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REPORT

EVALUATION OF RADIOLOGICAL CONDITIONS IN THE VICINITY OF HANFORD FOR 1965

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EVALUATION OF RADIOLOGICAL CONDITIONS IN THE VICINITY OF HANFORD FOR 1965

By

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SUMMARY STATEMENT

The evaluation of results obtained from Hanford environmental surveillance program for 1965 indicates that most of the environmental radiation dose received by the majority of persons living in the neighborhood of the Hanford project was due to natural sources and world-wide fallout rather than to Hanford operations.

Of the low-level wastes that are released to the environment from the Hanford plants, neutron-induced radionuclides present in reactor cooling water discharged to the Columbia River continued to be the source of greatest potential radiation dose to people in the environs. The primary pathways of exposure from this source are drinking water derived from the river, consumption of fish and waterfowl which inhabit the river, and foodstuffs grown on land irrigated with water pumped from the Columbia downstream from Hanford.

Residents of Richland were supplied throughout the year with drinking water from the Columbia River. The radiation dose from drinking this water was estimated to be about 7% of the appropriate limit. The gastrointestinal tract is the limiting organ for the mixture of radionuclides present in drinking water pumped from the Columbia River. In Pasco and Kennewick, which are further downriver, the estimated doses from drinking water were, respectively, about 2.5% and <0.5% of the limit for the GI tract. The only persons who received radiation doses attributable to Hanford greater than those that resulted from the drinking water were the people who ate local fish or waterfowl.

The highly unlikely but plausible combination of circumstances that would result in the greatest dose to an individual from the radionuclides released by the Hanford plant is postulated as:

- The consumption of some 200 meals per year of fish caught downstream from the reactors
- The consumption of meat and milk from cattle pastured on and fruit and vegetables grown on irrigated farms in the Riverview District
- The consumption of drinking water from the Pasco system

An individual with such habits could conceivably ingest enough radioactive materials of Hanford origin (mostly P^{32}) to provide an intake of ~12% of the Maximum Permissible Rate of Intake (MPRI) specified by the International Commission on Radiological Protection (ICRP) for individuals in the general population (with bone as the critical organ). The resultant annual dose to the GI tract and Whole Body would then have been about 90 and 40 mrem, respectively, during 1965.

Iodine-131 in the Hanford environs remained at very low concentrations in 1965. The Chinese nuclear test on May 14 caused a brief increase in I^{131}, but concentrations soon returned to the low levels experienced during most of 1965. The postulated "maximum" annual dose from I^{131} to the thyroid of a small child amounted to only about 4% of the Radiation Protection Guide recommended for individuals by the Federal Radiation Council.

Tabulated below is the composite level of compliance of Hanford contractors with the appropriate Radiation Dose Standards for individuals and population groups in uncontrolled areas.

SUMMARY OF RADIATION DOSES
IN THE HANFORD ENVIRONS—1965

Organ	Annual Dose (mrem)	Limit (mrem)	% of Limit
Maximum Individual			
GI Tract	86	1500	6%
Thyroid (infant)	58	1500	4%
Whole Body	38	500	8%
Bone	-- 360	--	12%(ICRP-MPRI)
Average Richland Resident			
GI Tract	37	500	7%
Thyroid (infant)	30	500	6%
Whole Body	5	170	3%
Bone	-- 279	--	0.9%(ICRP-MPRI)

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INTRODUCTION

The Hanford plant* is located in a semiarid region of southeastern Washington State (Figure 1) where the average annual rainfall is about 16 cm (6 in.). This section of the state has a sparse covering of natural vegetation primarily suited for grazing, although large areas near the project have gradually been put under irrigation during the past few years. The plant site (Figure 2) covers an area of about 1300 km^2 (500 mi^2). The Columbia River flows through the northern edge of the project and forms part of the eastern boundary. Near the plant production sites, the prevailing winds are from the northwest with strong drainage and cross winds causing distorted flow patterns. The meteorology of the region is typical of desert areas with frequent strong inversions occurring at night and breaking during the day to provide unstable and turbulent conditions.

The populated area of primary interest is the Tri-Cities (Richland, Pasco, and Kennewick) situated on the Columbia River directly downstream from the plant. Smaller communities in the vicinity are Benton City, West Richland, Mesa, and Othello; and these together with the surrounding agricultural area, bring the total population near the plant to about 80,000 people.

During the course of operation, various radioactive wastes are generated by the several plant facilities. High level wastes are concentrated and retained in storage within the project boundaries. Controlled releases of low-level wastes, for which concentration and storage is not feasible, are made to the ground. The Hanford practices governing radioactive waste disposal are described in the Hearings

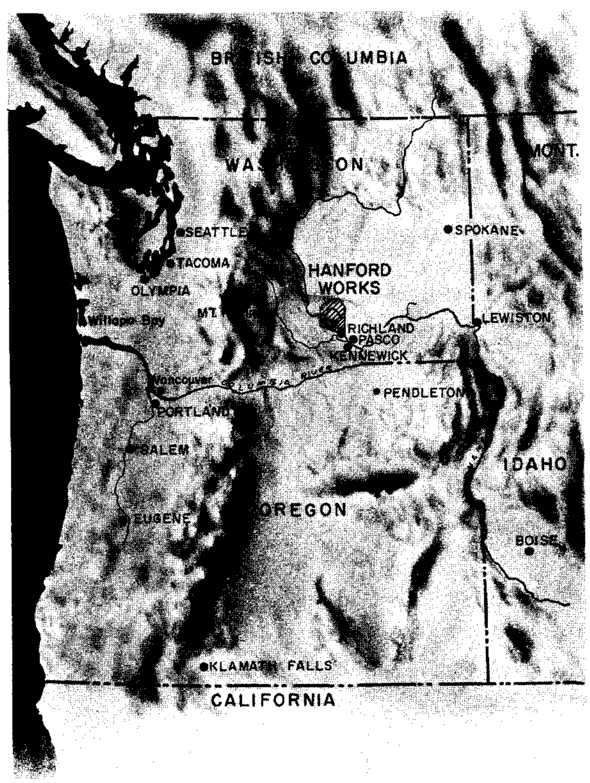

FIGURE 1. Geographical Relationship of Hanford to Pacific Northwest

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Operated during 1965 for the Atomic Energy Commission by the Battelle-Memorial Institute; Douglas-United Nuclear, Incorporated; and the General Electric Company.

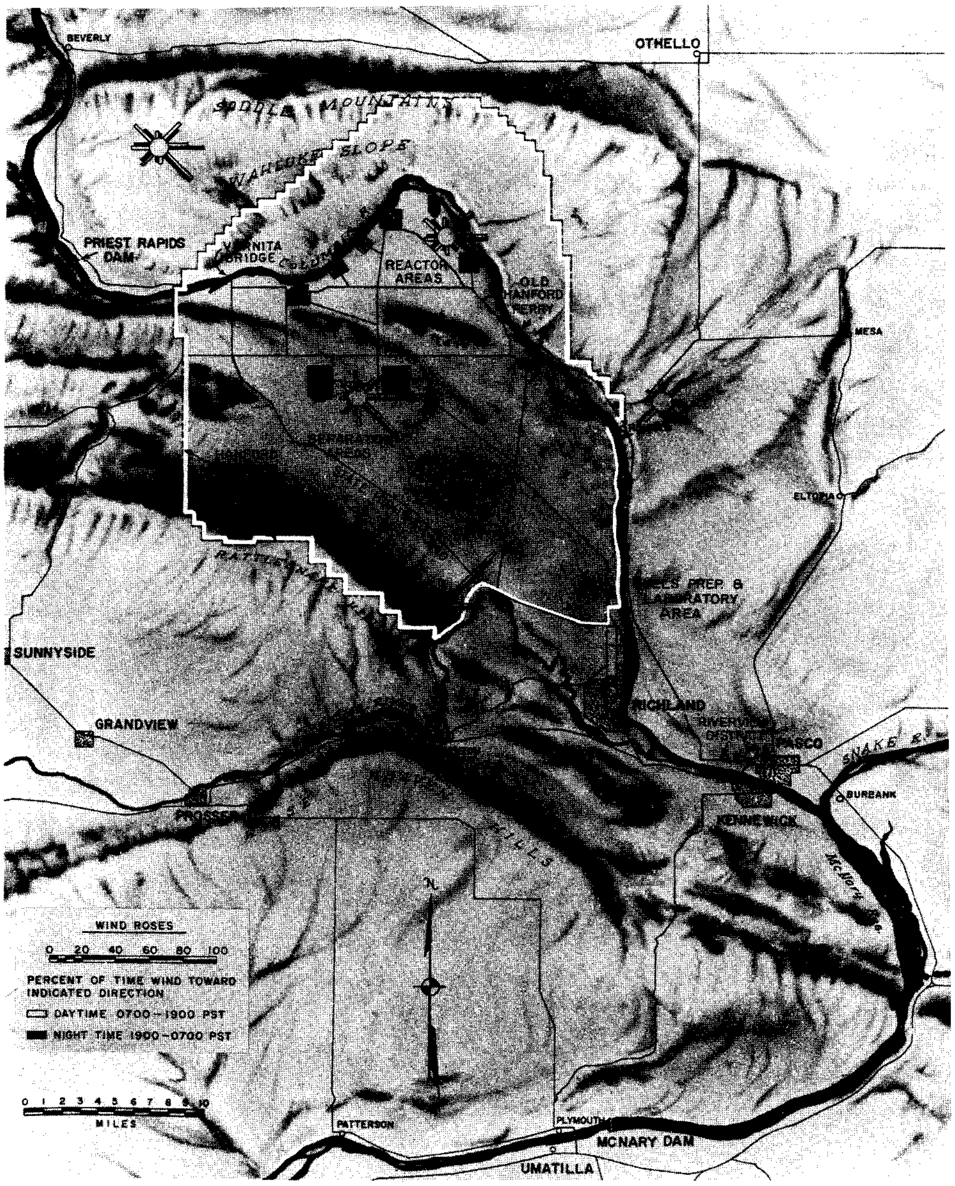

FIGURE 2. Features of Hanford Project and Vicinity

on Industrial Radioactive Waste Disposal held by the Joint Congressional Committee on Atomic Energy in 1959.[1]

It is the purpose of this report to present an evaluation of the combined off-project effects of the radioactive waste disposal practices of all Hanford contractors. Radiation protection practices, including the effects of radioactive waste disposal, are governed by AEC Manual Chapters 0524 and RL 0524.[2] The section to which this evaluation is addressed stipulates that radioactivity in effluents released to uncontrolled areas shall not result in a radiation dose to individuals exceeding 0.5 rem/yr to the whole body or gonads or 1.5 rem/yr to the thyroid or GI tract.

The significance of bone seekers, such as P^{32} and Sr^{90}, requires special consideration and treatment because the rate of intake of P^{32} has not been specifically studied by the Federal Radiation Council (FRC)(3) in relation to a dose-equivalent for the bone or bone marrow. We note that the FRC, in developing intake guides for Sr^{90} and Sr^{89}, apparently did not believe that a relative damage factor (n) should be used to change absorbed dose (rads) to a dose-equivalent (rem). Use of a computational scheme for P^{32} that is like that used by the FRC for Sr^{90} leads to a maximum permissible rate of intake that is substantially greater than that recommended by the International Commission of Radiological Protection (ICRP).(4) In the absence of definitive guidance, it is our judgment that the dose equivalent for P^{32} in bone derived by the ICRP (with the use of an n factor of 5) is not directly comparable with the dose specified in the FRC guide, (1.5 rem/yr). In view of the FRC instruction that ICRP-NCRP (National Committee on Radiation Protection and Measurement) dosimetry methods(4,5) be used where the FRC does not provide direct guidance, and in view of the more conservative rate of intake for P^{32} implied by the ICRP-NCRP recommendations, we have continued to use the ICRP values as a reference base. Further, rather than introduce additional confusion associated with dose-equivalents for bone derived by different techniques, we have expressed the data for bone seekers in terms of a maximum permissible rate of intake (MPRI).

The MPRI is taken as the maximum permissible concentration (MPC) in water for a given radionuclide, as recommended by the ICRP for persons in the neighborhood of controlled areas, multiplied by the rate of water intake as defined for the standard man. This amounts to one-tenth of the MPC for continuous occupational exposure multiplied by intake rates of 2.2 liters/day or 800 liters/yr (for annual estimates). In the case of P^{32} the MPRI is 16 μCi/yr.

The radiological units used throughout most of this report are mrems (dose-equivalent). For the nuclides of interest at Hanford, and the organs for which radiation doses (in mrads) and dose-equivalents (in mrems) are calculated, the units rad and rem are numerically equal.

This report presents estimates of the annual dose received by a hypothetical individual judged to have received the greatest amount of radiation dose from Hanford environmental sources. In addition, estimates of the dose received by people who are typical of the population adjacent to the Hanford project are presented. The latter evaluation has limited value, since dietary factors in the dose calculation for the typical resident are inherently conservative.*

**The infeasibility of obtaining completely realistic dietary data for the typical resident leads to these assumptions: no radioactive decay takes place during the transport of sanitary water to the user, there is no loss of radioactivity from food during preparation, and that results of USDA Dietary Surveys represent the diet of the typical resident of the Hanford environs.*

Included in this report are two types of measurements which are not necessarily relevant to dose evaluations. These are the concentrations of radionuclides in the Columbia River and concentration of I^{131} in cattle thyroids which serve as trend indicators and as support for data used in dose calculations.

The radiochemical data presented in Environmental Conditions section and in the appendices[(6)*] were supplied by the U.S. Testing Co., Inc., who performed all routine radioassays of environmental samples.

