Units	Sample	Less Than	Convert	New Unit
Columbia	Salmon	corbett	66	3	d	lcrers68	pci/g_wet	chinook		1.5000	pci/g_wet
		corbett	66	4	d	lcrers68	pci/g_wet	chinook	<	0.1000	pci/g_wet
		coyoterapids	64	9	d	bnwl90	pci/g	king	<	5.0000	pci/g_unk
		hanford	65	10	d	bnwl316app	pci/g	salmon		13.0000	pci/g_unk
		hanford	65	10	d	bnwl316app	pci/g	salmon		0.4000	pci/g_unk
		priestrapids	65	1	d	bnwl316app	pci/g	salmon	<	0.2000	pci/g_unk
		priestrapids	65	11	d	bnwl316app	pci/g	salmon	<	0.2000	pci/g_unk
		priestrapids	67	10	d	bnwl983app	pci/g	salmon		1.3000	pci/g_unk
		priestrapids	67	10	d	bnwl983app	pci/g	salmon		3.4000	pci/g_unk
		woodyisland	63	4	d	lcrers68	pci/g_wet	chinook		0.4000	pci/g_wet
		woodyisland	64	3	d	lcrers68	pci/g_wet	chinook		1.0000	pci/g_wet
		woodyisland	65	4	d	lcrers68	pci/g_wet	chinook		0.2000	pci/g_wet
		woodyisland	65	4	d	lcrers68	pci/g_wet	chinook		0.1000	pci/g_wet
		woodyisland	65	4	d	lcrers68	pci/g_wet	chinook		0.9000	pci/g_wet
		woodyisland	65	4	d	lcrers68	pci/g_wet	chinook		0.3000	pci/g_wet
		woodyisland	66	3	d	lcrers68	pci/g_wet	chinook	<	0.1000	pci/g_wet
		woodyisland	66	3	d	lcrers68	pci/g_wet	chinook	<	0.1000	pci/g_wet
		woodyisland	66	3	d	lcrers68	pci/g_wet	chinook	<	0.1000	pci/g_wet
		woodyisland	66	3	d	lcrers68	pci/g_wet	chinook		0.1000	pci/g_wet
		woodyisland	66	4	d	lcrers68	pci/g_wet	chinook	<	0.1000	pci/g_wet
		woodyisland	66	4	d	lcrers68	pci/g_wet	chinook	<	0.1000	pci/g_wet
		woodyisland	67	0	a	lcrers78	pci/g	chinook		0.2000	pci/g_unk
		woodyisland	67	3	d	lcrers68	pci/g_wet	chinook		0.1000	pci/g_wet
		woodyisland	67	4	d	lcrers68	pci/g_wet	chinook		0.1000	pci/g_wet
		woodyisland	67	4	d	lcrers68	pci/g_wet	chinook	<	0.1000	pci/g_wet
		woodyisland	67	4	d	lcrers68	pci/g_wet	chinook	<	0.1000	pci/g_wet
		woodyisland	67	4	d	lcrers68	pci/g_wet	chinook	<	0.1000	pci/g_wet
		woodyisland	68	0	a	lcrers78	pci/g	chinook	<	0.1000	pci/g_unk
		woodyisland	68	0	a	lcrers78	pci/g	chinook		0.2000	pci/g_unk
		woodyisland	68	4	d	lcrers78	pci/g_wet	chinook	<	0.1000	pci/g_wet
		woodyisland	68	4	d	lcrers78	pci/g_wet	chinook		0.2000	pci/g_wet
		woodyisland	68	4	d	lcrers78	pci/g_wet	chinook	<	0.1000	pci/g_wet
		woodyisland	68	4	d	lcrers78	pci/g_wet	chinook		0.4000	pci/g_wet
		woodyisland	68	5	d	lcrers78	pci/g_wet	chinook		0.2000	pci/g_wet
		woodyisland	69	0	a	lcrers78	pci/g	chinook		0.1000	pci/g_unk
		woodyisland	69	0	a	lcrers78	pci/g	chinook	<	0.1000	pci/g_unk
		woodyisland	69	3	d	lcrers78	pci/g_wet	chinook		0.1000	pci/g_wet
		woodyisland	69	4	d	lcrers78	pci/g_wet	chinook	<	0.1000	pci/g_wet

