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# ENVIRONMENTAL SURVEILLANCE AT HANFORD FOR CY-1970

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SEPTEMBER 1973

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# ENVIRONMENTAL SURVEILLANCE AT HANFORD FOR CY-1970

by

J. P. Corley, Manager

and Staff of the

Environmental Evaluations Section

September 1973

BATTELLE
PACIFIC NORTHWEST LABORATORIES
RICHLAND, WASHINGTON 99352

During 1970, the Hanford facilities were operated for the Atomic Energy Commission by: Atlantic Richfield Hanford Company; Pacific Northwest Laboratories of Battelle Memorial Institute; Douglas-United Nuclear, Incorporated, Hanford Environmental Health Foundation, and ITT Federal Support Services, Incorporated.

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# ENVIRONMENTAL SURVEILLANCE AT HANFORD FOR CY-1970

## INTRODUCTION

The primary mission at the Hanford site of the Atomic Energy Commission has been the production of plutonium. Activities have included nuclear fuel fabrication, plutonium production and test reactor operation, chemical separations of irradiated fuels, laboratory support and research, waste storage and disposal, and plant support operations. In recent years, privately-owned facilities located within the Hanford site boundaries have included a power generating station, an office building, and a radioactive waste burial site.

Low-level wastes from Hanford operations, fallout from nuclear weapons testing, naturally-occurring radioelements, and cosmic radiation all contribute to radioactivity in the Hanford environs. The most significant Hanford contributions to off-plant radioactivity and consequent population doses have usually originated with reactor cooling water released to the Columbia River.(1,2,3) Between December, 1964 and December, 1970, all but one (KE) of the eight production reactors with once-through cooling were deactivated. The only other production reactor remaining in operation at Hanford during 1970 was N Reactor, which has a closed primary cooling loop and releases only minor quantities of radioactivity to the river.

The purpose of this annual report is to present an evaluation of the combined off-site effects of the radioactive effluents released to uncontrolled areas by all Hanford contractors during 1970. Analytical data and other measurements on which this evaluation is based have been published in a separate volume (BNWL-1669 ADD). The previous reports in this series were BNWL-1505 and BNWL-1505 APP(1) for the year 1969.

## SUMMARY OF RESULTS

The 1970 Hanford environmental surveillance program indicated continued compliance of the Hanford contractors and their operations with applicable environmental standards. Most of the environmental radiation dose for people living in the Hanford environs was due to natural sources and regional fallout rather than to Hanford operations. Although much reduced from previous years, the largest source of radioactivity released to man's immediate environment from Hanford continued to be reactor cooling water discharged from the Columbia River.

The basic standards for evaluating the adequacy of radiological control at Hanford are taken to be radiation doses to specified population groups, as given in AEC Manual, Chapter 0524 Appendix,[4] and listed in Table 1. Concentration Guides from AECM 0524 and FRC Action Guides[7] are used to supplement the basic dose standards.

TABLE 1. Summary of Applicable Dose Standards (mrem/yr)

| Type of Exposure | Individuals with Maximum Probable Dose | Average Dose to a Suitable Sample of the Exposed Population |
|---|---|---|
| Whole body, gonads, or bone marrow | 500 | 170 |
| Other organs | 1500 | 500 |

The surveillance program included sampling and analysis on a routine basis of river water, municipal drinking water, groundwater, air, milk, foodstuffs, fish, shellfish, and gamebirds. Measurements were made of external gamma exposure rates at land stations, in the river, over the river surface, and along the river shoreline. Contamination surveys were made at selected ground plots and along public highways adjacent to the Hanford site. Columbia River water and Richland drinking water were routinely sampled for chemical and biological analysis, and air quality measurements were made at locations adjacent to the site boundaries.

Shutdown in February, 1970, of KW Reactor, one of the two remaining single-pass, river water-cooled production reactors, as well as an extended outage of all reactors, greatly reduced the major remaining source of population exposure from Hanford operations. In 1970, average river concentrations of radionuclides were less than 3% of the Concentration Guides, and transport rates of radionuclides in the river were much reduced from 1969. The radionuclide showing the highest average percentage of its Concentration Guide in treated water at the Richland water plant was $^{24}Na$ at 2.1%. Reductions from 1969 values were seen in radionuclide concentrations in Columbia River fish, shoreline radiation levels, and direct radiation measurements of the river.

Groundwater contamination originating in the chemical separations areas showed no appreciable advance toward the Columbia River. Tritium in groundwater around N Reactor area may have contributed to an apparent small increase measured in river tritium concentration between Vernita and Richland, but the average downstream concentration from all sources, including weapons test and natural formation, was less than 0.05% of the Concentration Guide.

Airborne radioactivity measurements continued to show the occasional presence of fallout from weapons testing. Particulate radioactivity concentrations around the site perimeter, however were essentially the same as at more distant locations, indicating a lack of contribution from Hanford sources. Land-based gamma radiation measurements showed the same pattern, with a small increase from 1969 to 1970. Radioiodines were not detected in air or milk samples except during a fallout occurrence.

Unusually high concentrations of $^{32}P$ were found in four of fifteen ducks collected at two trenches receiving undiluted reactor cooling water. Immediate consumption of a normal meal of the duck with the highest $^{32}P$ concentration in muscle, 0.14 μCi/g, could theoretically have resulted in a radiation dose to skeletal bone of about 6 rem, four times the applicable standard. However, based on hundreds of ducks collected during years of routine sampling along the river and nearer public hunting areas, radionuclide concentrations in ducks resident for extended periods on open water around the plant facilities are not representative of those in birds likely to be taken and consumed by the public. Corrective action was taken to prevent any further access by waterfowl to the trenches.

As in past years, annual radiation doses resulting from Hanford operations were calculated for the bone, whole body, GI tract, and thyroid for both a hypothetical Maximum Individual and the Average Richland Resident.

During 1970, calculated doses of Hanford origin were all much less than one-tenth of the applicable dose standards, reflecting a general and significant decrease from comparable 1969 values.