ENVIRONMENTAL CONDITIONS

A discussion and interpretation of the results of the several Hanford environmental sampling programs are presented in the following text and figures. The raw data from many of these programs are presented in the appendices.[(6)]

Radionuclides in the Columbia River

All of Hanford's production reactors use Columbia River water for cooling. At the older reactors, some elements present in the cooling water are transformed into radionuclides during the single pass through the reactors. In addition, radioactive materials formed on the surfaces of fuel elements and process tubes are eventually carried away by the cooling water to the river. H and F Reactors were shut down permanently on April 21, 1965 and June 25, 1965, respectively

In contrast with the older production reactors, the N Reactor uses recirculating demineralized water as a primary coolant. Only a very small amount of radionuclides generated in auxiliary systems, such as the control rod cooling water, are released directly to the river.

The relative abundance of the radionuclides found in the cooling water of the older production reactors, as adjusted to 4 hr after leaving the reactor, is shown in Table I.

Many of the radionuclides formed in reactor cooling water are short-lived and decay rapidly after formation. In addition to radioactive decay, some fraction of most radionuclides is removed from the river water by sedimentation and by uptake by aquatic organisms. Also present in the river are radionuclides contributed by fallout from nuclear weapons testing.

Samples of river water were collected above the production areas at Vernita Ferry and below the areas at the Richland and Pasco water plant intakes, at McNary Dam, the Dalles Dam, and Bonneville Dam. Where possible, cumulative sampling equipment was installed and provided a more representative sample than the periodic "grab" samples obtained in the past. This cumulative sampling technique, however, makes it impractical to calculate the amounts of very short-lived nuclides; these must still be measured from "grab" samples. The average concentration

* *The Appendices mentioned above are a compilation of results from radiochemical analyses of samples collected in the Hanford environs during 1965. They are now published as a supplemental report (BNWL-316 APP) which is available upon request.*

TABLE I. Relative Abundance of Reactor Effluent Radionuclides[(a)]

Major, 90%	Minor, 9%	Trace, 1%		
Na^{24}	P^{32}	H^{3}	Y^{91}(b)	Ce^{143}(b)
Si^{31}	Zn^{69m}	C^{14}	Y^{93}(b)	Ce^{144}(b)
Cr^{51}	Ga^{72}	S^{35}	Nb^{95}	Pr^{142}(b)
Mn^{56}	As^{76}	Ca^{45}	Mo^{99}	Pr^{143}(b)
Cu^{64}	Sr^{92}	Sc^{46}	Ru^{103}	Nd^{147}(b)
	I^{132}	Mn^{54}	Ru^{106}	Pm^{147}(b)
	La^{140}(b)	Fe^{59}	Sb^{122}	Pm^{149}(b)
	Eu^{152m}(b)	Co^{60}	Sb^{124}	Pm^{151}(b)
	Sm^{153}(b)	Ni^{65}	I^{131}	Eu^{152}(b)
	Dy^{165}(b)	Zn^{65}	I^{133}	Eu^{156}(b)
	Np^{239}	Sr^{87m}	I^{135}	Gd^{153}(b)
		Sr^{89}	Cs^{136}	Gd^{159}(b)
		Sr^{90}	Cs^{137}	Tb^{160}(b)
		Sr^{91}	Ba^{140}	Tb^{161}(b)
		Y^{90}(b)	Ce^{141}(b)	Ho^{166}(b)
				Er^{169}(b)
				Er^{171}(b)

(a) *Trace nuclide composition based on analyses by the Radiological Analysis Operation made in 1964.*

(b) *These radionuclides as a group are denoted hereafter as RE + Y (Rare Earth + Yttrium).*

of radionuclides measured routinely at Richland, Pasco, and Bonneville Dam are shown in Table II, and the results of analyses for several nuclides in river water samples are available in Appendix A, Tables 1-9.[(6)]

Measurements on traverses across the river at Richland indicate a slightly nonuniform distribution of the longer-lived radioisotopes at this cross-section. Entries of the Yakima River some 16 km (10 mi) above Pasco and of the Snake River some 48 km (30 mi) above McNary Dam slightly influence the distribution of radionuclides at these two points. The magnitude of the influence varies with seasonal

TABLE II. Annual Average Concentrations of Several Radionuclides in Columbia River Water—1965

Radionuclides	Richland	Pasco	Bonneville Dam
	pCi/liter		
RE + Y[(a)]	730	--[(b)]	--
Na^{24}	3100	--	--
P^{32}	140	87	23
Cr^{51}	7000	4100	1700
Cu^{64}	2500	--	--
Zn^{65}	180	160	70
As^{76}	1000	--	--
Sr^{90}	1	--	--
I^{131}	10	7	3
Np^{239}	1600	390	--
Total Beta	(12 counts/min/ml)	--	

(a) *See Table I for definition.*

(b) *The (-) indicates insufficient data to provide a meaningful annual average.*

changes in the flow rate of the tributaries. Bonneville Dam is approximately 490 km (240 mi) below the Hanford reactors and represents the farthest downstream location where river water is routinely sampled for Hanford's environmental surveillance program.

The seasonal variation in flow rate of the Columbia River markedly affects the quantity of water available for dilution of reactor effluent released to the river. Also affected by the flow rate is the time required for a specific volume of water to move from one location to another. The flow rates (data supplied by the USGS) of the Columbia River at Richland and Bonneville Dam are shown in Figure 3, and the variation in concentrations of several radionuclides in river water at Richland are shown in Figure 4. The transport rate of these same radionuclides past Richland is shown in Figure 5 and Appendix A, Tables 12 and

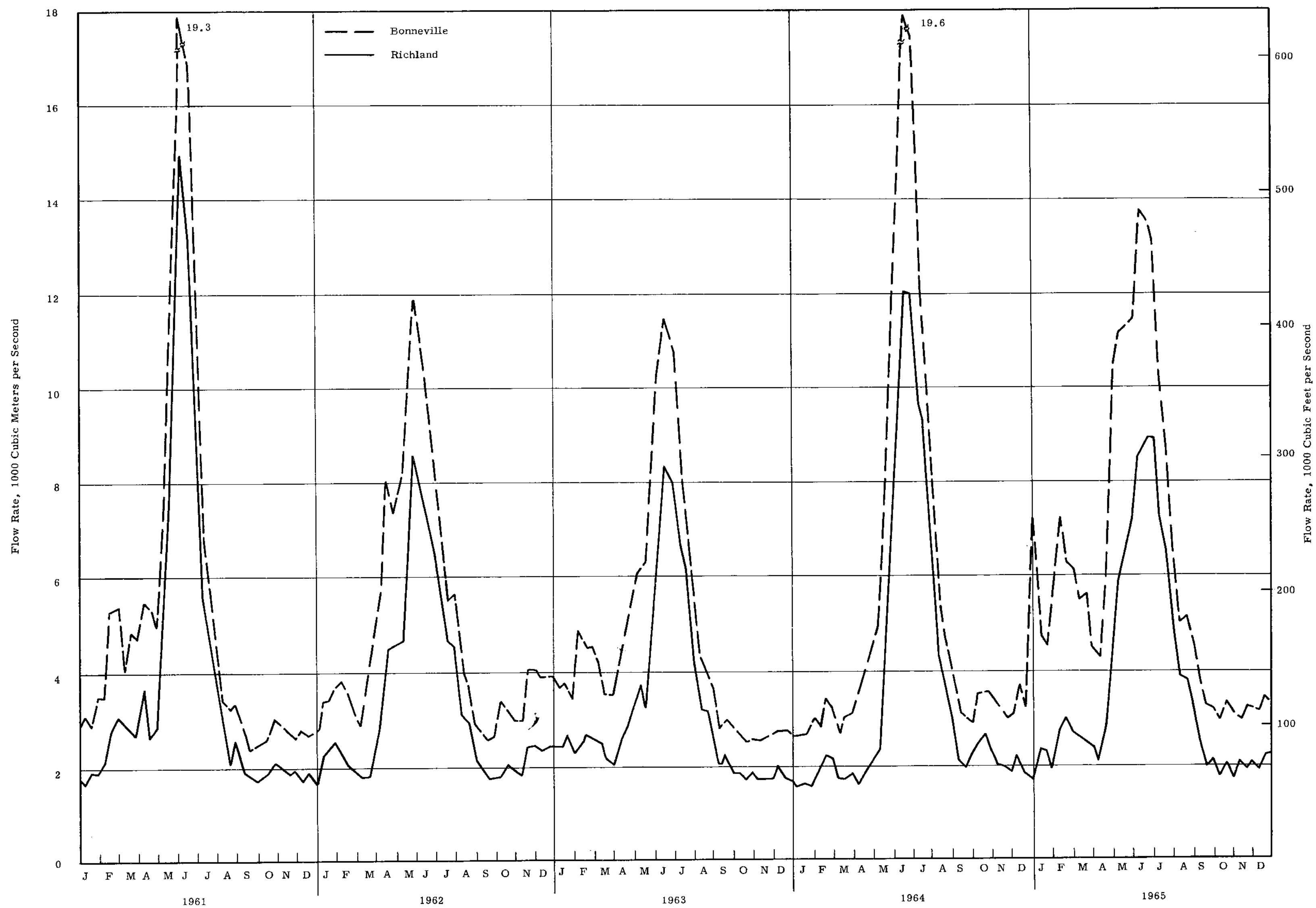

FIGURE 3. Flow Rate of Columbia River at Richland and Bonneville Dam

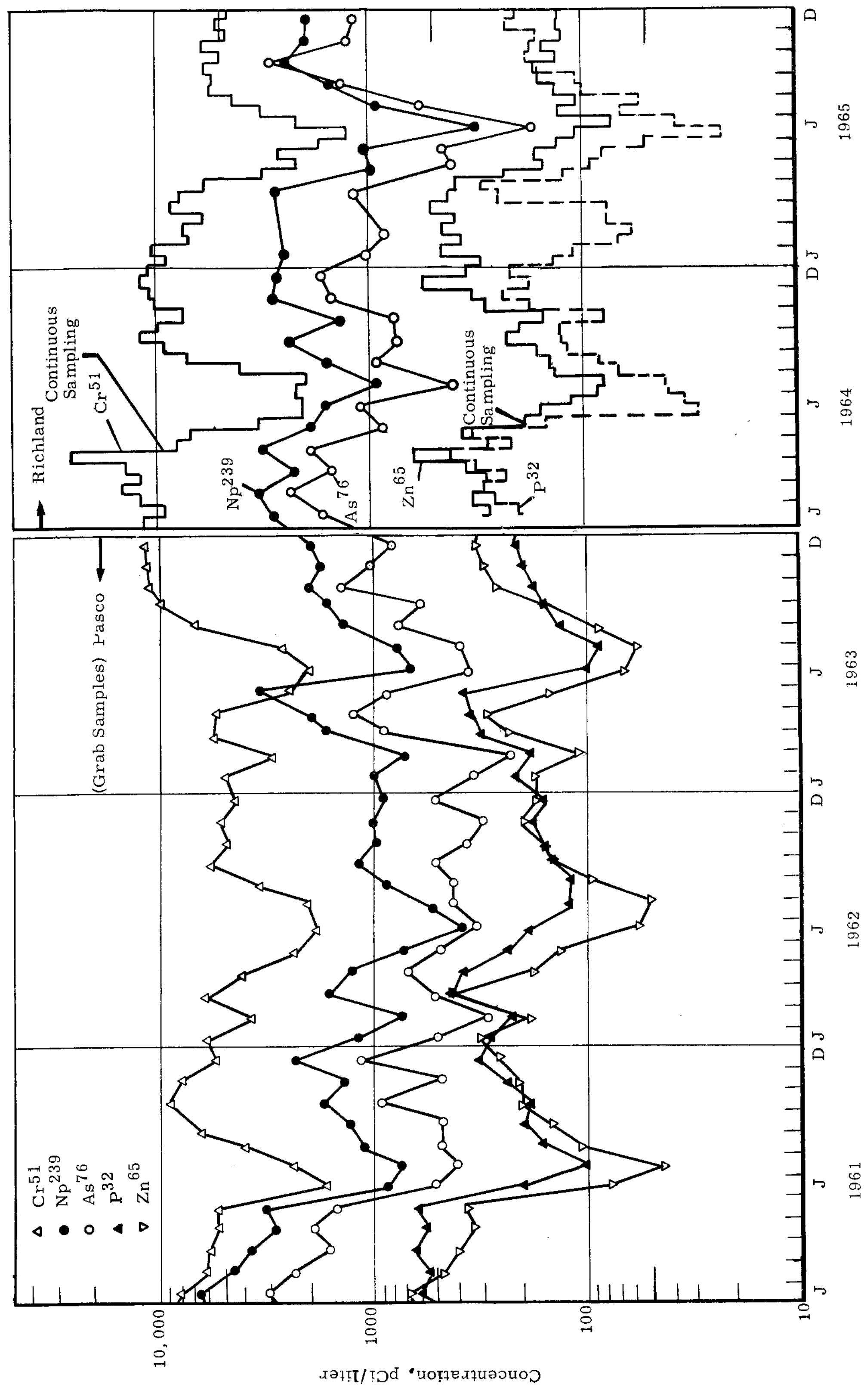

FIGURE 4. *Radionuclides in Columbia River Water at Pasco and Richland, Washington*