Table D.1. (contd)

Group	Type	Location	Year	Month	Tim	Document	Original Units	Sample	Less Than	Convert	New Unit
		woodyisland	70	0	a	lcrers78	pci/g	chinook	<	0.1000	pci/g_unk
		woodyisland	70	0	a	lcrers78	pci/g	chinook		0.1000	pci/g_unk
		woodyisland	70	3	d	lcrers78	pci/g_wet	chinook		0.2000	pci/g_wet
		woodyisland	70	4	d	lcrers78	pci/g_wet	chinook	<	0.1000	pci/g_wet
		woodyisland	70	4	d	lcrers78	pci/g_wet	chinook	<	0.1000	pci/g_wet
		woodyisland	70	4	d	lcrers78	pci/g_wet	chinook	<	0.1000	pci/g_wet
		woodyisland	70	4	d	lcrers78	pci/g_wet	chinook	<	0.1000	pci/g_wet
		woodyisland	71	0	a	lcrers78	pci/g	chinook	<	0.1000	pci/g_unk
		woodyisland	71	4	d	lcrers78	pci/g_wet	chinook	<	0.1000	pci/g_wet
Columbia	Steelhead	burbank	66	9	d	bnwl439app	pci/g	steelhead	<	0.2000	pci/g_unk
		coyoterapids	64	1	d	bnwl90	pci/g	steelhead	<	5.0000	pci/g_unk
		coyoterapids	64	2	d	bnwl90	pci/g	steelhead	<	5.0000	pci/g_unk
		coyoterapids	64	3	d	bnwl90	pci/g	steelhead	<	5.0000	pci/g_unk
		coyoterapids	64	8	d	bnwl90	pci/g	steelhead	<	5.0000	pci/g_unk
		coyoterapids	64	8	d	bnwl90	pci/g	steelhead	<	5.0000	pci/g_unk
		coyoterapids	64	8	d	bnwl90	pci/g	steelhead		7.0000	pci/g_unk
		coyoterapids	64	9	d	bnwl90	pci/g	steelhead	<	5.0000	pci/g_unk
		coyoterapids	65	1	d	bnwl316app	pci/g	steelhead	<	0.2000	pci/g_unk
		coyoterapids	65	9	d	bnwl316app	pci/g	steelhead		1.2000	pci/g_unk
		coyoterapids	65	9	d	bnwl316app	pci/g	steelhead		4.0000	pci/g_unk
		coyoterapids	65	10	d	bnwl316app	pci/g	steelhead		0.3000	pci/g_unk
		coyoterapids	66	1	d	bnwl439app	pci/g	steelhead	<	0.2000	pci/g_unk
		coyoterapids	66	1	d	bnwl439app	pci/g	steelhead	<	0.2000	pci/g_unk
		coyoterapids	66	3	d	bnwl439app	pci/g	steelhead		0.3000	pci/g_unk
		coyoterapids	66	3	d	bnwl439app	pci/g	steelhead		0.9000	pci/g_unk
		coyoterapids	66	3	d	bnwl439app	pci/g	steelhead		11.0000	pci/g_unk
		coyoterapids	66	10	d	bnwl439app	pci/g	steelhead	<	0.2000	pci/g_unk
		coyoterapids	66	10	d	bnwl439app	pci/g	steelhead	<	0.2000	pci/g_unk
		coyoterapids	67	10	d	bnwl983app	pci/g	steelhead		0.3000	pci/g_unk
		coyoterapids	67	10	d	bnwl983app	pci/g	steelhead		0.9000	pci/g_unk
		coyoterapids	67	10	d	bnwl983app	pci/g	steelhead	<	0.2000	pci/g_unk
		coyoterapids	72	9	d	bnwl1727add	uci/g_wet	steelhead	<	0.2000	pci/g_wet
		hanford	64	10	d	bnwl90	pci/g	steelhead	<	5.0000	pci/g_unk
		hanford	66	7	d	bnwl439app	pci/g	steelhead	<	0.2000	pci/g_unk
		mcnary	64	2	d	bnwl90	pci/g	steelhead	<	5.0000	pci/g_unk
		mcnary	66	10	d	bnwl439app	pci/g	steelhead	<	0.2000	pci/g_unk
		priestrapids	65	1	d	bnwl316app	pci/g	steelhead		4.4000	pci/g_unk
		priestrapids	65	1	d	bnwl316app	pci/g	steelhead		9.7000	pci/g_unk
		priestrapids	65	8	d	bnwl316app	pci/g	steelhead	<	0.2000	pci/g_unk
		priestrapids	65	8	d	bnwl316app	pci/g	steelhead	<	0.2000	pci/g_unk
		priestrapids	65	12	d	bnwl316app	pci/g	steelhead		1.8000	pci/g_unk
		priestrapids	67	10	d	bnwl983app	pci/g	steelhead	<	0.3000	pci/g_unk
		richland	65	3	d	bnwl316app	pci/g	steelhead		48.0000	pci/g_unk