The hypothetical Maximum Individual postulated to receive the largest plausible dose from Hanford sources is assumed to have the following sources of exposure:

- 200 meals of fish caught downstream from the reactors.
- 500 hours on the river shoreline catching the fish.
- milk, meat, and produce in season from farms irrigated with river water.
- drinking water from a municipal water supply taken from the river.

For 1970, the annual skeletal bone dose for this Maximum Individual was calculated as 94 mrem, or 6% of the applicable standard of 1500 mrem. Doses to both the GI tract and whole body were estimated to be about 2% of the respective standards.

For thyroid dose estimates, an infant with a 2-gram thyroid, consuming milk and some vegetables from river-irrigated farms, was considered the Maximum Individual. Dietary habits postulated for such an infant could have resulted in an annual dose to the thyroid of about 2% of the standard of 1500 mrem.

The Average Richland Resident is also defined as an adult for estimation of bone, whole body, and GI tract doses, and as an infant for estimation of thyroid dose. The dietary and recreational habits of the average Richland resident have been determined from local surveys. The small radiation doses received by this population group in 1970 from Hanford operations continued to originate in most part from nuclides discharged to the Columbia River in reactor cooling water and taken into the Richland municipal supply. For dose estimation, radionuclide concentrations measured at the Richland water treatment plant were adjusted for dilution and radioactive decay in the water distribution system. For 1970, the calculated GI tract and bone doses were 2% of the standard of 500 mrem per year for this population group. The whole body dose was estimated to be about 1% of the standard of 170 mrem per year. The thyroid dose to the average Richland infant was calculated to be about 2% of the standard of 500 mrem per year.

Water quality measurements on Columbia River water above and below the Hanford facilities indicated that the river met Washington State water quality standards for pH, turbidity, dissolved oxygen, coliform organisms, and chemical concentrations. Small increases from upstream to downstream locations were seen in average temperature, coliform organisms, nitrate ion, and hexavalent chromium concentrations.

Local air quality measurements showed occasional episodes of high particulate (non-radioactive) concentrations exceeding Washington State standards, but only in conjunction with strong winds and blowing dust. As with other air quality measurements, Hanford operations in 1970 did not appear to have a significant impact.

## HANFORD SITE DESCRIPTION

The Hanford site is a semi-arid region of southeastern Washington state (Figure 1) where the annual average rainfall is about 16 cm (6 inches). This section of the state has a sparse covering of natural vegetation primarily suited for grazing, although large areas near the site 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 Hanford site and forms part of the eastern boundary. As indicated by the wind roses shown in Figure 2, prevailing winds near the plant production sites 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 but breaking during the day to provide unstable and turbulent conditions.

The nearest population center is the Tri-Cities area (Richland, Pasco, and Kennewick) situated on the Columbia River directly downstream from the plant. Smaller communities in the vicinity include Benton City, West Richland, Mesa and Othello. The population of the communities near the plant together with the surrounding agricultural area, is about 100,000.

The farming area closest to Hanford is on Wahluke Slope, about 11 km (7 miles) from N Reactor but much of the land east and south of the project