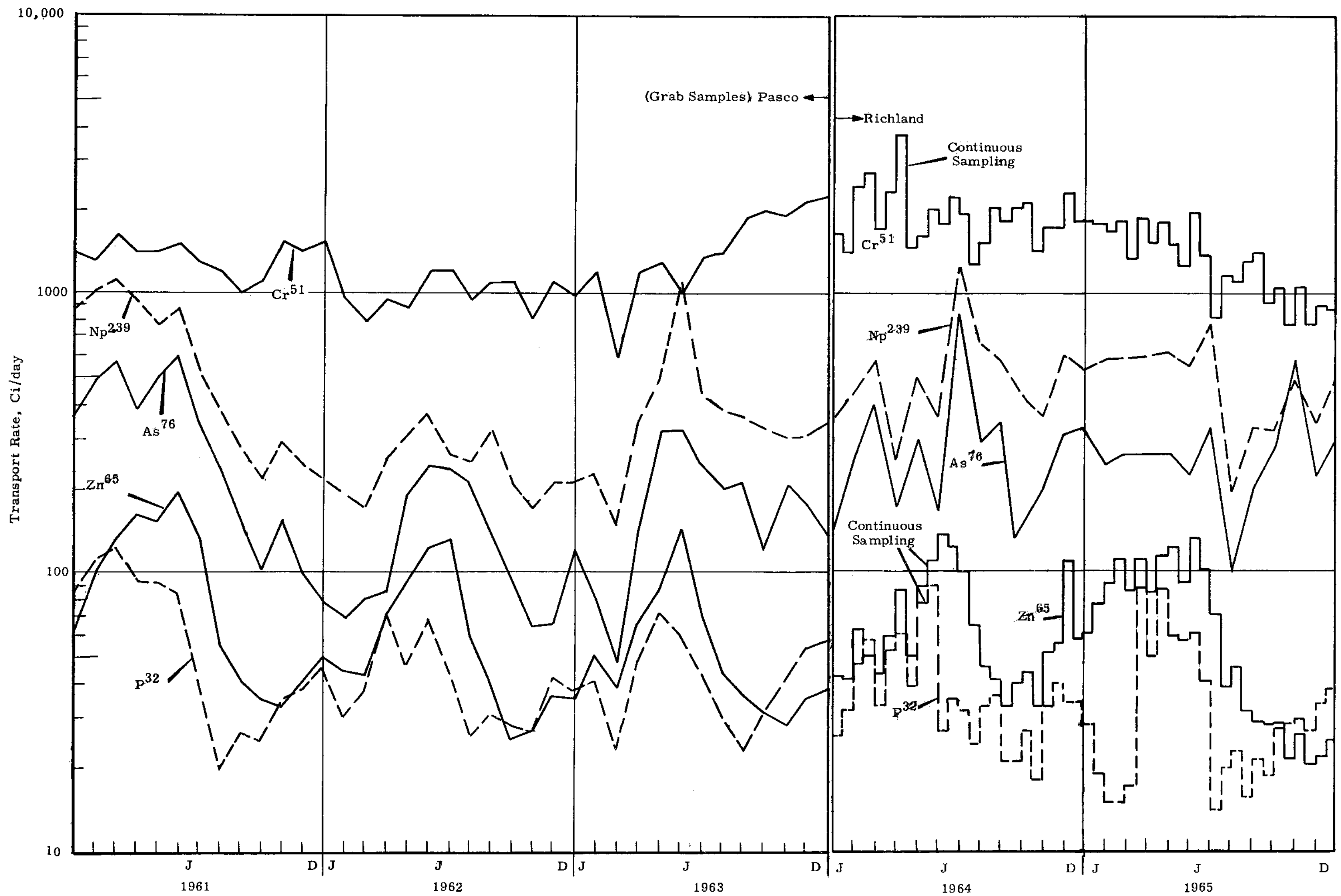

FIGURE 5. Transport Rate of Radionuclides at Pasco and Richland, Washington

13.[6] The transport rate of radionuclides passing Bonneville Dam provides an upper limit on the quantities entering the Pacific Ocean from the Columbia River. The annual average transport rate of selected radionuclides past this dam is given in Table III. Detailed measurements are available in Appendix A, Table 17.[6]

TABLE III. Annual Average Transport Rate of Selected Radionuclides Past Bonneville Dam

Radionuclides	1965	1964	1963[a]	1962[a]
	Ci/day			
P^{32}	11	12	12	13
Cr^{51}	800	860	860	650
Zn^{65}	49	44	28	29

[a] *Rate of transport at Vancouver, Washington.*

An estimate of the inventory of these radionuclides which exist in the ocean may be calculated by assuming an equilibrium between the rate of addition through the river and the rate of decay in the ocean. A constant rate of entry into the ocean equivalent to that indicated by the 1965 Bonneville Dam measurements would imply an inventory of about 230 Ci of P^{32}, 32,000 Ci of Cr^{51}, and 17,000 Ci of Zn^{65}.

Radionuclides in Drinking Water

The city of Richland is the first community downstream from the Hanford reactors that uses the Columbia River as a source of sanitary water supply. Pasco and Kennewick, a few miles further downstream, also use the Columbia River as a source of sanitary water. Continuous sanitary water samples were collected at the Richland water plant, and periodic samples were collected at Pasco and Kennewick. All of these samples were analyzed for the important individual radionuclides. The detailed results of analyses of sanitary water from these three cities are available in Appendix B, Tables 1—5,[6] and are summarized in Table 4.

TABLE IV. Annual Average Concentration of Several Radionuclides Measured in Sanitary Water—1965

Radionuclide	Richland	Pasco	Kennewick
	pCi/liter		
RE + Y[a]	80	27	--[b]
Na^{24}	2300	710	80
P^{32}	100	28	10
Cr^{51}	7200	3600	1400
Cu^{64}	1000	190	50
Zn^{65}	100	70	<15
As^{76}	410	100	16
Sr^{90}	1	1	--
I^{131}	8	6	<2
Np^{239}	1600	760	60
Total Beta	(6.7 counts/min/ml)	(2.4 counts/min/ml)	(0.39 counts/min/ml)

[a] *See Table I for definition.*
[b] *The (--) indicates insufficient data to provide a meaningful annual average.*

The concentrations of short-lived radionuclides in the water at the time it is consumed are less than shown in Table IV because there is a significant transport time between the water plant and most consumers. The transport time may vary from hours to days depending upon the location of the customers on the distribution system and the water demand.

The calculated annual average dose to the GI tract and whole body and the percent MPRI for bone from sustained consumption of sanitary water throughout the year at the three cities is presented in Table V.

The relative contribution of several radionuclides in the Richland sanitary water to the calculated annual dose to the GI tract is shown in Figure 6, and long-term trends in the GI tract dose for Pasco and Richland sanitary water are shown in Figure 7.

The GI tract dose of Richland and Pasco residents was significantly lower in 1965 than in the past years.[7,8] This is primarily attributed to the permanent shutdown of the three Hanford reactors.

An unusual release of radioactive materials occurred on September 29, 1965 from the Plutonium Recycle Test Reactor (PRTR)[9]. The minor effects of this release are included in the annual averages of sanitary water data, and in the corresponding radiation doses from the consumption of sanitary water.

Radionuclides in Fish and Waterfowl

The Columbia River is popular for sports fishing both above and below the Hanford plant, and the fish that feed downstream from the reactors acquire some radionuclides from the reactor effluent. The concentration of several radionuclides measured in different kinds of fish from several locations on the river are available in Appendix C, Tables 1-10.[6] P^{32} is the radionuclide of greatest significance. Whitefish are the sports fish

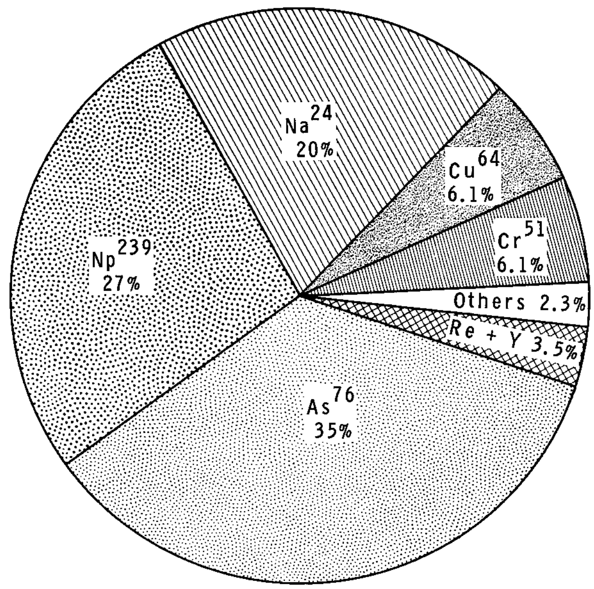

FIGURE 6. Relative Contribution of Radionuclides to GI Tract Dose, Richland Sanitary Water, 1965

TABLE V. Calculated Annual Dose for Selected Organs from Routine Ingestion of Sanitary Water[a]—1965

	Whole Body, mrem	GI Tract, mrem	Bone, % MPRI	Thyroid (Small Child) (0.4 l/day), mrem
Richland	2.5	35	0.8	19
Pasco	<1	13	0.3	15
Kennewick	<1	1	<0.1	<5

(a) Here and elsewhere in this report where a dose (mrem) from an ingested nuclide is expressed, the determination is made from parameters used by the ICRP to translate dose rates into Maximum Permissible Concentrations for drinking water. In most cases, the estimated annual intakes of individual radionuclides were multiplied by conversion factors derived from the ICRP parameters and published by Vennart and Minski.[10]

The "standard man"[4] average intake rate of 1.2 liter/day was used in this calculation.

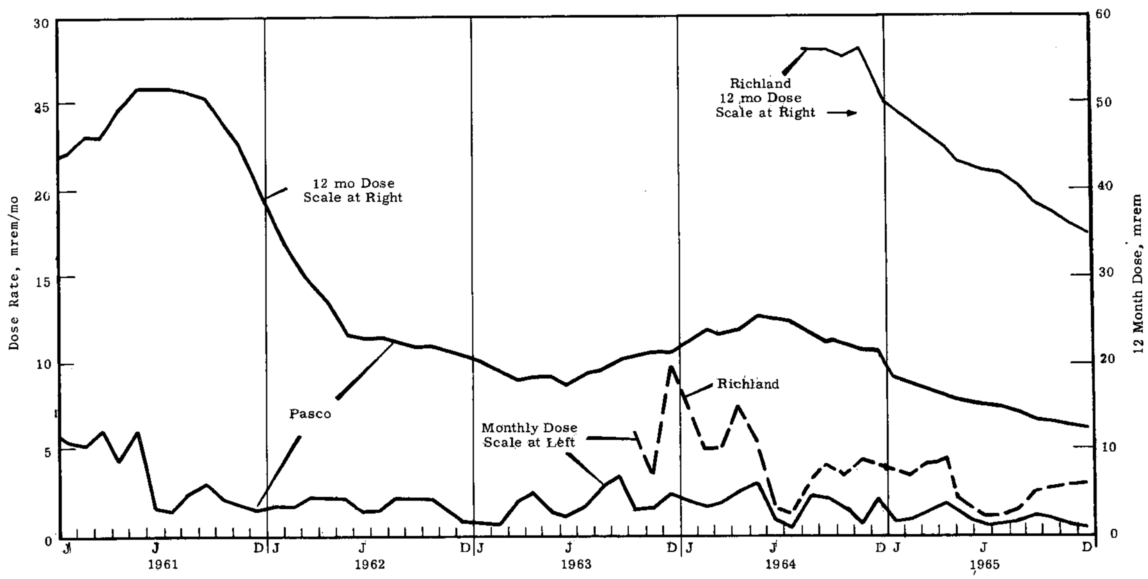

FIGURE 7. Calculated Dose to GI Tract from Drinking Pasco and Richland Sanitary Water

that usually contain the greatest concentration of radioactive materials. Further, they can be caught during winter months when other sports fish are difficult to sample. For these reasons, whitefish are sampled most intensively to follow trends. The results of the measurements are illustrated in Figure 8.

The average concentrations of P^{32} and Zn^{65} in whitefish sampled downstream from the reactors during 1965 were 200 pCi/g and 27 pCi/g of flesh, respectively. These concentrations were substantially lower than those observed in previous years,[7,8] due in part to the retirement (during the period December 1964 to June 1965) of three Hanford reactors.

The quantities and kinds of fish caught by local fishermen have been estimated previously from surveys carried out by personnel of the State of Washington, Department of Game; and additional dietary data collected during 1965 did not change these estimates. Those individuals who probably ingest the largest amounts of P^{32} are fishermen who claim to eat bass, crappie, perch, and catfish as often as three to fives times a week. This large number of fish meals indicates an annual intake of about 40 kg of fish. On the basis of the 40 kg of fish consumption claimed by the "maximum individual" (200 fish meals/year), the intake of P^{32} during 1965 could have been approximately 1.7 μCi, or approximately 11% of the MPRI for bone as the critical organ.