Table D.1. (contd)

Group	Type	Location	Year	Month	Time	Document	Original Units	Sample	Less Than	Convert	New Unit
		ringold	64	8	d	bnwl90	pci/g	steelhead		70.0000	pci/g_unk
		ringold	64	8	d	bnwl90	pci/g	steelhead		44.0000	pci/g_unk
		ringold	64	12	d	bnwl90	pci/g	steelhead		65.0000	pci/g_unk
		ringold	64	12	d	bnwl90	pci/g	steelhead		62.0000	pci/g_unk
		ringold	65	8	d	bnwl316app	pci/g	steelhead		42.0000	pci/g_unk
		ringold	65	8	d	bnwl316app	pci/g	steelhead	<	0.2000	pci/g_unk
Ocean	Salmon	45n125w (AK) (latitude, longitude)	67	0	d	bnwl715	dis/min/kg_wet	silver		0.1755	pci/g_wet
		60n149w (AK)	67	0	d	bnwl715	dis/min/kg_wet	silver		0.0264	pci/g_wet
		60n149w	67	0	d	bnwl715	dis/min/kg_wet	silver		0.0695	pci/g_wet
		60n149w	67	0	d	bnwl715	dis/min/kg_wet	silver		0.0459	pci/g_wet
		60n150w	67	0	d	bnwl715	dis/min/kg_wet	sockeye		0.0050	pci/g_wet
		alakanuk (AK)	67	0	d	bnwl715	dis/min/kg_wet	king		0.0205	pci/g_wet
		alakanuk	67	7	m	bnwlsa2019	d/m/kg_wet	king		0.0205	pci/g_wet
		alakanuk	67	7	m	bnwlsa2019	d/m/kg_wet	chum		0.0255	pci/g_wet
		alakanuk	67	7	m	bnwlsa2019	d/m/kg–wet	chum		0.0000	pci/g_wet
		alakanuk	67	7	m	bnwlsa2019	d/m/kg_wet	chum		0.0100	pci/g_wet
		alakanuk	67	7	m	bnwlsa2019	d/m/kg_wet	chum		0.0000	pci/g_wet
		ilwaco (WA)	67	0	d	bnwl715	dis/min/kg_wet	silver		0.3805	pci/g_wet
		ilwaco	67	9	m	bnwlsa2019	d/m/kg_wet	silver		0.3805	pci/g_wet
		ilwaco	67	9	m	bnwlsa2019	d/m/kg_wet	silver		0.1755	pci/g_wet
		kenai (AK)	67	0	d	bnwl715	dis/min/kg_wet	sockeye		0.0255	pci/g_wet
		kenai	67	7	m	bnwlsa2019	d/m/kg_wet	chum		0.0909	pci/g_wet
		kenai	67	7	m	bnwlsa2019	d/m/kg–wet	sockeye		0.0255	pci/g_wet
		kenai	67	7	m	bnwlsa2019	d/m/kg_wet	sockeye		0.0050	pci/g_wet
		seward (AK)	67	0	d	bnwl715	dis/min/kg_wet	silver		0.0477	pci/g_wet
		seward	67	10	m	bnwlsa2019	d/m/kg_wet	silver		0.0477	pci/g_wet
		seward	67	10	m	bnwlsa2019	d/m/kg–wet	silver		0.0264	pci/g_wet
		seward	67	10	m	bnwlsa2019	d/m/kg–wet	silver		0.0695	pci/g_wet
		seward	67	10	m	bnwlsa2019	d/m/kg_wet	silver		0.0459	pci/g_wet

Resources

This resource list provides the complete reference information for each document noted in the column entitled "Document" in Table D.1.