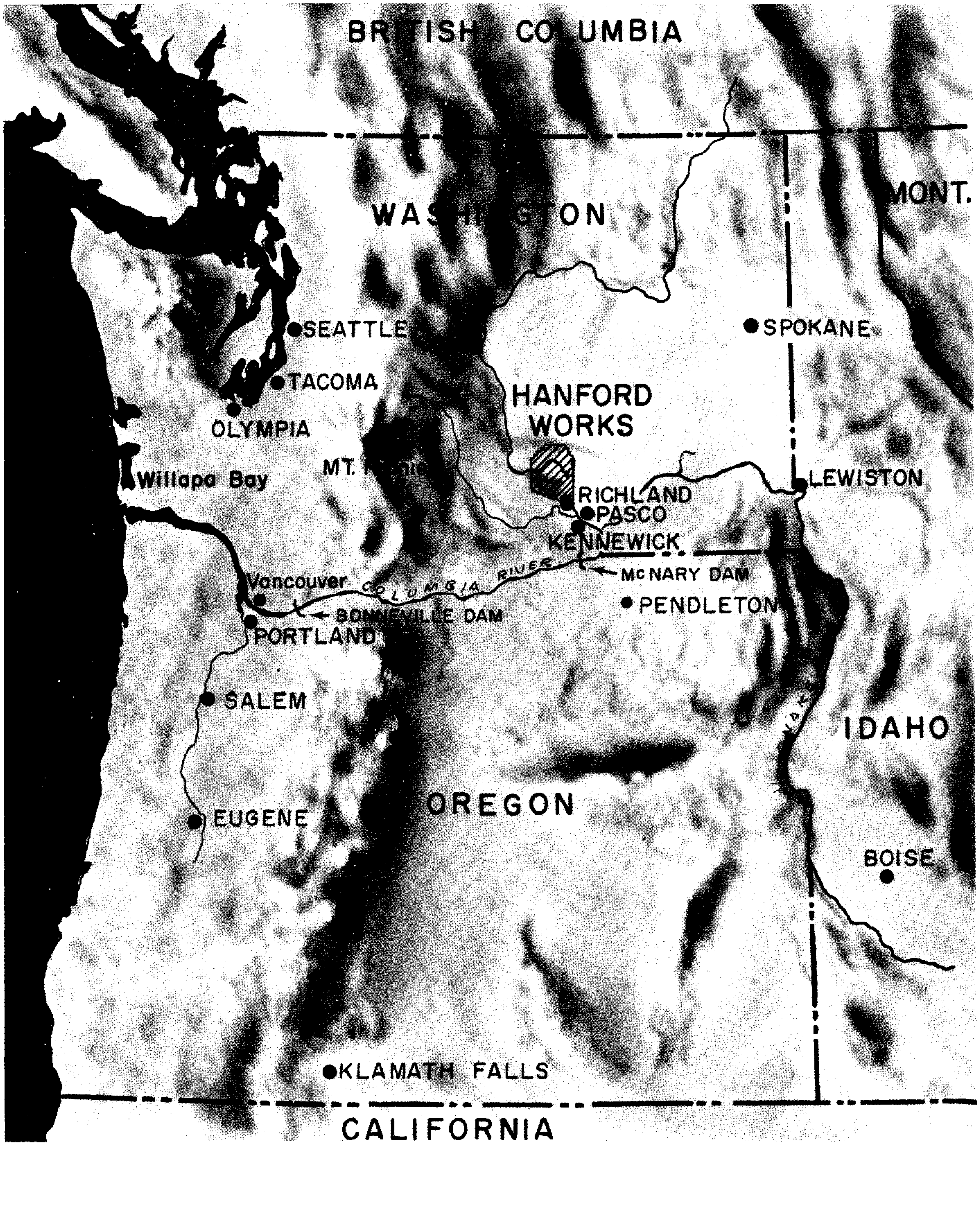


FIGURE 1. Geographical Relationship of Hanford to the Pacific Northwest

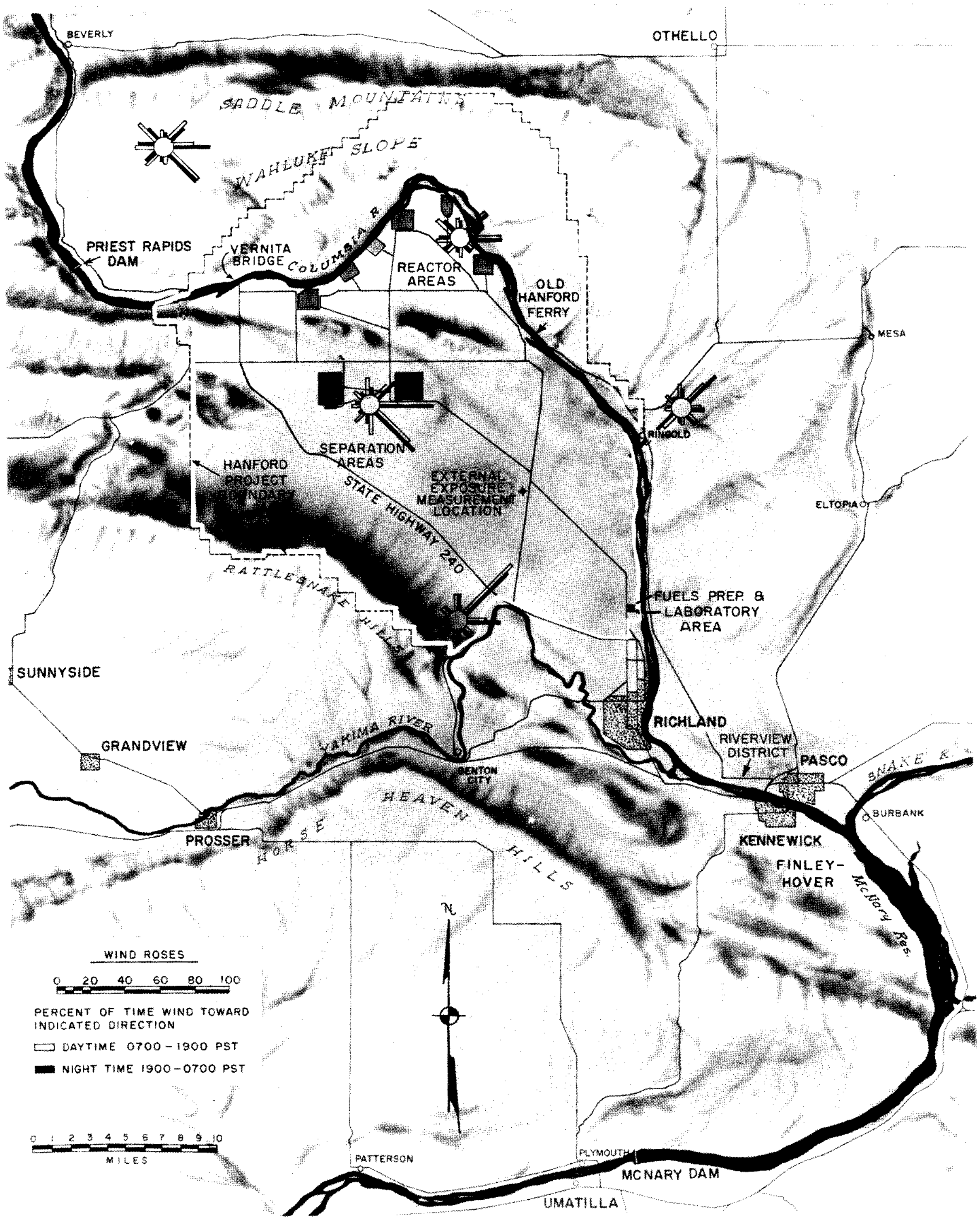


FIGURE 2. Features of Hanford Project and Vicinity

boundary is under cultivation. Most irrigated farms near the Hanford plant obtain water from the Yakima River or from the Columbia River above the plant. However, two small irrigated areas using Columbia River water taken downstream from the reactor are the Ringold farms and the Riverview district west of Pasco. These are about 40 km (25 miles) and 70 km (45 miles), respectively, downstream from the N Reactor. The principal products from the larger farm plots are hay, fruit, beef, and dairy products.

## STANDARDS FOR EVALUATION

Basic regulations governing radiological criteria for the Hanford environment are embodied in AEC Manual, Chapter 0524 Appendix,[4] which specifies radioactivity release limits, Concentration Guides, and Population Dose Criteria. Federal Air Quality[5] and Washington State Water Quality Standards[6] are used for air and water quality comparisons. Applicable portions of these several standards are given in Appendix A.

For the Hanford environs, annual radiation doses from the various exposure pathways described in the following sections have been combined for comparisons with standards for both individuals and the general population. As in previous years, a hypothetical Maximum Individual has been assigned pessimistic dietary and other habits in order co estimate doses for comparison with the standards for individuals. For thyroid dose comparisons the Maximum Individual has been assumed to be an infant.