Many persons have been counted in the Hanford Whole Body Counter, including some avid fishermen. Amounts of Zn^{65} detected in these people were much less than expected on the basis of their stated consumption of fish. These

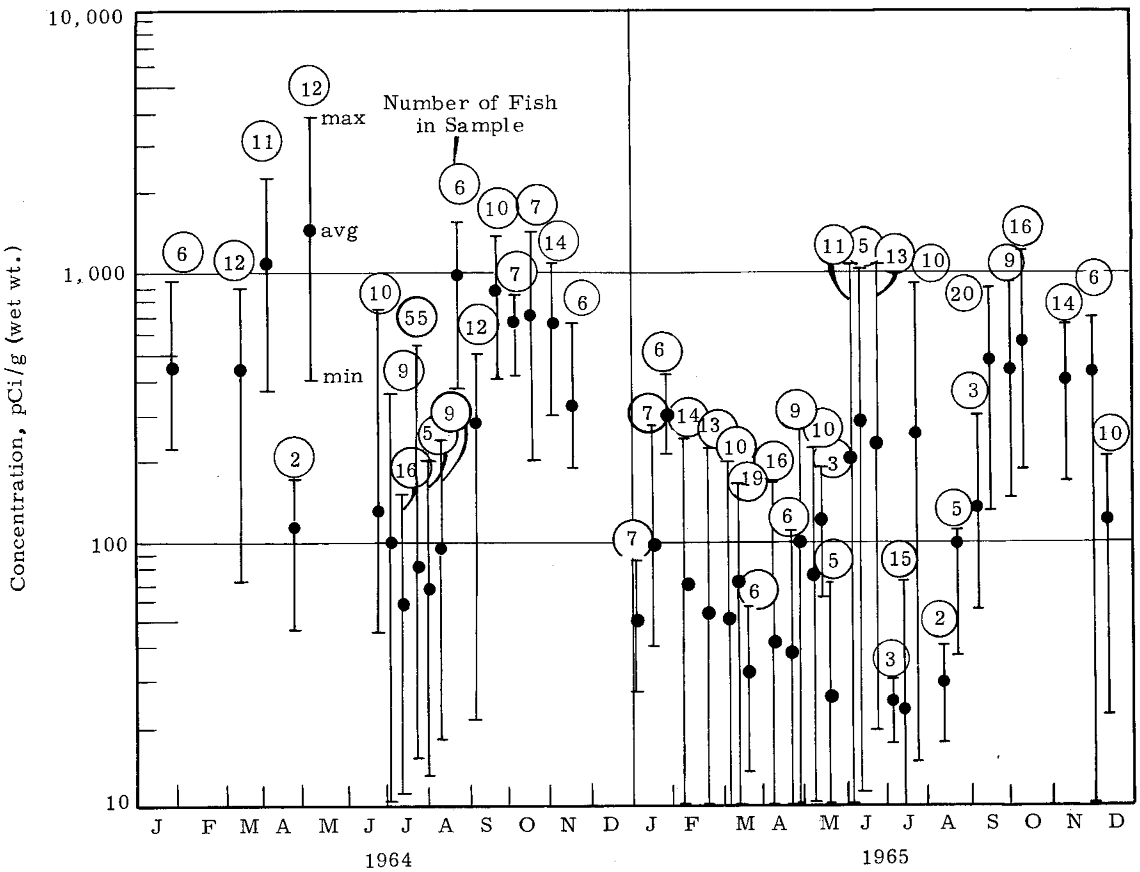

FIGURE 8. P^{32} in Whitefish Caught in Columbia River Between Ringold and Richland

results supported the findings of past years which suggested that fishermen tend to over-estimate their fish consumption. Therefore, the actual ingestion rates of both P^{32} and Zn^{65} are undoubtedly substantially lower than we currently postulate from the fishermen's estimates.

Migratory waterfowl, such as ducks and geese, that have utilized the Hanford section of the Columbia River and the swamps and ponds within the project boundaries may contain P^{32}, Zn^{65}, and small amounts of other radionuclides. Some of these waterfowl remain in this general area throughout the year. Results of the radioassay of waterfowl samples collected within the Hanford project and in the environs are available in Appendix C, Tables 11 and 12.[6] Seventy-five of the water fowl samples collected during 1965 had concentrations of P^{32} <50 pCi/g of flesh (wet weight), 20 samples were above 50 pCi/g but <500 pCi/g, and the remaining 3 samples were >500 pCi/g. The maximum concentration was 950 pCi P^{32}/g. However, as a potential source of this radionuclide to people, the waterfowl are of much less significance than the fish because they cannot be harvested in such large numbers by individuals and because of "dilution" by large flights of migrating birds that move through the region at the time of the year when hunting is allowed.

Radionuclides in Marine Organisms

Zn^{65} and P^{32} are the only radionuclides in the reactor effluent that are found in sufficient abundance beyond the mouth of the Columbia River to be of radiological interest. Oysters have been found to contain higher concentrations of Zn^{65} than other common sea food organisms. Concentrations of Zn^{65} and P^{32} periodically measured in oysters grown in the Willapa Bay area are shown in Figure 9, and the analytical results are available in Appendix D, Table I.(6) Annual average concentrations of Zn^{65} have decreased over the past 2 years while P^{32} concentrations have remained at about the same level during that time.(7,8) The average concentrations in samples taken throughout 1965 were 40 pCi Zn^{65}/g and 4 pCi P^{32}/g.

Consumption of oysters containing these concentrations at the rate of one meal (230 g) per week would result in an annual dose of about 5 mrem to the GI tract and 3 mrem to the whole body. These intakes represent 0.3% of the MPRI for bone as the critical organ.

Radionuclides in the Atmosphere

At Hanford, gaseous waste from the chemical separations facilities is released to the atmosphere through 70 m high stacks after most of the radioactive materials have been removed by filtration and scrubbing. These radioactive materials are primarily associated with process vessel off-gases. Ventilation air from laboratory and reactor buildings contains comparatively minor amounts of radioactive materials under normal operating conditions.

Measurements of airborne I^{131} were made routinely at numerous locations

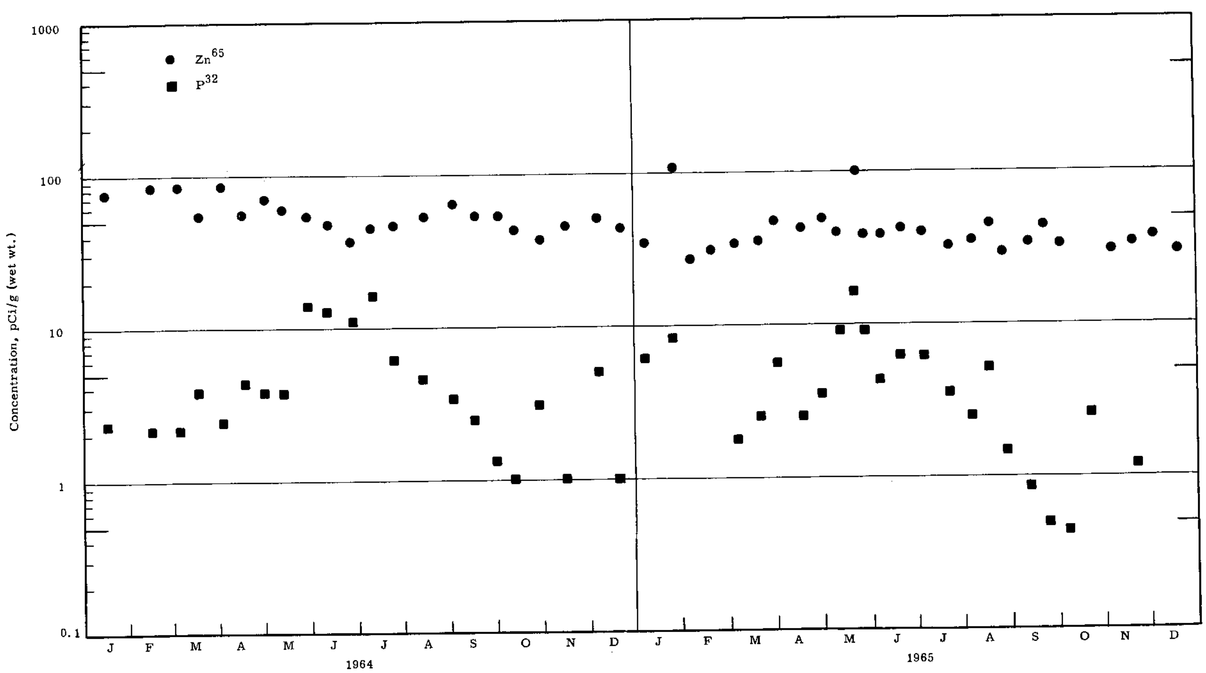

FIGURE 9. *Zn^{65} and P^{32} in Willapa Bay Oysters*

within the Hanford reservation and around the plant perimeter. The results of I^{131} measurements for the past few years are summarized in Table VI with a more detailed tabulation in Appendix E. Table 1.[6]

The four locations listed in Table VI lie within a 45° sector southeast to south of the separations center. Such concentrations sustained in inspired air imply an annual dose to the thyroid of the "standard man" of less than 1 mrem.

Air filter sampling is maintained at several locations within the Hanford reservation and around the plant perimeter. The results of air sampling at these locations are shown in Figure 10 and are tabulated in detail in Appendix E, Table 2.[6]

Air filter results are not used in estimating exposure but serve to illustrate the trends in atmospheric contamination. Sudden changes in concentration (e.g., fallout from the May 14 Chinese weapons test) are used to signal the need for shifted emphasis in other portions of the environmental monitoring program related to atmospheric contamination.

Radionuclides in Milk and Produce

The radioactivity found in locally grown agricultural produce can be influenced by deposition of airborne radionuclides or by irrigation with river water containing reactor effluent radionuclides. The chemical separations facilities are generally the principal local source of airborne radionuclides. The closest farming area to the separations facilities is about 21 km (13 mi) away. Ventilation stacks of the reactors or laboratory facilities could, under certain conditions, become of some small interest. In addition to the radioactive

TABLE VI. Annual Average I^{131} Concentrations in the Atmosphere

Location	Distance from Separation Stacks, km	1965	1964	1963	1962
		pCi/m³			
Prosser Barricade[a]	23	0.03	0.02	--	--
Benton City	32	0.03	0.06	0.03	0.08
Richland	37	0.02	0.02	0.02	0.04
Pasco	51	0.03	0.01	0.02	0.08

(a) Installed during October 1963.

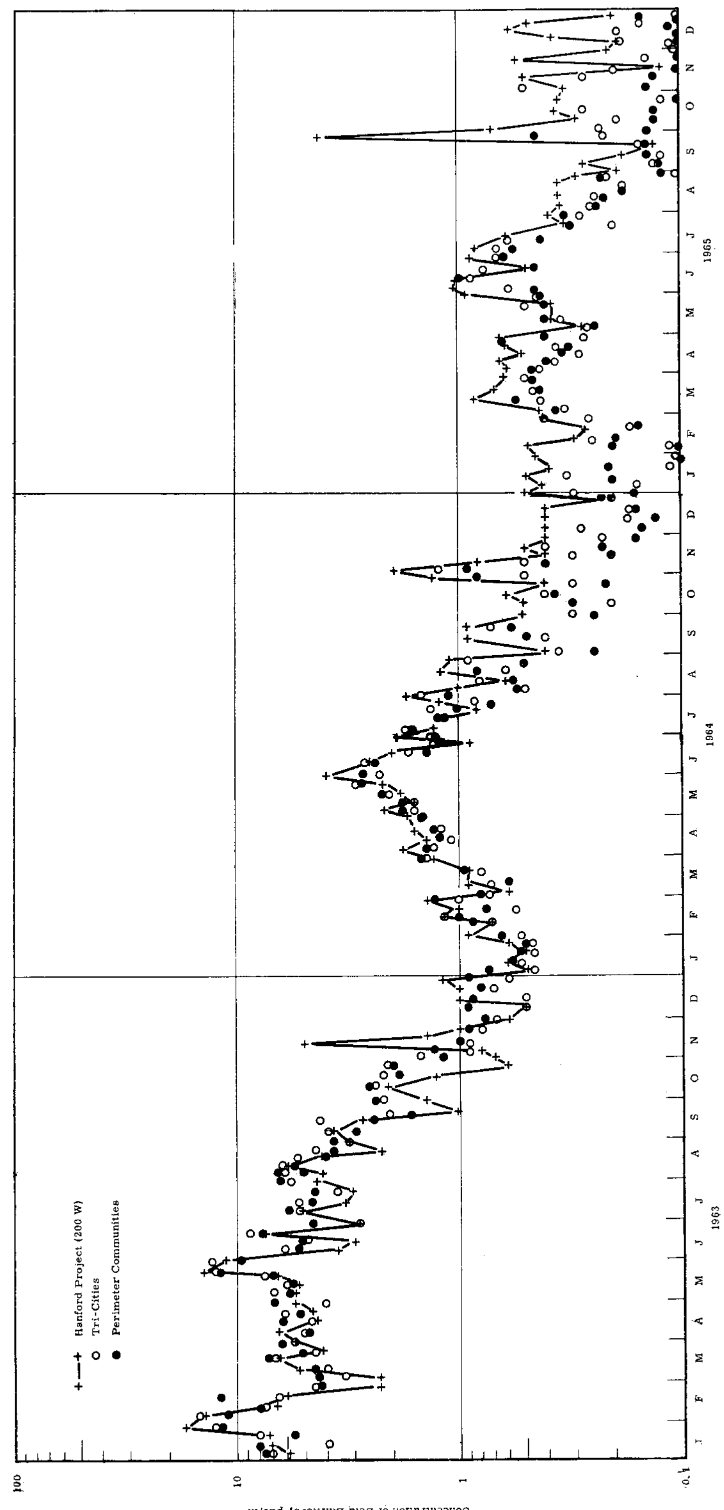

FIGURE 10. Radioactive Particulates in the Air in the Hanford Environs

materials released to the Columbia River from the PRTR (see the section Radionuclides in Drinking Water), radioiodine and noble gases were released to the atmosphere. The minor effects of the atmospheric release are included in the annual averages of environmental sample data, and in the corresponding radiation dose estimates.

Most irrigated farms near the Hanford plant use water drawn from the Yakima River, or from the Columbia River above the project. There are, however, two small areas which regularly take water from the Columbia River downstream from the reactors for irrigation. They are the Ringold farms and the Riverview district west of Pasco, located respectively 24 and 48 km (15 and 30 mi) downstream from the reactors. The Ringold farms, approximately 21 km east of the production areas, involve about 20 people working some 2 km^2 (500 acres) of land with fruit as the principal product. The Riverview farm area consists of about 21 km^2 (5300 acres) supporting about 1000 families, the majority of which live on plots of 4000 m^2 (1 acre) or less and raise family gardens. The principal products from the larger farm plots are hay, fruit, beef, and dairy products. This area is centered 48 km southeast of the chemical separations plants. Another agricultural area near the project is Benton City, located on the Yakima River about 32 km (20 mi) directly south of the separations facilities.