BNWL90. Wilson, R. H., and R. F. Foster. 1965. *Evaluation of Radiological Conditions in the Vicinity of Hanford for* 1964. **BNWL-0090,** Battelle, Pacific Northwest Laboratories, Richland, Washington.

BNWL316app. Foster, R. F., D. Moore, and T. H. Essig. 1966. ***Evaluation*** *of Radiological Conditions in the Vicinity of Hanford for* 1965 *Appendices.* BNWL-0316-APP, Battelle, Pacific Northwest Laboratories, **Richland,** Washington

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BNWL715-Pt.2. Nielsen, J. M. ***Pacific*** *Northwest Laboratory Annual Report for* 1967 *to the USAEC Division of Biology and Medicine,* ***Volume*** *11: Physical Sciences,* Part 2. Radiological Sciences. **BNWL-715-Pt.2,** Battelle, Pacific Northwest Laboratories, Richland, Washington.

BNWL983app. Corley, J. P., and C. B. Woolridge. 1969. ***Evaluation*** *of Radiological Conditions in the Vicinity of Hanford for* ***1967*** *Appendices.* **BNWL-0983-APP, Battelle,** Pacific Northwest Laboratories, Richland, Washington.

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LCRERS78. Toombs, G. L., and R. D. Paris. 1978. *Comprehensive* ***Report*** *for Lower Columbia River Environmental Radiological Survey in Oregon* ***1967-1977.*** Environmental Radiation Surveillance Program, Radiation Control Section, Oregon State Health Division.

Appendix E

Bioconcentration Factors for Waterfowl

Appendix E

Bioconcentration Factors for Waterfowl

Summary statistics for phosphorus-32 and zinc-65 in waterfowl downriver from the Hanford single-pass production reactors are summarized in Table E.1. Approximately 7300 measurements of radionuclides in waterfowl were summarized to compile these data. The two general types of ducks are diver ducks (those that eat small fish and invertebrates) and puddle ducks (those that eat near-surface water plants and grain crops). A third category, geese, which feed in a similar manner to puddle ducks, was included in this summary because historical data were available. Approximately 72 percent of the measurements were for puddle ducks (e.g., mallards, gadwall, pintail, shovelers, widgeon, and woodduck), 17 percent were for diver ducks (e.g., goldeneye, bufflehead, canvasback, merganser, coot, scaup, and ruddyduck), and 11 percent were for geese.

The column headings are described below:

Nuclide = Radionuclide; standard abbreviations for the element and isotope number
Class = Type of waterfowl (diver ducks, puddle ducks, or geese)
N = Number of samples collected
Mean = Average in picocuries per gram (pCi/g)
STD = Standard deviation of the mean
Max = Maximum measurement
Median = Middle measurement
Min = Minimum measurement
P95 = Ninety-fifth percentile
P5 = Fifth percentile

Table E.1. Bioconcentration Factors (L/kg) for Waterfowl Using Historical Waterfowl Data and WSU-CHARIMA Modeled Water Concentrations

Nuclide	Class	N	Mean	STD	Max	Median	Min	P95	P5
p32	diver duck	341	3499.87	5628.65	39592.76	622.916	0.00000	14337.25	23.6150
p32	puddle duck	827	959.67	2256.70	34868.98	286.236	0.00000	5129.90	35.9195
p32	all ducks	1168	1701.29	3764.30	39592.76	342.888	0.00000	8787.35	30.3951
p32	geese	143	253.72	262.19	1584.95	238.481	0.00000	617.03	0.0000
zn65	diver duck	101	284.47	464.79	3278.69	53.300	0.64935	1176.63	2.6140
zn65	puddle duck	415	89.46	147.03	1421.34	44.417	0.00000	355.33	2.3985
zn65	all ducks	516	127.63	255.59	3278.69	44.417	0.00000	87.24	2.4476
zn65	geese	77	63.24	119.32	657.37	21.527	0.00000	390.87	0.1350

Appendix F

Summary Radionuclide Concentrations in Upland Gamebirds, 1967-1970

Appendix F

Summary Radionuclide Concentrations in Upland Gamebirds, 1967-1970

The column headings are described below:

Nuclide	=	Radionuclide; standard abbreviations for the element and isotope number
Sample	=	Type of upland gamebird (pheasant, quail, or both)
N	=	Number of samples collected
Mean	=	Average in picocuries per gram (pCi/g)
STD	=	Standard deviation of the mean
Max	=	Maximum measurement
Median	=	Middle measurement
Min	=	Minimum measurement
P95	=	Ninety-fifth percentile
P5	=	Fifth percentile

Table F.1. Radionuclide Concentrations (pCi/g) in Upland Gamebirds, 1967-1970

Nuclide	Sample	N	Mean	STD	Max	Median	Min	P95	P5
p32	pheasant	46	60.8224	295.702	1990	2.350	1	124	1
p32	quail	98	17.9864	53.870	490	4.125	1	86	1
zn65	pheasants&quail	144	4.91361	18.2088	214	4.815	0.2	10	0.2

Appendix G

Summary Radionuclide Concentrations in Shellfish from the Pacific Ocean near the Columbia River, 1960-1970

Appendix G

Summary Radionuclide Concentrations in Shellfish from the Pacific Ocean near the Columbia River, 1960-1970

Table G.1 summarizes the data for phosphorus-32 and zinc-65 concentrations in shellfish sampled from the Pacific Ocean near the mouth of the Columbia River. Information included in this file are summary statistics for various locations and radionuclides.

The column headings are described below:

OBS = Line number (not part of data)
Nuclide = Radionuclide; standard abbreviations for the element and isotope number
Location = Location where the sample was collected
Class = Type of shellfish (oysters, crabs, and clams)
Year = Year sample collected
N = Number of samples collected
Mean = Average in picocuries per gram (pCi/g) wet weight
STD = Standard deviation of the mean
Median = Middle measurement
P95 = Ninety-fifth percentile
P5 = Fifth percentile

Table G.1. Radionuclide Concentrations (pCi/g wet weight) in Shellfish from the Pacific Ocean near the Columbia River, 1960-1970