For the general population, annual radiation doses have been estimated in recent years[1,2,3] for what is called the Average Richland Resident, using the best available information on dietary patterns and recreational habits. As in 1969, contributions from sources external to the body are included in the 1970 dose estimates for the GI tract, whole body, and bone. The thyroid dose estimate is for an infant who is expected to have no exposure to external radiation of Hanford origin.

The total dose received by a specified organ of the body may result from three sources of exposure: (1) radionuclides deposited within that organ, (2) radionuclides elsewhere in the body, and (3) sources external to the body. For purposes of these evaluations, the estimated dose to a critical organ from internal emitters does not include contributions from radionuclides deposited elsewhere in the body.

For thyroid dose calculations, the Federal Radiation Council gave specific guidance[7] for permissible daily $^{131}I$ intake for infants, assuming a thyroid size of 2 grams. Concentration Guides for radioiodines given in AEC Manual, Chapter 0524 Appendix, Table II are based on the same assumption. This guidance has been used both for the translation of radioiodine intake to dose and for the selection of appropriate groups for dose evaluation. For whole body, GI tract, and bone dose calculations, ICRP values[8,9] are used for the several physiological parameters involved in translating intake to dose.

The radiological unit used throughout most of this report is the rem (dose-equivalent). When the contributing nuclides of interest in the Hanford environment are considered with the organs (other than skeletal bone) for which radiation doses (in rads) are calculated, the values in rad or rem units are numerically equal. For bone-seeking nuclides an additional factor to account for non-uniform distribution in the bone is included in the dose-equivalent to intake ratios. For external exposure, a 1:1 equivalence of exposure in Roentgens to absorb dose in rad has been assumed.

## SURVEILLANCE PROGRAM

The routine surveillance program at Hanford is primarily designed to demonstrate compliance with the applicable standards described above, although other pruposes are also served, including emergency preparedness and trend detection.

Environmental surveillance at Hanford in 1970 included measurement of environmental exposure rates and sampling of air, drinking water, surface water, groundwater, soil, vegetation, milk, locally produced foodstuffs, wild game and fish. Appendix B lists those samples and measurements obtained routinely at or beyond the plant boundaries.

Air was sampled with constant volume air pumps, operating at 40 ℓ/min. (1.5 cfm), with a particulate filter and iodine sampling device in series.

Particulate filter media for off-site samples was 47 mm diameter HV-70,* an asbestos fiber mat filter. In addition to individual filter analyses, all filters were composited in one of four groups for monthly gamma scans and quarterly measurements for plutonium and $^{90}Sr$.

Radioiodines were routinely sampled with a potassium-iodide-impregnated charcoal in a 15 cm (6 inch) long cartridge during the last half of the year; caustic (NaOH) scrubber (bubbler) samplers were used for the first half of 1970. Although the reported analytical limit (see Appendix D) for radioiodines with the charcoal cartridge was somewhat higher ($7 \times 10^{-14}$ μCi/ml) than with the caustic scrubbers ($2 \times 10^{-14}$ μCi/ml), the greater efficiency of the charcoal for any organically-bound radioiodine present in the atmosphere provided the incentive for the changeover.

A further significant change was made at mid-year by the adoption of thermoluminescent dosimeters (TLD-200**) for external gamma radiation monitoring, replacing pencil-type ionization chambers for this purpose. These dosimeters were deployed in a specially-designed shielded package to protect them against damage and to reduce over-response at low-photon energies.

Water was sampled by integrating samplers and/or periodic one-liter grab samples with analyses for biological, chemical and radioactive content. Containers for collection of weekly integrated water samples for radiochemical analysis were pre-dosed with concentrated $H_2SO_4$ to minimize wall deposition and biological activity in the collected sample. Groundwater was sampled at five off-site wells and analyzed for tritium and nitrate ion.

Cattle fodder (hay or grass) was sampled when milk samples were collected at farms within local milksheds. Vegetation was normally analyzed only when positive analyses were obtained on the milk samples.

Foodstuffs (meat, milk, eggs, chicken, produce and oysters) and potential foodstuffs (gamebirds, fish and deer) were sampled for radioactivity on schedules varying from weekly to annually. Commercial samples of milk and other foods were purchased to provide a comparison with local samples.

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*Trade name of Hollingsworth-Vose Company.
**Trade name of Harshaw Chemical Co. for $CaF_2$(Dy).

Appendix C gives brief descriptions of the methods used for routine analyses. Routine radioanalyses were performed by U.S. Testing Company, Richland, Washington. Chemical and biological measurements in Columbia River water made by Battelle-Northwest laboratories; those in sanitary water and in air were made by the Hanford Environmental Health Foundation, Richland, Washington.

## SOURCES AND LEVELS OF ENVIRONMENTAL RADIOACTIVITY

Radioactive wastes continued to be generated during 1970 by the KE and N production reactors, the chemical processing plants, and the laboratories. High-level wastes were concentrated and retained in storage in the chemical processing areas. Controlled releases of low-level wastes, for which concentration and storage were not feasible, were made to the ground, to the atmosphere, and to the Columbia River.

Changes of significance in plant operations during 1970 included the retirement in February of KW Reactor, the seventh of the eight Hanford production reactors using single-pass cooling to be retired since 1964. Two plutonium production reactors, one single-pass (KE) and one recirculating coolant dual-purpose reactor (N), remained in operation. From February to April and again in September, no reactors were operating.

A marked reduction from 1969 occurred in releases of radioiodine from the chemical processing facilities. Effects of a reported atmospheric nuclear weapons test were detected temporarily in air and milk in December.

In late December, 1969, two ducks collected during routine surveillance from the K Reactor area trench were found to contain greater amounts of radioactivity, primarily $^{32}P$, than birds taken from the river. The trench received single-pass reactor coolant, and the ducks had apparently consumed algae from this site. Initial followup in January, 1970, involved collection of waterfowl from all open ponds and trenches at the Hanford site. One duck was found at the K trench and one more with unusually high $^{32}P$ concentrations was found residing on the N Reactor trench. Corrective action was taken to prevent further access by gamebirds. As in past years, none of the many gamebirds collected along the river and close to public hunting areas showed any similar concentrations of radionuclides.