A comprehensive milk surveillance program maintained during 1965 included samples from local farms and dairies and from commercial supplies available to people in the Tri-Cities. The concentrations of radionuclides found in milk sold by commercial outlets were similar to that reported by the U.S. Public Health Service and the Washington State Department of Health.(11) Milk from local farms irrigated with water drawn from the river downstream from the reactors contained P^{32} and Zn^{65} as well as fission products of fallout origin.

The concentrations of I^{131} measured in milk samples collected during 1965 are shown in Figures 11 and 12. Generally, the average concentration of I^{131} in both local and commercial milk was at or below the analytical limit of 3 pCi/liter except for a brief increase during the late spring (following the Chinese nuclear weapons test on May 14) and again during the fall months (following a small, transient increase in the release rate of I^{131} from a chemical separations facility during the latter part of October). The maximum concentration of I^{131} observed in milk was 26 pCi/liter on November 9, 1965.

Dairy farms in the Ringold and Riverview area that utilize the Columbia River for irrigation of pasture land and hay fields produce milk

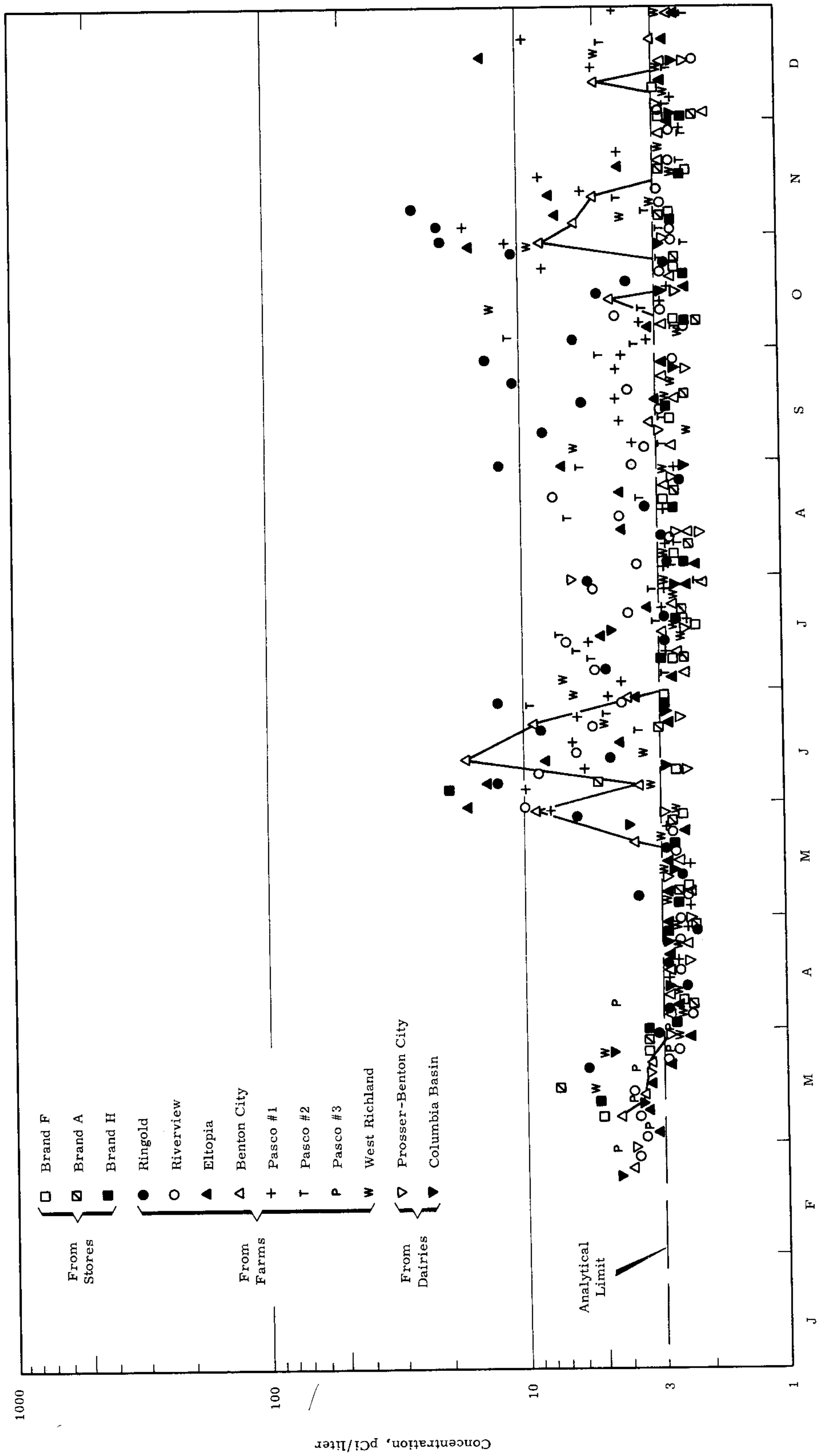

FIGURE 11. I^{131} in Local Milk

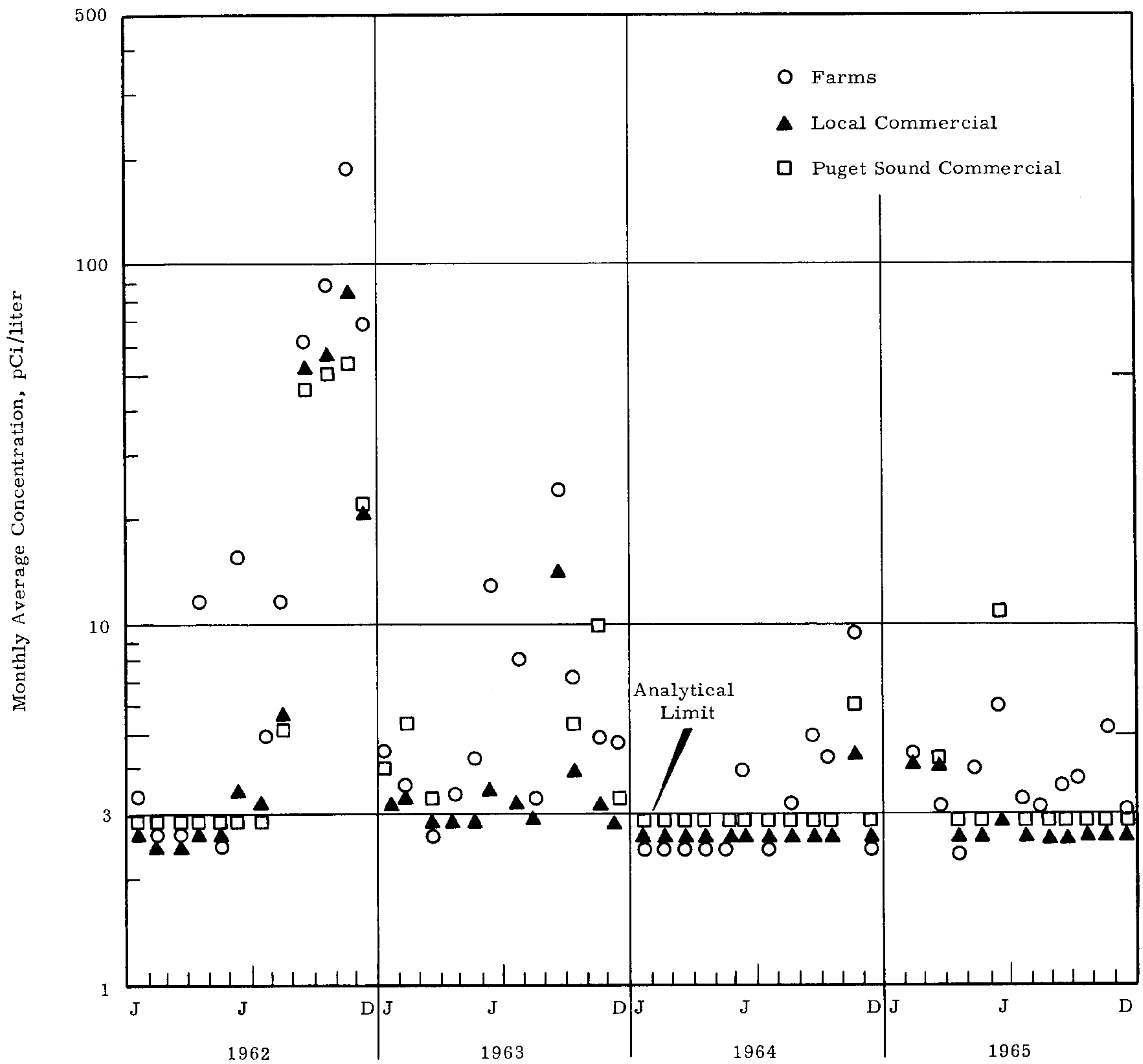

FIGURE 12. I^{131} in Locally Available Milk

containing both P^{32} and Zn^{65} (Figures 13 and 14). During 1965 the average concentration of P^{32} in milk from these farms was about 490 pCi/liter (much lower than the 1964 average of 1600 pCi/liter) and the concentration of Zn^{65} was 480 pCi/liter. The highest concentration of P^{32} in milk (1000 pCi/liter) was observed during early September, a period of heavy irrigation and rapid growth of pasture grass. Commercial milk distributed in the Tri-Cities usually does not contain P^{32} and Zn^{65} because it is obtained principally from areas not irrigated with Columbia River water.

Adult residents consuming milk (1 liter/day) obtained from the Ringold-Riverview area would receive an annual dose from P^{32} and Zn^{65} amounting to