OBS	Nuclide	Location	Class	Year	N	Mean	STD	Median	P95	P5
1	p32	willapabay	oyst	60	6	0.5700	0.3933	0.620	1.0	0.10
2	p32	willapabay	oyst	61	12	1.7183	3.4210	0.185	12.0	0.10
3	p32	willapabay	oyst	62	22	2.9182	3.1419	2.000	6.6	0.93
4	p32	willapabay	oyst	63	26	3.9300	3.2947	2.300	10.0	0.88
5	p32	willapabay	oyst	64	24	4.6667	4.2575	3.150	14.0	1.30
6	p32	willapabay	oyst	65	26	3.7154	2.6016	2.750	9.0	1.00
7	p32	willapabay	oyst	66	25	3.0400	1.9545	2.600	7.5	1.00
8	p32	willapabay	oyst	67	24	3.3750	3.1734	1.500	10.0	1.00
9	p32	willapabay	oyst	68	24	1.8708	1.1969	1.100	3.5	1.00
10	p32	willapabay	oyst	69	21	3.2762	3.6543	1.000	9.8	1.00
11	p32	willapabay	oyst	70	12	1.0917	0.3175	1.000	2.1	1.00
12	zn65	alaska	crab	67	1	0.1000	.	0.100	0.1	0.10
13	zn65	alaska	crab	68	1	0.1000	.	0.100	0.1	0.10
14	zn65	alaskacoast	crab	63	2	0.2000	0.0000	0.200	0.2	0.20
15	zn65	astoria	crab	62	2	28.5000	0.7071	28.500	29.0	28.00
16	zn65	astoria	crab	63	9	22.5556	4.5426	23.600	27.2	12.20
17	zn65	astoria	crab	64	7	17.1143	2.0724	16.400	20.7	14.50
18	zn65	astoria	crab	65	8	13.6250	2.0268	13.750	16.7	10.40
19	zn65	astoria	crab	66	8	12.2750	1.5563	12.000	15.2	9.90
20	zn65	astoria	crab	67	8	11.0750	1.2937	11.050	13.2	9.40
21	zn65	astoria	crab	68	8	11.2500	1.8966	11.250	13.8	8.60
22	zn65	astoria	crab	69	10	6.6400	1.1664	6.600	8.5	4.30
23	zn65	astoria	crab	70	9	3.6667	1.0989	3.300	5.1	1.90
24	zn65	cannonbeach	crab	68	1	6.4000	.	6.400	6.4	6.40
25	zn65	coosbay	clam	66	2	1.3000	0.7071	1.300	1.8	0.80
26	zn65	coosbay	oyst	63	1	3.9000	.	3.900	3.9	3.90
27	zn65	coosbay	oyst	70	1	0.1000	.	0.100	0.1	0.10
28	zn65	graylandbeach	clam	60	3	8.5000	7.3655	10.000	15.0	0.50
29	zn65	longbeach	clam	60	2	22.5000	3.5355	22.500	25.0	20.00
30	zn65	longisland	clam	60	1	2.0000	.	2.000	2.0	2.00
31	zn65	nahalemriverj	crab	68	1	9.1000	.	9.100	9.1	9.10
32	zn65	nahalemriverj	crab	69	2	4.2000	0.8485	4.200	4.8	3.60
33	zn65	nyaquinabay	crab	62	1	13.9000	.	13.900	13.9	13.90
34	zn65	oceancity	clam	60	3	13.0000	6.2450	11.000	20.0	8.00
35	zn65	oceanpark	clam	60	4	18.2500	4.4253	18.000	23.0	14.00
36	zn65	olympia	oyst	60	1	0.5000	.	0.500	0.5	0.50
37	zn65	oyhut	clam	60	2	11.0000	4.2426	11.000	14.0	8.00
38	zn65	oysterville	oyst	60	1	55.0000	.	55.000	55.0	55.00
39	zn65	palixriver	oyst	60	1	58.0000	.	58.000	58.0	58.00
40	zn65	portorford	crab	67	1	0.7000	.	0.700	0.7	0.70
41	zn65	purdy	oyst	60	1	0.5000	.	0.500	0.5	0.50
42	zn65	seasidebeach	clam	62	2	20.2500	22.5567	20.250	36.2	4.30
43	zn65	seasidebeach	clam	63	2	13.9500	1.9092	13.950	15.3	12.60
44	zn65	seasidebeach	clam	64	1	23.8000	.	23.800	23.8	23.80
45	zn65	seasidebeach	clam	65	1	12.6000	.	12.600	12.6	12.60
46	zn65	seasidebeach	clam	66	1	9.4000	.	9.400	9.4	9.40

Table G.1. (contd)