## RADIOACTIVITY IN THE COLUMBIA RIVER

### Nuclides Present in Reactor Effluent

Cooling of the Hanford production reactors (with the exception of N Reactor) was accomplished by a once-through passage of treated Columbia River water. N Reactor uses recirculating, demineralized water as a primary coolant. Some cooling water, containing radioactive material, is lead off to a ground disposal site with overflow to the N trench; liquid wastes are collected and transported to the chemical processing areas for processing and disposal. Most of the radionuclides discharged to the ground decay before reaching the river via passage through the soil. Others are absorbed or filtered by soil particles and retained. Although some radionuclides eventually enter the river, the total quantitiy of radioactivity entering the Columbia River from N Reactor is a very small fraction of that previously released from the single-pass reactors (KE and KW) and has generally not been detectable in the river at the downstream plant boundary.

At the older single-pass production reactors, some chemical elements present in the cooling water are activated while passing through the reactors. Other elements adhere to films formed on surfaces of fuel elements and process tubes, are activated, and are eventually discharged with the cooling water to the river. Table 2 shows the relative abundance of the radionuclides found in the cooling water of the single-pass production reactors, four hours after leaving the reactor.

Many of the radionuclides found in reactor cooling water are short-lived and disappear quickly due to radioactive decay. In addition, sedimentation and uptake by aquatic organisms removes some fraction of most radionuclides from the river water. Small amounts of fission products are released to the river from the fissioning of natural uranium present in the river water used for cooling, from occasional fuel element cladding failures, and from weapons test fallout from nuclear weapons testing. Some radionuclides probably also entered the river from the ground disposal sites, but their contribution to the total radioactivity in the river in 1970 was not detectable.

TABLE 2. Relative Abundance of Radionuclides in Single-Pass Reactor Effluent[a]

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

[a] Trace nuclide composition based on analyses made in 1964 and 1968.
[b] These radionuclides as a group are denoted hereafter as RE+Y (Rare Earths + Yttrium).

River Flow Rates

Seasonal fluctuations in flow rate of the Columbia River affect the concentrations of radionuclides released in the river by varying the quantity of water available for dilution. In addition, the scouring of sediments deposited in reservoirs behind each Columbia River dam causes seasonal fluctuations in transport rates of those longer-lived nuclides accumulated in the sediments. The fluctuating flow rate also affects the time required for a specific volume of water to move from one location to another, which in turn affects the time available for decay of the short-lived nuclides before exposure to the public.

Figure 3 shows the weekly average flow rates of the Columbia River at Priest Rapids and Bonneville Dams as determined from daily average flow rates published by the U.S. Geological Survey.[(10)] For 1970, the average river flow rate at Priest Rapids was 2790 $m^3$/sec (96,400 $ft^3$/sec) which was less than the 1948-1962 annual average of 3770 $m^3$/sec (133,000 $ft^3$/sec).

River Concentrations

During 1970, samples of river water were collected upstream from the production reactors at Vernita and below the reactors at the Richland water plant intake and at Bonneville Dam. Where possible, cumulative sampling equipment was used to provide a more representative sample than periodic "grab" samples. This cumulative sampling technique, however, prevents evaluation of the concentrations of radionuclides with very short half-lives; the more prevalent of these radionuclides (RE+Y, $^{24}$Na, $^{56}$Mn, $^{64}$Cu, $^{76}$As, $^{122}$Sb, and $^{239}$Np) were measured in monthly "grab" samples. Detailed measurements are reported in the Addendum to this document.

Table 3 shows the annual average concentrations of selected radionuclides in river water at Richland and at Bonneville Dam for 1966-1970. The data for 1966 reflect the effects of complete reactor shutdown during July and August. Comparison of 1970 with 1969 concentrations indicates a major reduction for all radionuclides released to the river.

Table 4 shows concentrations for a larger list of nuclides at Richland and Vernita for 1970 only. Activation product nuclides and $^{239}$Np are attributed to Hanford reactor operations. $^{90}$Sr, $^{239}$Pu, and total alpha-emitter