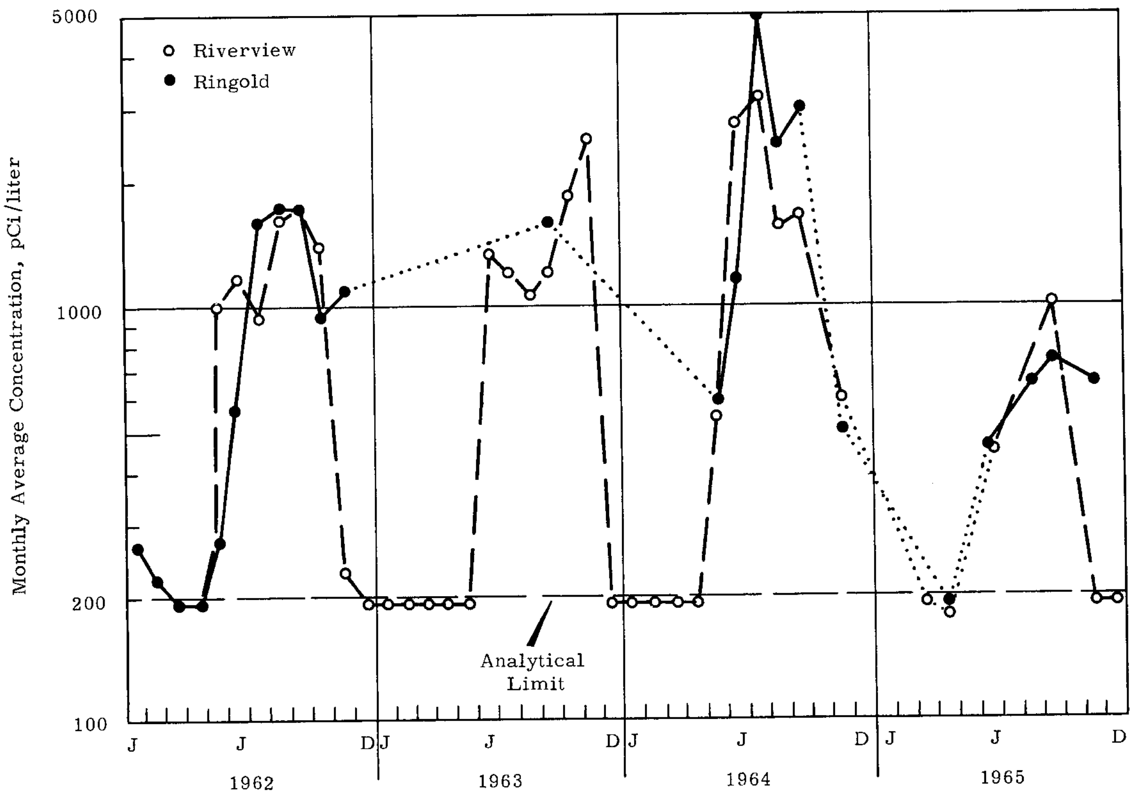

FIGURE 13. P^{32} *in Locally Produced Milk*

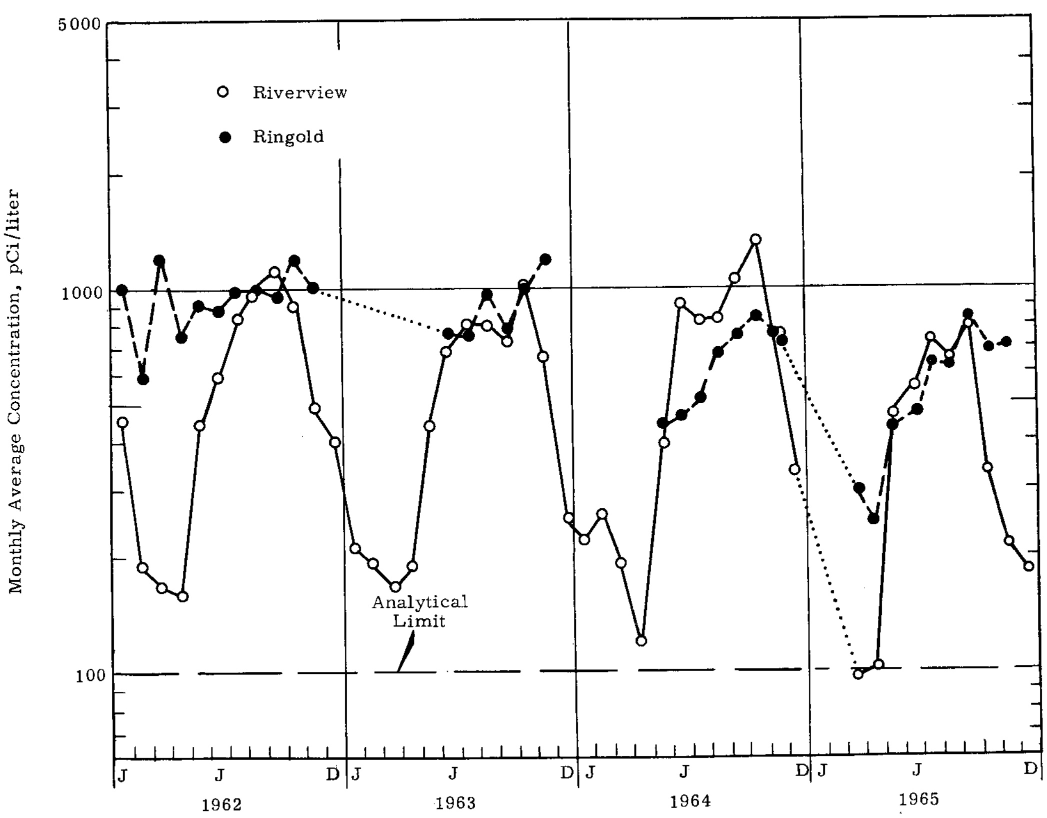

FIGURE 14. Zn^{65} *in Locally Produced Milk*

about 4 mrem to the GI tract and 2 mrem to the whole body. The intake of P^{32} and Zn^{65} would be equal to about 0.8% of the MPRI for bone. The intake of I^{131} would have resulted in a dose of about 2 mrem to the thyroid. Concentrations of radionuclides measured in milk are tabulated in Appendix F, Table 1.(6)

Miscellaneous fresh farm produce was sampled periodically for radioanalysis during the 1965 growing season from local farms and commercial outlets. Results of these measurements, tabulated in Appendix F, Tables 3-5,(6) were similar to those of previous years(7,8) and indicated that only small quantities of radionuclides are present in locally grown produce.

The concentrations of I^{131} found in samples of fresh vegetables collected from local farms and markets during the period of May through September were less than or approximately equal to the analytical limit of 0.05 pCi/g. There was no significant difference noted in concentrations found in local farm produce and in produce purchased from commercial outlets. If these fresh vegetables had been consumed at the rate of 100 g/day throughout the 5 month growing season, the average annual intake from this source would have been about 730 pCi I^{131}. Such an intake would imply an annual dose of about 1 mrem to the thyroid of a typical adult Richland resident.

Concentrations of I^{131} in Cattle Thyroids

Thyroids of cattle are collected periodically from slaughter houses in Moses Lake, Yakima, Walla Walla, Wenatchee, and Pasco, and are sent to Hanford for radioanalysis. Since the concentration of I^{131} in bovine thyroids is about two orders of magnitude higher than that in the pasture grass or in milk, it is advantageous to use thyroid measurements to follow probable trends in concentrations of I^{131} in milk and farm produce, especially when the levels in milk and vegetables are below the analytical limit. The average concentrations measured in beef thyroids during 1965 are shown in Figure 15. The maximum concentration was 150 pCi I^{131}/g from one sample collected in November at Pasco.

Data obtained from the cattle thyroids program for 1965 are tabulated in Appendix G, Table 1.(6)

External Radiation

Ionization chambers are stationed on the Hanford reservation and in Richland to estimate the gamma radiation exposure from external sources. Measurements in air 1 m above ground during 1965 averaged about 0.32 mR/day or 120 mR/yr at Hanford (Figure 16) and about 0.30 mR/day or 110 mR/yr at Richland (Figure 17), somewhat lower than measured during the past 2 yr.(7,8) Essentially all of this exposure is from natural background and worldwide fallout from nuclear testing. Measurements of external radiation are tabulated in Appendix H, Table 1.(6)

Direct radiation measurements are also made in the Columbia River at several locations with pocket-type ionization chambers submerged 0.6 to 1.5 m below the surface of the water. Exposure rates are higher in the river than over ground because of the presence of gamma emitters (especially

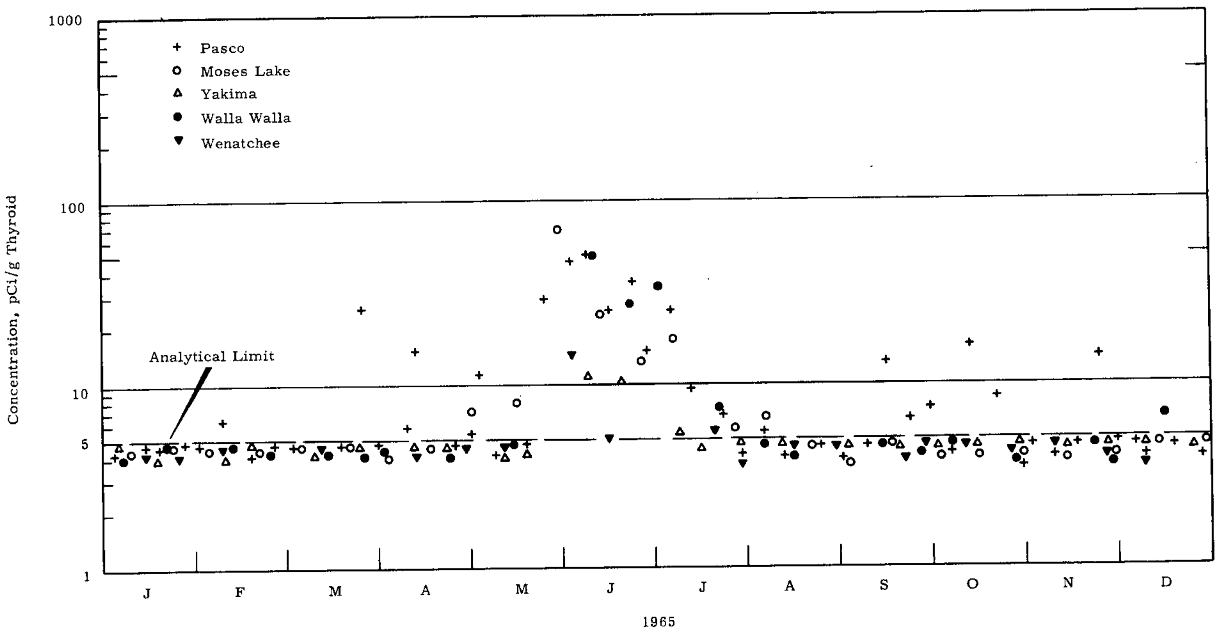

FIGURE 15. I^{131} *in Thyroids of Beef*

Na^{24}) in reactor effluent. In the vicinity of Richland, the average exposure rate in the water during the months of April through October was about 2 mR/day. A person swimming or boating in the river for a total of 240 hr during the year could have received a whole body exposure of about 20 mR. Measurements of immersion exposure rates in the river are tabulated in Appendix H, Table 2.(6)

An estimate of the external radiation exposure received by people that fish from the shore in the vicinity of the Hanford project is complicated by the daily fluctuation in the level of the river, but the exposure rate at the river's edge during 1965 was lowest during the freshet in late June and highest during low river flow rates in the fall months. Recent measurements of the gamma ray spectrum indicate that Zn^{65} accumulated by algae growth on the substrate at the river's edge is responsible for a major portion of a fisherman's radiation exposure. Assuming that an avid fisherman spent as many as 500 hr on the river bank in the vicinity of Richland during 1965, his external exposure could have been about 15 mR.

Radioactive Wastes Released to Ground

Liquid wastes from the chemical separations areas are routed to various facilities dependent upon their

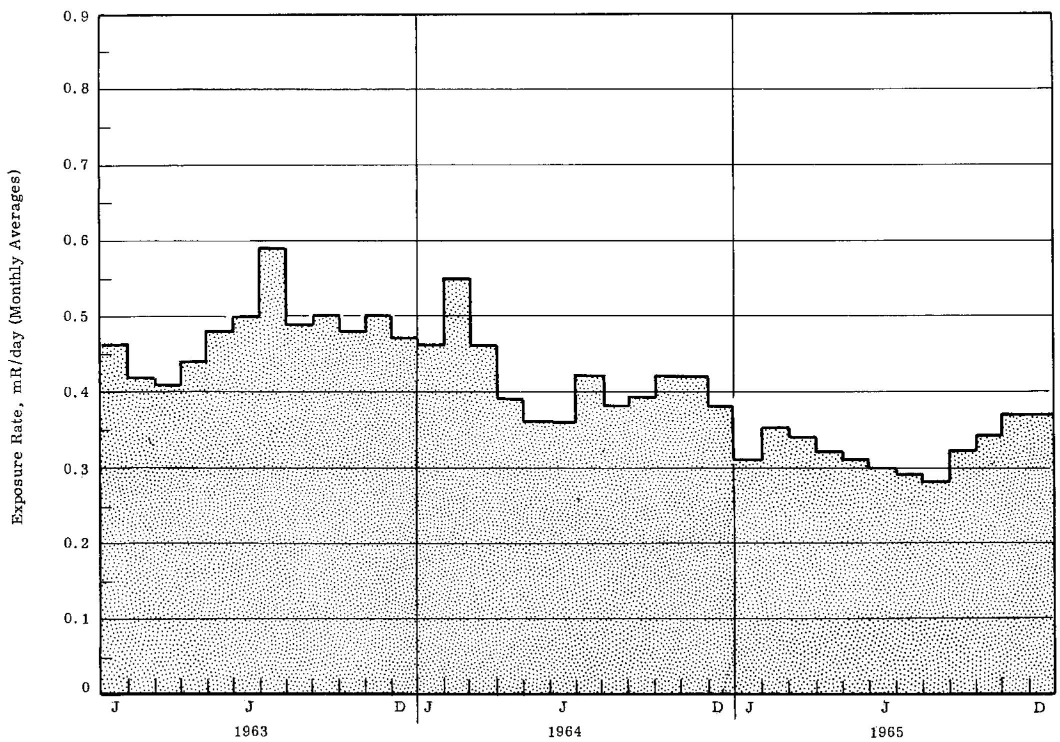

FIGURE 16. External Exposure Rate as Measured at Hanford Test Location

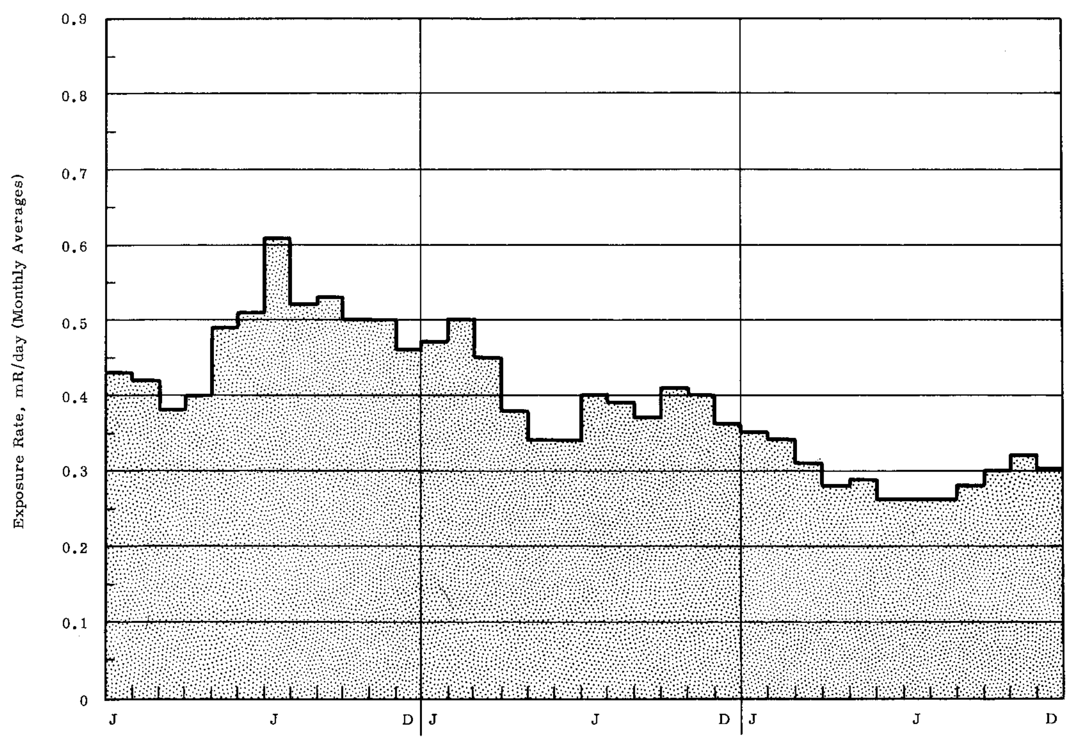

FIGURE 17. External Exposure Rate as Measured at Richland

burden of radionuclides. High level wastes (normally containing concentrations greater than 100 μCi/cm^3) are stored in underground concrete tanks lined with steel. Intermediate level wastes (ordinarily containing concentrations in the range of 5 x 10^{-5} μCi/cm^3 to 100 μCi/cm^3) are sent to underground "cribs" from which they percolate into the soil. The areas selected for intermediate waste disposal and high level waste storage have soil with good ion exchange capacity and ground water depths of 50 to 100 m. Low level wastes (usually containing less than 10^{-5} μCi/cm^3) are sent to depressions in the ground where surface ponds or "swamps" have been formed as a result of the continuous addition of the relatively large volumes of water.