OBS	Nuclide	Location	Class	Year	N	Mean	STD	Median	P95	P5
47	zn65	seasidebeach	clam	67	1	7.7000		7.700	7.7	7.70
48	zn65	seasidebeach	clam	68	1	6.8000		6.800	6.8	6.80
49	zn65	seasidebeach	clam	70	1	1.9000		1.900	1.9	1.90
50	zn65	tillamookbay	clam	61	1	0.4000		0.400	0.4	0.40
51	zn65	tillamookbay	clam	62	10	3.0400	1.0987	2.900	5.3	1.70
52	zn65	tillamookbay	clam	63	11	2.0818	1.2836	1.700	5.6	0.90
53	zn65	tillamookbay	clam	64	10	1.4300	0.3093	1.250	2.1	1.20
54	zn65	tillamookbay	clam	65	9	1.5556	0.7732	1.200	3.4	1.00
55	zn65	tillamookbay	clam	66	13	2.5077	2.0443	1.100	6.5	0.70
56	zn65	tillamookbay	clam	67	12	1.2667	0.9903	1.000	4.2	0.40
57	zn65	tillamookbay	clam	68	11	0.6727	0.2453	0.700	1.1	0.30
58	zn65	tillamookbay	clam	69	8	0.3875	0.1553	0.350	0.7	0.20
59	zn65	tillamookbay	clam	70	7	0.2571	0.0976	0.30	0.4	0.100
60	zn65	tillamookbay	crab	62	7	18.3000	6.4645	17.40	27.4	10.000
61	zn65	tillamookbay	crab	63	8	14.0125	1.3346	14.15	16.0	11.800
62	zn65	tillamookbay	crab	64	11	11.8818	1.9518	10.90	16.1	9.400
63	zn65	tillamookbay	crab	65	8	9.0625	1.4725	9.30	11.4	6.400
64	zn65	tillamookbay	crab	66	12	7.1833	1.0667	7.20	8.8	4.700
65	zn65	tillamookbay	crab	67	12	7.3250	2.5983	5.85	12.1	4.600
66	zn65	tillamookbay	crab	68	13	6.9154	1.1127	7.20	8.5	5.100
67	zn65	tillamookbay	crab	69	12	4.0250	0.6771	4.15	5.1	2.700
68	zn65	tillamookbay	crab	70	11	2.2364	0.5971	2.10	3.4	1.500
69	zn65	tillamookbay	oyst	62	7	23.8143	7.2066	22.00	37.0	15.000
70	zn65	tillamookbay	oyst	63	11	17.8545	5.1839	18.70	27.9	7.100
71	zn65	tillamookbay	oyst	64	11	14.4091	3.9142	12.80	23.4	9.600
72	zn65	tillamookbay	oyst	65	12	13.7333	3.5831	13.05	20.0	8.000
73	zn65	tillamookbay	oyst	66	12	9.1167	4.1817	7.90	21.6	5.600
74	zn65	tillamookbay	oyst	67	11	10.4455	3.6977	10.20	18.2	5.000
75	zn65	tillamookbay	oyst	68	11	8.2091	2.8984	8.40	13.9	3.900
76	zn65	tillamookbay	oyst	69	12	6.3917	1.0689	6.45	7.6	4.500
77	zn65	tillamookbay	oyst	70	10	3.2800	0.9976	3.20	4.7	1.600
78	zn65	willapabay	oyst	60	6	55.0000	12.7436	52.50	78.0	40.000
79	zn65	willapabay	oyst	61	21	67.3240	47.3477	66.00	140.0	0.095
80	zn65	willapabay	oyst	62	25	91.0400	18.5416	92.00	116.0	64.000
81	zn65	willapabay	oyst	63	38	71.3735	37.3005	82.00	123.6	0.092
82	zn65	willapabay	oyst	64	24	53.9750	17.5002	52.50	86.0	37.000
83	zn65	willapabay	oyst	65	26	39.0000	16.3902	36.00	48.0	26.000
84	zn65	willapabay	oyst	66	26	28.1538	6.6795	28.00	39.0	16.000
85	zn65	willapabay	oyst	67	25	32.2000	13.4381	30.00	44.0	20.000
86	zn65	willapabay	oyst	68	24	25.2500	6.0235	24.50	34.0	17.000
87	zn65	willapabay	oyst	69	21	19.0000	3.5496	18.00	24.0	14.000
88	zn65	willapabay	oyst	70	12	13.0083	4.5113	12.00	21.0	7.700
89	zn65	willapaharbor	crab	60	2	9.5000	9.1924	9.50	16.0	3.000
90	zn65	winchesterbay	crab	70	1	0.1000		0.10	0.1	0.100
91	zn65	yaquina/agatebeach	crab	68	1	3.4000		3.40	3.4	3.400
92	zn65	yaquina/agatebeach	crab	69	1	5.5000		5.50	5.5	5.500
93	zn65	yaquina/agatebeach	crab	70	2	0.5500	0.6364	0.55	1.0	0.100
94	zn65	yaqudagatebeach	oyst	62	1	3.2000		3.20	3.2	3.200
95	zn65	yaquina/agatebeach	oyst	64	1	2.3000		2.30	2.3	2.300

Table G.1. (contd)

OBS	Nuclide	Location	Class	Year	N	Mean	STD	Median	P95	P5
96	zn65	yaquina/agatebeach	oyst	65	1	3.3000	.	3.30	3.3	3.300
97	zn65	yaquidagatebeach	oyst	66	1	2.0000	.	2.00	2.0	2.000
98	zn65	yaquina/agatebeach	oyst	67	1	1.1000	.	1.10	1.1	1.100
99	zn65	yaquina/agatebeach	oyst	68	1	1.2000	.	1.20	1.2	1.200
100	zn65	yaquina/agatebeach	oyst	69	1	0.2000	.	0.20	0.2	0.200
101	zn65	yaquidagatebeach	oyst	70	2	0.7000	0.1414	0.70	0.8	0.600
102	zn65	yaquinabay	crab	67	1	2.2000	.	2.20	2.2	2.200

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