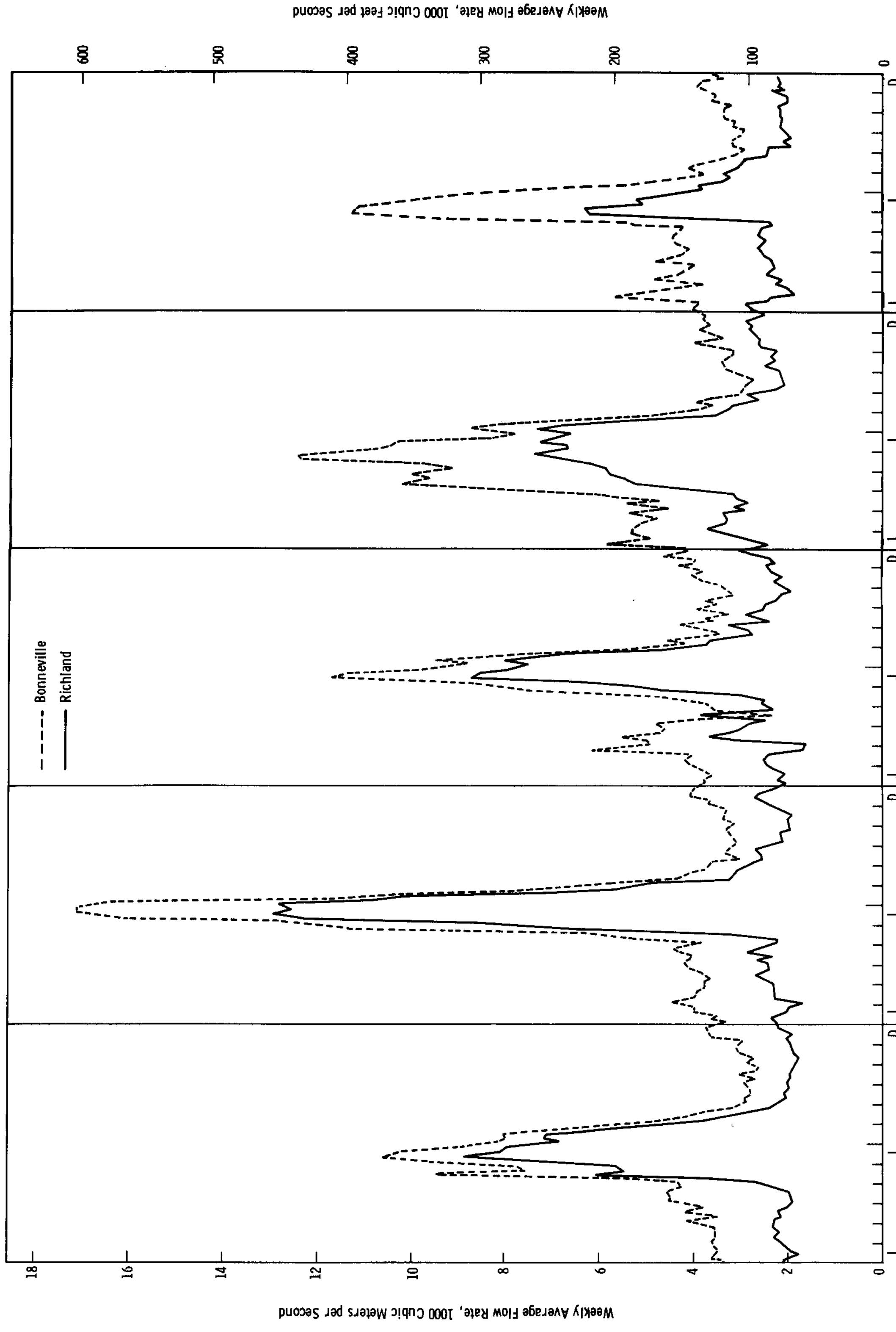


FIGURE 3. Weekly Average Flow Rate of the Columbia River at Richland and Bonneville Dams, 1966-1970

concentrations are near or below analytical limits, and do not indicate a significant contribution from Hanford by comparison with upstream analyses at Vernita. The small increase in measured tritium concentrations between Vernita and Richland is probably due to releases from the operating reactors. The average concentration of any nuclide in the river at Richland during 1970 did not exceed 3% of the Concentration Guide.*

Bonneville Dam, approximately 490 km (240 miles) below the Hanford reactors, is the farthest downstream location where river water is routinely sampled as part of the Hanford environmental surveillance program. Measurements at this location provide an upper limit to the annual transport of specific nuclides into the Pacific Ocean (see Table 5).

## Transport Rates

Figures 4a and 4b show the river transport rates of several radionuclides past Richland for the years 1966-1970. The transport rates at Richland in 1970 for the five radionuclides shown were significantly lower than the 1969 values. Table 5 shows the annual average transport rates of selected radionuclides past Bonneville Dam. More detailed measurements are presented in the Addendum to this report.

## Trend Indicator - Whitefish

The Columbia River is popular for sports fishing both above and below the Hanford reservation. Fish feeding downstream from the reactors contain some radionuclides originating from reactor effluent, acquired for the most part through food chains. $^{32}P$ is the most significant of these nuclides with regard to population doses. Changes in river concentrations and temperatures may induce changes in concentrations in biological media, and the ultimate uptake of radionuclides at each trophic level depends on complex environmental interrelationships.

Whitefish are the sports fish that usually contain the greatest concentrations of radioactive materials, and they can be caught during winter

*Since the Concentration Guides in Table 4 are based on doses to several different organs of the body, these percentages are not additive.

TABLE 3. Annual Average Concentrations of Selected Radionuclides in the Columbia River, 1966-1970
($10^{-9}$ μCi/ml)

| Radionuclide | 1966 Richland | 1966 Bonneville Dam | 1967 Richland | 1967 Bonneville Dam | 1968 Richland | 1968 Bonneville Dam | 1969 Richland | 1969 Bonneville Dam | 1970 Richland | 1970 Bonneville Dam |
|---|---|---|---|---|---|---|---|---|---|---|
| $^{32}P$ | 140 | 23 | 190 | 25 | 92 | 15 | 73 | 14 | 28 | 5 |
| $^{46}Sc$ | 30 | | 60 | 18 | 100 | 20 | 72 | | 43 | |
| $^{51}Cr$ | 3600 | 1300 | 3200 | 1400 | 1500 | 530 | 720 | 240 | 300 | 100 |
| $^{65}Zn$ | 200 | 43 | 220 | 62 | 86 | <30 | 72 | 25 | 34 | 10 |
| $^{131}I$ | 18 | 3 | 8 | 3 | 7.4 | <3.2 | 4.0 | | <2 | |

No entry indicats no analyses were made.

TABLE 4. Concentrations of Radionuclides in the Columbia River at Richland and Vernita - 1970
($10^{-9}$ μCi/ml)