One important objective in the management of wastes placed in the ground is the prevention of radiologically important radionuclides from reaching the ground water in quantities that could ultimately cause significant human radiation exposure should they migrate to the Columbia River. For this reason wells have been drilled in and around crib and tank storage areas to detect any leaks in the tanks and to measure radionuclides that have reached the ground water. Virtually all of the radionuclides present in the ground water have been introduced with liquids sent to the cribs. Figure 18 shows the probable extent and concentration of radioactive materials

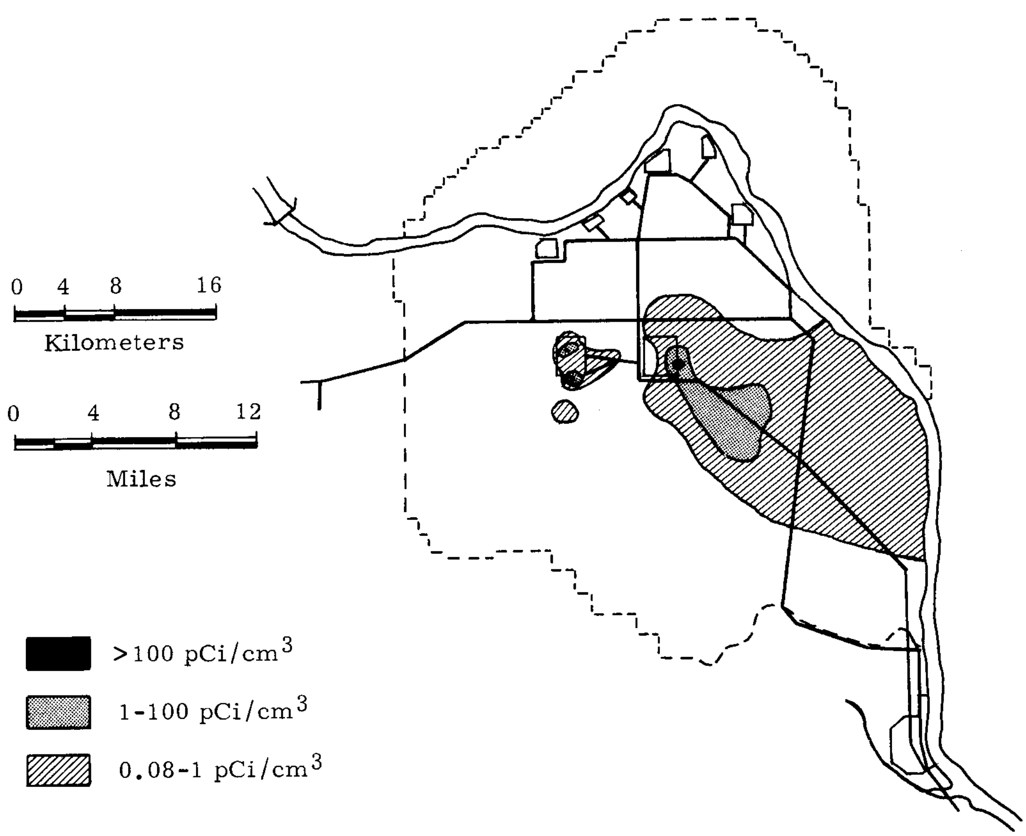

FIGURE 18. Probable Extent of Beta Emitters (Excluding H^3) in Ground Water, 1965

(excluding H^3) in the ground water. The bulk of this radioactive material is Ru^{106}–Rh^{106}.

A substantial amount of H^3 has also been sent to the ground with the intermediate level liquid wastes from the separations plants. Figure 19 shows the probable extent and concentration of tritium in the ground water in December 1965.(12,13) In all probability, some H^3 and Ru^{106}–Rh^{106} originating at the chemical processing areas is now entering the Columbia River. However, the contribution of these nuclides is too small to be detectable in the river water and any exposure from them is therefore negligible.

Fallout from Nuclear Weapons Testing

In addition to the radiation dose received by residents of the Hanford environs from Hanford originated radionuclides and from natural background radiation, a dose increment due to fallout nuclides is also received. Locally, this increment is below the national average because of the low rainfall in this region (16 cm/yr.) Measurements of fallout, like measurements of natural background radiation, are necessary to place the radiation dose resulting from Hanford operations into proper perspective. The fallout nuclides of interest during 1965 were H^3, Sr^{90}, I^{131}, and Cs^{137}. Although a small transient increase in I^{131}

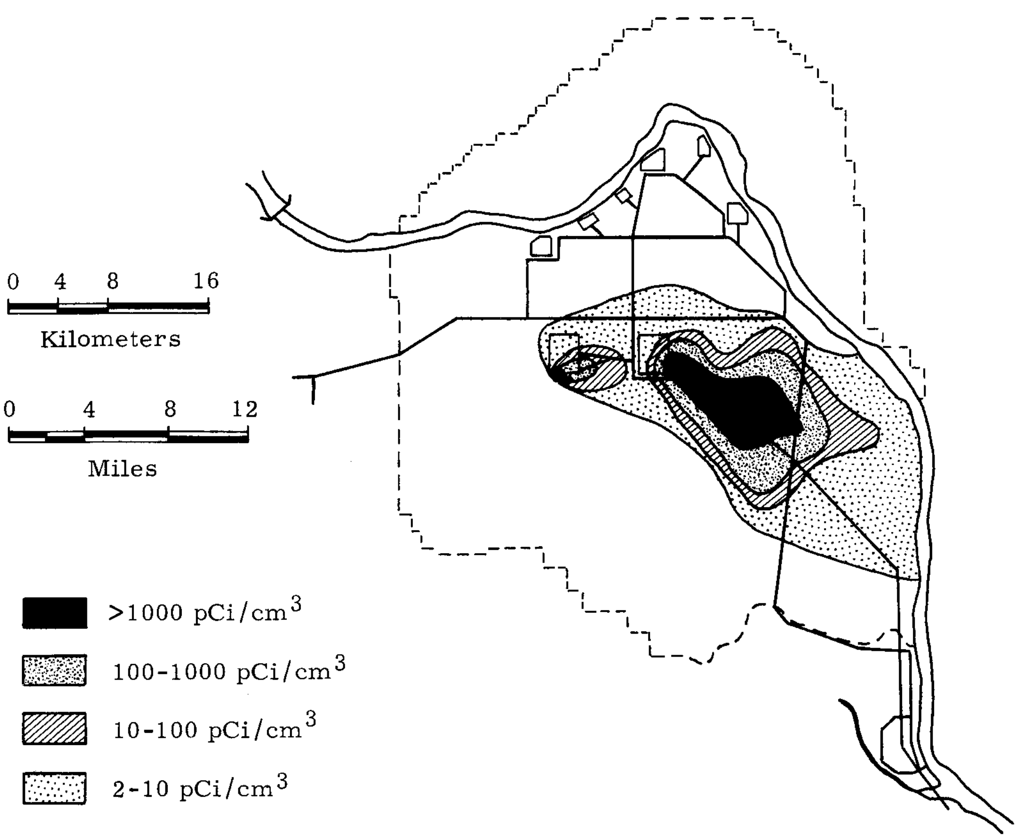

FIGURE 19. Probable Extent of Tritium in Ground Water, 1965

concentrations was observed in May and June (following the Chinese nuclear weapons test), the resulting thyroid dose was negligible.

Tritium (another fallout nuclide), although occasionally detectable in Columbia River water, was at such low levels (near or below the detection level of 1000 pCi/liter) that routine consumption of water obtained from the Columbia River implied an annual dose to the whole body of the Maximum Individual of less than 1 mrem. No H^3 was detectable by routine methods in any other environmental media.

Concentrations of Sr^{90} measured in milk produced locally are shown in Figure 20. These values are similar to concentrations found in commercial milk produced in areas that are remote from the Hanford plant. Sr^{90} found in milk from local farms averaged about 8 pCi Sr^{90}/liter. The concentration of Cs^{137} in milk (Figure 21) analyzed at Hanford was generally near the analytical limit of 30 pCi Cs^{137}/liter. Worldwide fallout is the principal source of Sr^{90} and Cs^{137} in milk.

About 10% of the total intake of Sr^{90} by local residents during 1965 came from drinking water obtained from the Columbia River. As in the case of milk, this Sr^{90} was of fallout origin.

Based on the same dietary information used in other sections of this report, the total intake of Sr^{90} during 1965 was about 0.007 μCi for the Maximum Individual and 0.006 μCi for the

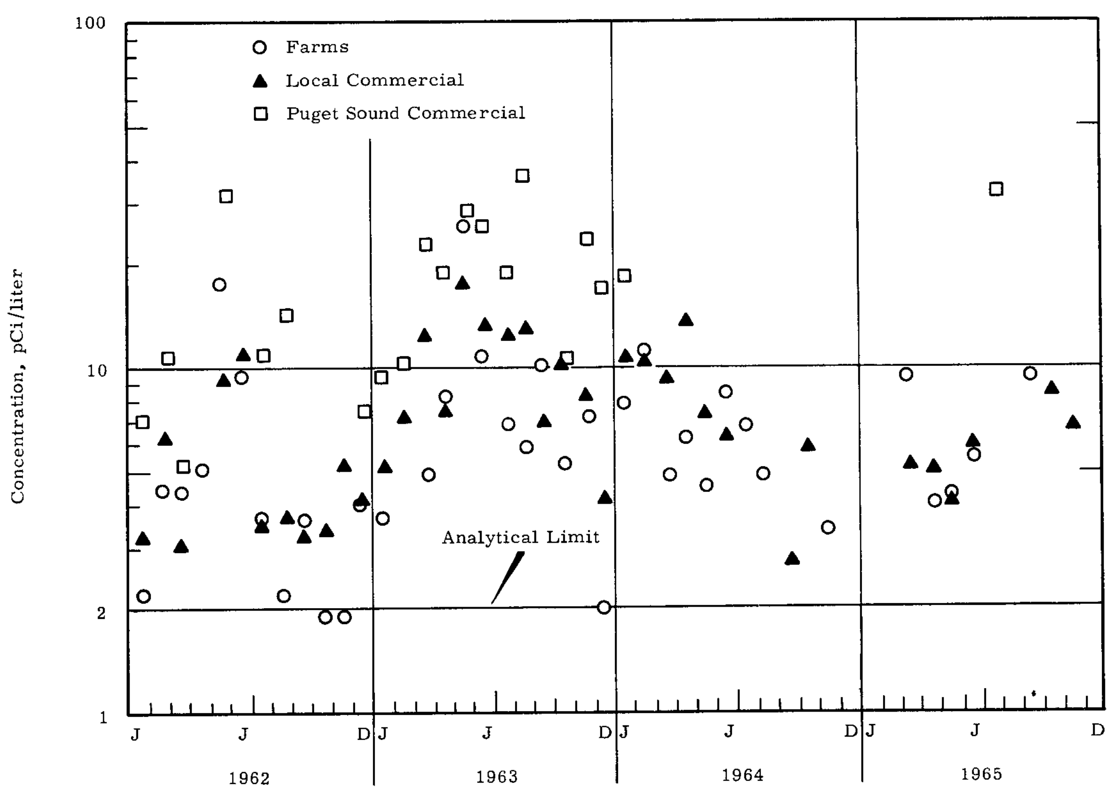

FIGURE 20. Sr^{90} in Locally Available Milk

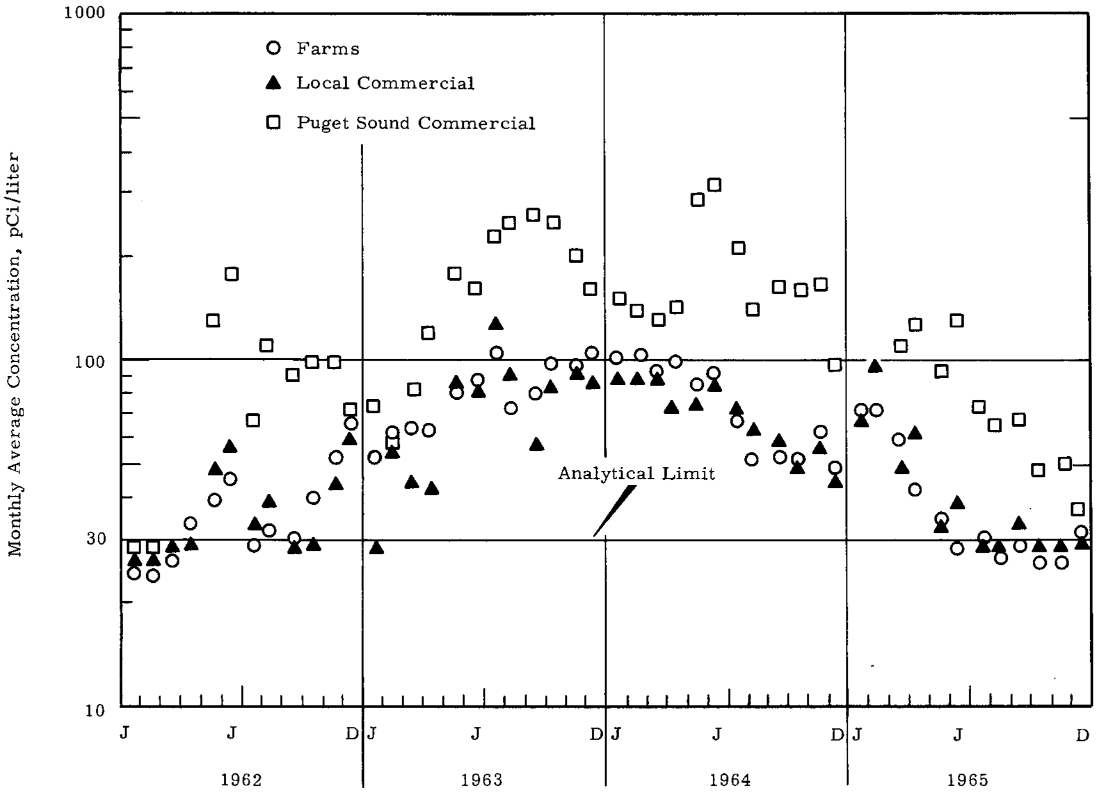

FIGURE 21. Cs^{137} in Locally Available Milk

average Richland resident. The total intake of Cs^{137} during 1965 was about 0.06 μCi for the Maximum Individual and about 0.04 μCi for the average Richland resident. The estimated annual dose from fallout radionuclides present in the Hanford environs is given in Table VII.