| Radionuclides | [a]Analy. Limit | Concentration Guide | VERNITA No. of Samples | VERNITA Max. | VERNITA Min. | VERNITA Avg. | VERNITA % of C.G. | RICHLAND No. of Samples | RICHLAND Max. | RICHLAND Min. | RICHLAND Avg. | RICHLAND % of C.G. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alpha | 0.5 | 30[c] | 12 | 0.97 | * | 0.59 | 2.0 | 12 | 1.2 | * | 0.60 | 2.0 |
| RE+Y[b] | 5 | 40,000[c] | | | | | | 5 | 670. | 180. | 340. | 0.9 |
| $^{3}H$ | 1,000 | 3,000,000 | 12 | 2600. | * | 840. | 0.03 | 12 | 2700. | * | 1100. | 0.04 |
| $^{24}Na$ | 35 | 30,000 | | | | | | 23 | 2300. | 60. | 900. | 3.0 |
| $^{32}P$ | 6 | 20,000 | | | | | | 44 | 93. | 9.1 | 28. | 0.1 |
| $^{46}Sc$ | 20 | 40,000 | | | | | | 51 | 120. | * | 43. | 0.1 |
| $^{51}Cr$ | 70 | 2,000,000 | | | | | | 51 | 1200. | * | 300. | 0.02 |
| $^{56}Mn$ | 50 | 100,000 | | | | | | 5 | 230. | 63. | 100. | 0.1 |
| $^{64}Cu$ | 20 | 200,000 | | | | | | 5 | 1500. | 460. | 800. | 0.4 |
| $^{65}Zn$ | 20 | 100,000 | | | | | | 51 | 99. | * | 34. | 0.03 |
| $^{76}As$ | 5 | 20,000 | | | | | | 5 | 180 | 48. | 130. | 0.7 |
| $^{90}Sr$ | 0.5 | 300 | 12 | 0.61 | * | 0.44 | 0.1 | 12 | 0.7 | * | * | <0.2 |
| $^{122}Sb$ | 5 | 30,000 | | | | | | 5 | 400. | 42. | 120. | 0.4 |
| $^{131}I$ | 2 | 300 | | | | | | 51 | 5.4 | * | * | <0.6 |
| $^{239}Np$ | 10 | 100,000 | | | | | | 5 | 1400. | 320. | 570. | 0.6 |
| $^{239}Pu$ | 0.025 | 5,000 | 2 | * | * | * | <0.0005 | 2 | * | * | * | <0.0005 |

(a) See Appendix for definition of analytical limit.
(b) Rare Earths plus Yttrium separation.
(c) Calculated from isotopic mixture.
*Less than the analytical limit (see Appendix D).

TABLE 5. Annual Average Transport Rate of Selected Radionuclides Past Bonneville Dam, 1966-1970
(Ci/day)

| RADIONUCLIDE | 1966 | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|---|
| $^{32}P$ | 9 | 12 | 6.2 | 7.1 | 2.3 |
| $^{46}Sc$ | | 10 | 7.5 | | |
| $^{51}Cr$ | 430 | 610 | 200 | 100 | 40 |
| $^{65}Zn$ | 21 | 40 | <13 | <15 | 4.7 |

No entry indicates no routine analysis was made.

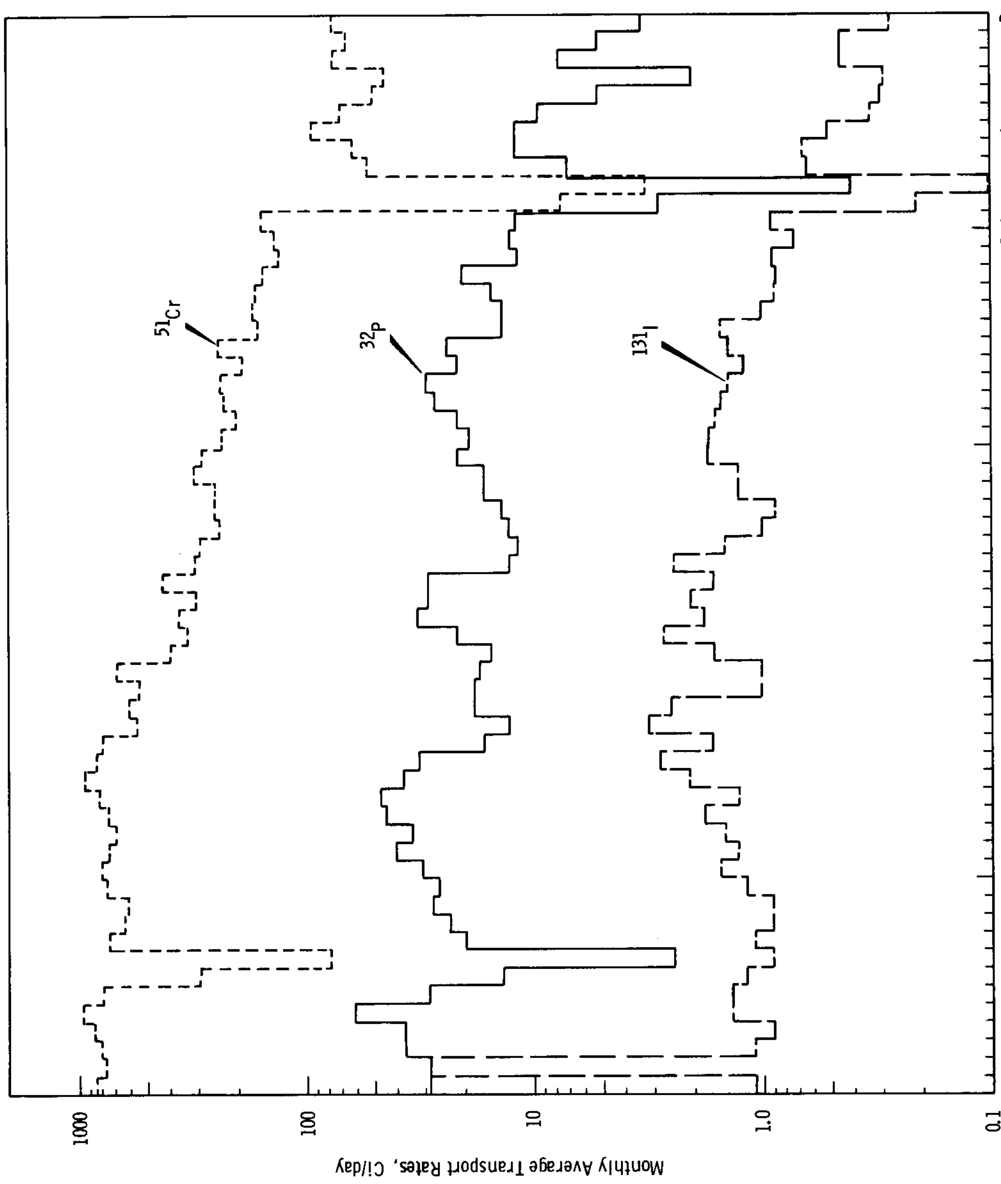


FIGURE 4a. $^{32}$P, $^{51}$Cr, and $^{131}$I Transport Rates in the Columbia River at Richland, 1966-1970 (Ci/day)