TABLE VII. Annual Radiation Dose from Fallout Nuclides-1965

Nuclide	Organ	Maximum Individual (mrem)	Average Richland Resident (mrem)
Sr-90	GI Tract	1	1
	Whole Body	1	1
	Bone	(2% MPRI)	(5% MPRI)
Cs-137	GI Tract	1	1
	Whole Body	2	1
	Bone	(0.2% MPRI)	(0.3% MPRI)

RADIATION EXPOSURE SUMMARY

It is not possible to determine the precise radiation dose received by every individual because of variations in the kinds and quantity of food consumed, variations in sources of food supply, and many variations in personal living habits. These inherent variations between individuals require a somewhat subjective approach when estimating the probable radiation exposure in relation to various established limits. The FRC has provided two sets of guides against which doses from environmental sources may be judged; i.e., one for the individuals that receive the greatest dose, and the other for the average dose received by the general population (taken as one-third of that set for individuals). For the Hanford environs, doses from the various sources described in the preceding sections have been complied in two ways to allow comparisons with guides for both the individual and the general population. In one case a hypothetical, but plausible, individual has been assigned dietary and other habits that would result in what would seem to be the greatest rational dose. For the general population, a dose has been estimated for what is called the typical Richland resident. Some residents may receive a larger dose than calculated for the typical Richland resident but it is improbable that any receive as much as that calculated for the "maximum" individual. Included in this intermediate group are families that subsist largely on foodstuffs produced on farms irrigated with water taken from the Columbia River downstream from the reactors.

The Maximum Individual

Attempts have been continued to identify the individuals living in the Hanford environs that receive the greatest radiation dose. Experience accumulated from the environmental surveillance program indicates such individuals are undoubtedly persons that frequently eat fish caught locally in the Columbia River and foodstuffs grown on farms irrigated with Columbia River water. Additional data collected during 1965 continued to support the assumption that fish, consisting mainly of crappie, perch, bass, and catfish caught near Burbank (Figure 2), are the most important source of radionuclides for the "maximum" individual. On the basis of an assumed consumption of 200 meals/yr and radiochemical analyses of such fish, the intakes of P^{32} and Zn^{65} for the "maximum" individual during 1965 would have amounted to 1.7 and 0.4 μCi, respectively. Whether this amount of fish was actually eaten by the individual was not confirmed. However, other persons reporting an unusually high consumption of local fish were counted in the Whole Body Counter and were found to have far less Zn^{65} deposited (by a factor of $\sim$0.03) than predicted on the basis of their estimates of the quantties of fish eaten. As a basis for calculating the intake of radionuclides from fish, we have continued to use the maximum reported consumption of 200 fish meals per year.

The consumption rates of other foods for the hypothetical maximum individual are based on the maximum intakes described in various dietary surveys. It is assumed that this individual consumes each day 2 liters of water from the Pasco system, 1 liter of milk, 230 g of beef, and nearly 200 g of fresh leafy vegetables (in season), all produced on river irrigated farms in the Riverview District. The composite doses from these sources are illustrated in ure 22.

In the case of the thyroid gland, it is probable that the maximum exposure occurred in small children because of the relatively small thyroid mass in which the I^{131} accumulates. The thyroid of a small child is assumed to weigh 2 g compared with 20 g for the adult. On the basis of a daily intake of 1 liter of milk, 50 g of fresh leafy vegetables produced in the Riverview District, and 0.8 liter of water from

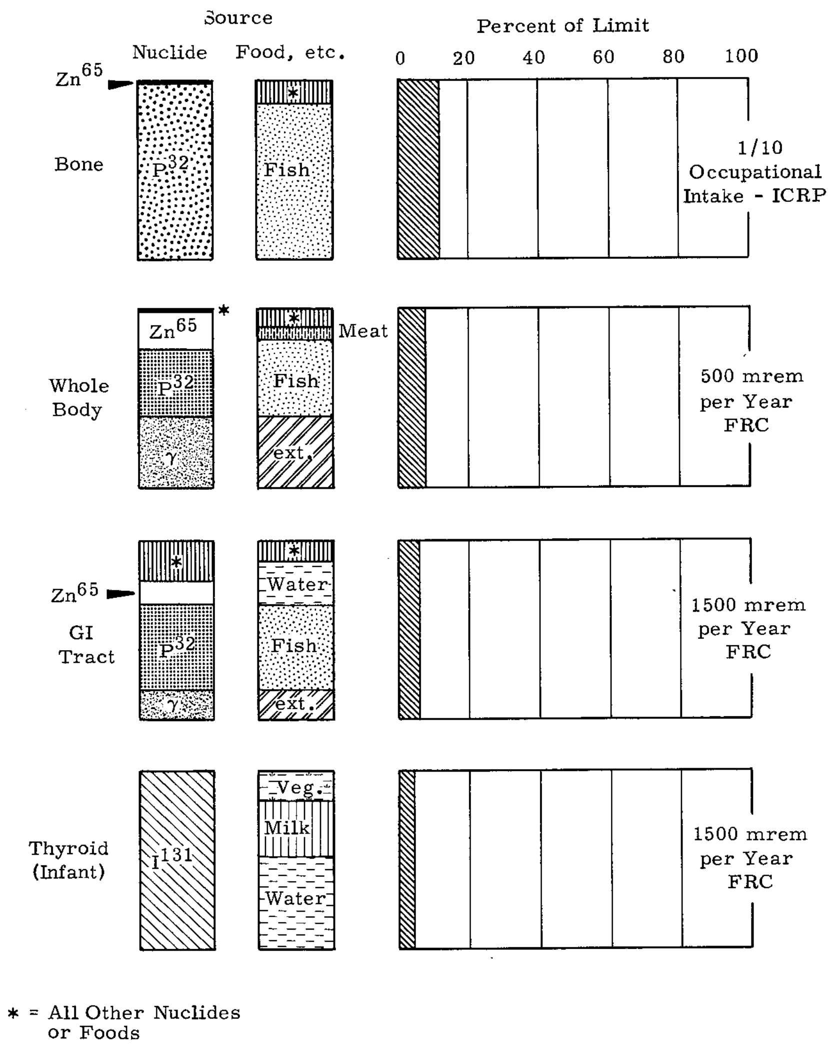

FIGURE 22. Estimated Dose to "Maximum" Individual, 1965

the Pasco system, the estimated annual intake of I^{131} was about 3400 pCi for a small child in 1965. Such an intake would result in a thyroid dose of 58 mrem or 3.9% of the FRC Radiation Protection Guide for individuals.

The Typical Richland Resident

The vast majority of people who live in Richland, Pasco, and Kennewick obtain their food from local commercial stores (rather than directly from farms) and consume little or no fish caught from the Columbia River. The principal sources of radionuclides ingested by these people are worldwide fallout (see the section Fallout from Nuclear Weapons Testing) and drinking water obtained from the Columbia River. It is assumed that the contribution from fallout of Sr^{90} and Cs^{137} is the same in all three cities. These contributions were estimated with the use of data obtained from dietary surveys made elsewhere in the US and reported by the Federal Radiation Council,[3] but adjusted on the basis of the concentration in milk sold in local stores during 1965. The estimated annual intakes of Sr^{90} and Cs^{137} during 1965 represented about 5% and 0.3%, respectively, of the MPRI (bone as the critical organ).

The contribution from Hanford created radionuclides in drinking water is substantially different for the three cities as discussed previously in the section, Radionuclides in Drinking Water. The GI tract dose in Richland was greater than in the cities further downriver because the short-lived nuclides are in greater abundance. As shown in Figure 23, the estimated dose to typical Richland residents for 1965 was about 35 mrem or 7% of the maximum permissible dose. The contribution to the GI tract dose from other sources was relatively insignificant and, conversely, the concentrations of bone seeking radionuclides, such as P^{32} and Sr^{90}, in water were so low that drinking water did not contribute any significant radiation dose to the bone.

For calculating a dose to the thyroid gland, the most appropriate sample of the exposed population would appear to

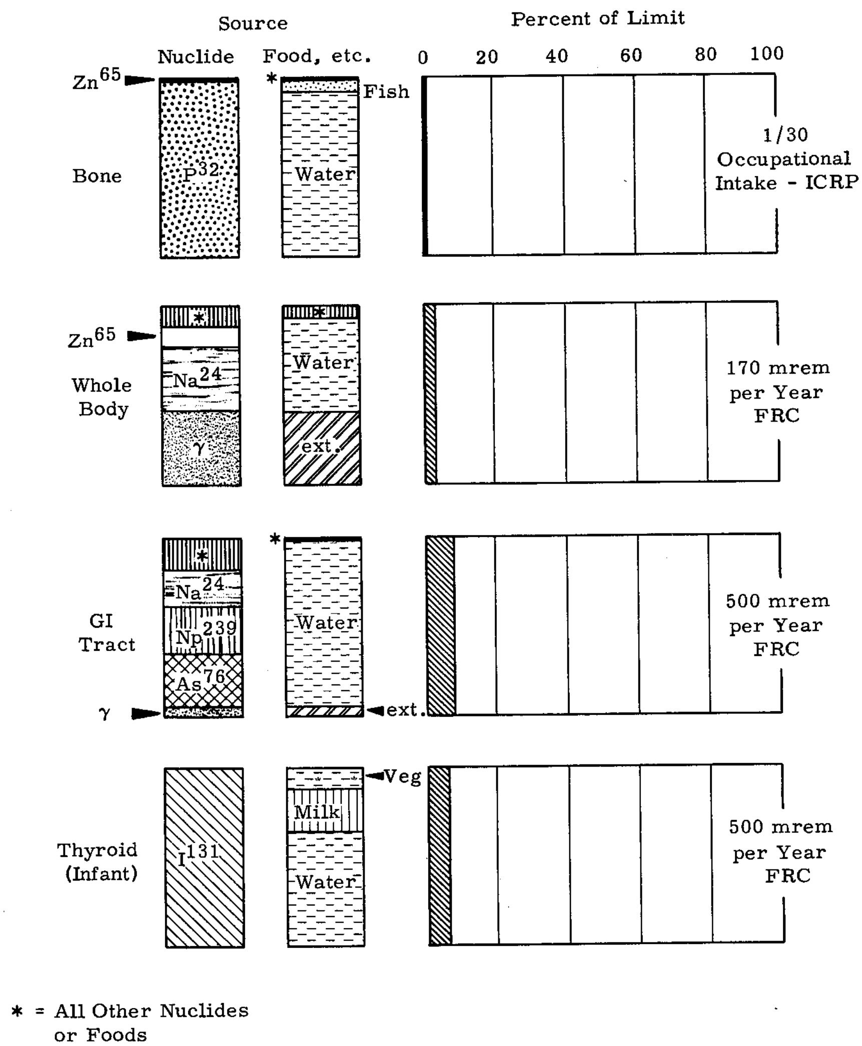

FIGURE 23. Estimated Dose to "Typical" Richland Resident, 1965.

be small children living in Richland who drank water from the municipal system (0.4 liter/day), milk (0.6 liter/day) obtained from the local stores, and fresh vegetables (25 g/day) obtained from local markets. The total intake of I^{131} during the year from these sources would be about 1800 pCi or an average of about 5 pCi/day. This is in the middle of the FRC Range I (the most favorable range) and indicates a radiation dose of 30 mrem for 1965 (Figure 23).

The estimated whole body dose (Figure 23) of the average Richland resident from nuclides of Hanford origin was 5 mrem. Whole body doses from natural background (excluded from the FRC Guide) and fallout sources in this region are estimated at about 110 mrem/yr and 2 mrem/yr, respectively.

CONCLUSIONS

During 1965, the environmental surveillance program of the Hanford environs again showed that the amounts of radioactive materials present were well within nationally accepted limits at all times and that releases of radioactive wastes were well controlled.

P^{32} released to the Columbia River in reactor effluent continued to be the most significant source of radiation from the Hanford project. This P^{32} is concentrated by fish that inhabit the river downstream from the reactors. Individuals who regularly eat such fish as a major part of their diet throughout the year could conceivably have taken in as much as 11% of the annual permissible amount of this bone seeker.

There was one unusual release of radionuclides from the Hanford plant during 1965 that warranted special assessment of the radiation dose to persons in the environs.[9]

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Kennewick, Washington

Pasco Water Department
Pasco, Washington

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Richland, Washington

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Yakima, Washington

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Olympia, Washington

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Wenatchee, Washington

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