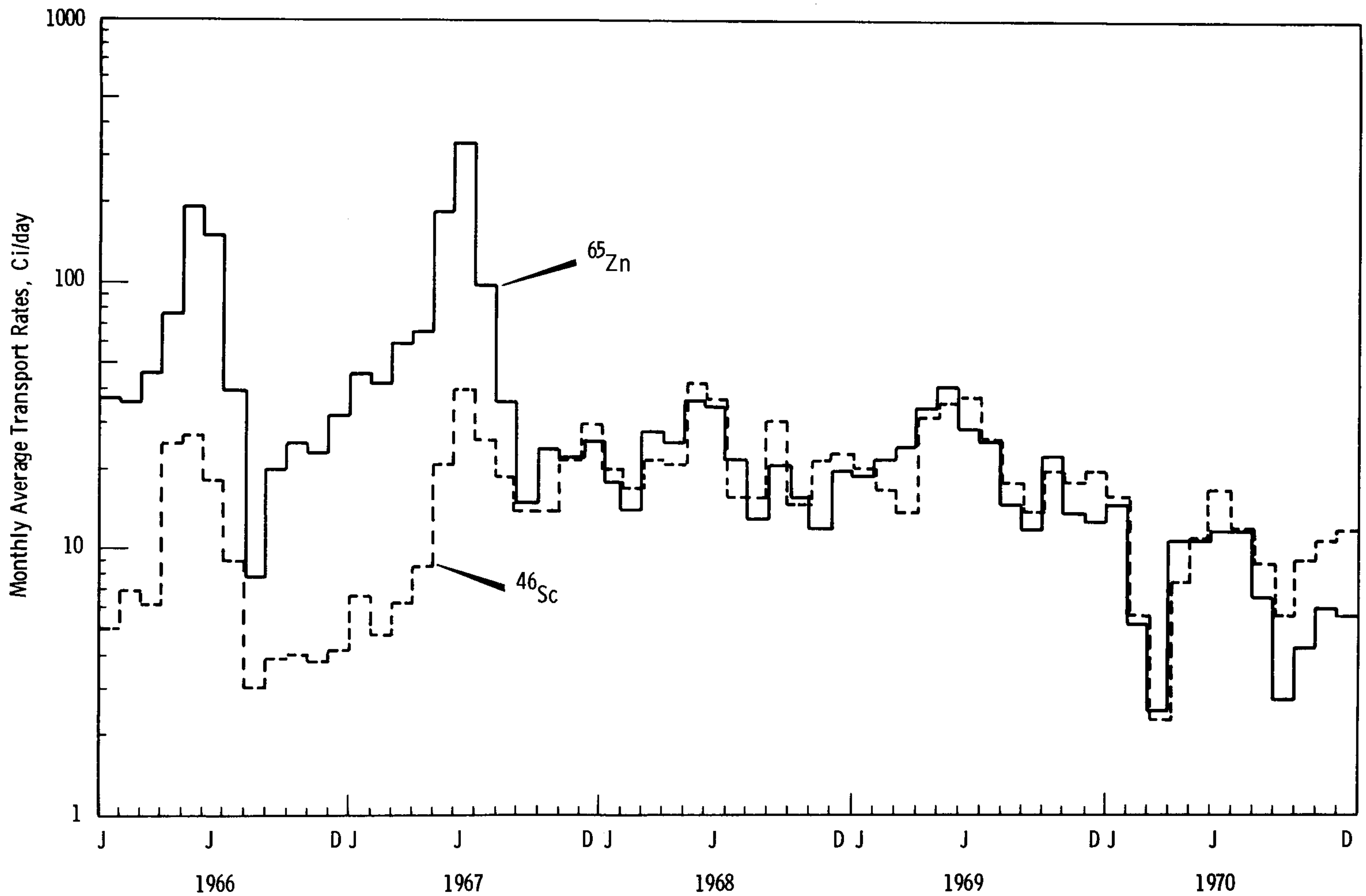


FIGURE 4b. $^{46}Sc$ and $^{65}Zn$ Transport Rates in the Columbia River at Richland, 1966-1970 (Ci/day)

months when other sports fish are difficult to sample. Therefore, $^{32}P$ data accumulated from whitefish sampling near the plant boundary (Figure 5) are useful as a long-term trend indicator of concentrations in biological media, even though whitefish are not the most significant source of radionuclides for the local fish-consuming population.

Concentrations of $^{32}P$ in whitefish during 1970 tend to follow the same seasonal trends observed in past years. As expected from river concentrations, the average concentration of $^{32}P$ in whitefish sampled downstream from the reactors during 1970 decreased to $1.7 \times 10^{-5}$ µCi/g from $3.4 \times 10^{-5}$ µCi/g during 1969.[1]

## RADIOACTIVITY IN GROUNDWATER

Radioactivity in the groundwater beneath the Hanford project results primarily from ground disposal of wastes in the chemical separations areas. These wastes are routed to various facilities, dependent upon their radionuclide burden and chemical content. High-level wastes* are stored in underground concrete tanks lined with steel. Intermediate-level wastes** are sent to underground "cribs" (covered liquid waste disposal sites) from which they percolate into the soil. The areas selected for intermeidate-level waste disposal and high-level waste storage have soil with good ion exchange capacity and depths to groundwater of 50 to 100 meters. Low-level wastes*** are usually sent to depressions in the ground where surface ponds or "swamps" have been formed as the result of the continuous addition of relatively large volumes of water.

One important objective in the management of wastes placed in the ground is to prevent radionuclides from reaching the groundwater in quantities that could cause significant human radiation exposure should they ultimately migrate to the Columbia River. An extensive groundwater surveillance program is maintained at Hanford to aid in achieving this objective. Hundreds of wells have been drilled at various locations around the Hanford

*High-level: >100 µCi/ml
**Intermediate-level: $5 \times 10^{-5}$ µCi/ml to 100 µCi/ml
***Low-level: $<5 \times 10^{-5}$ µCi/ml

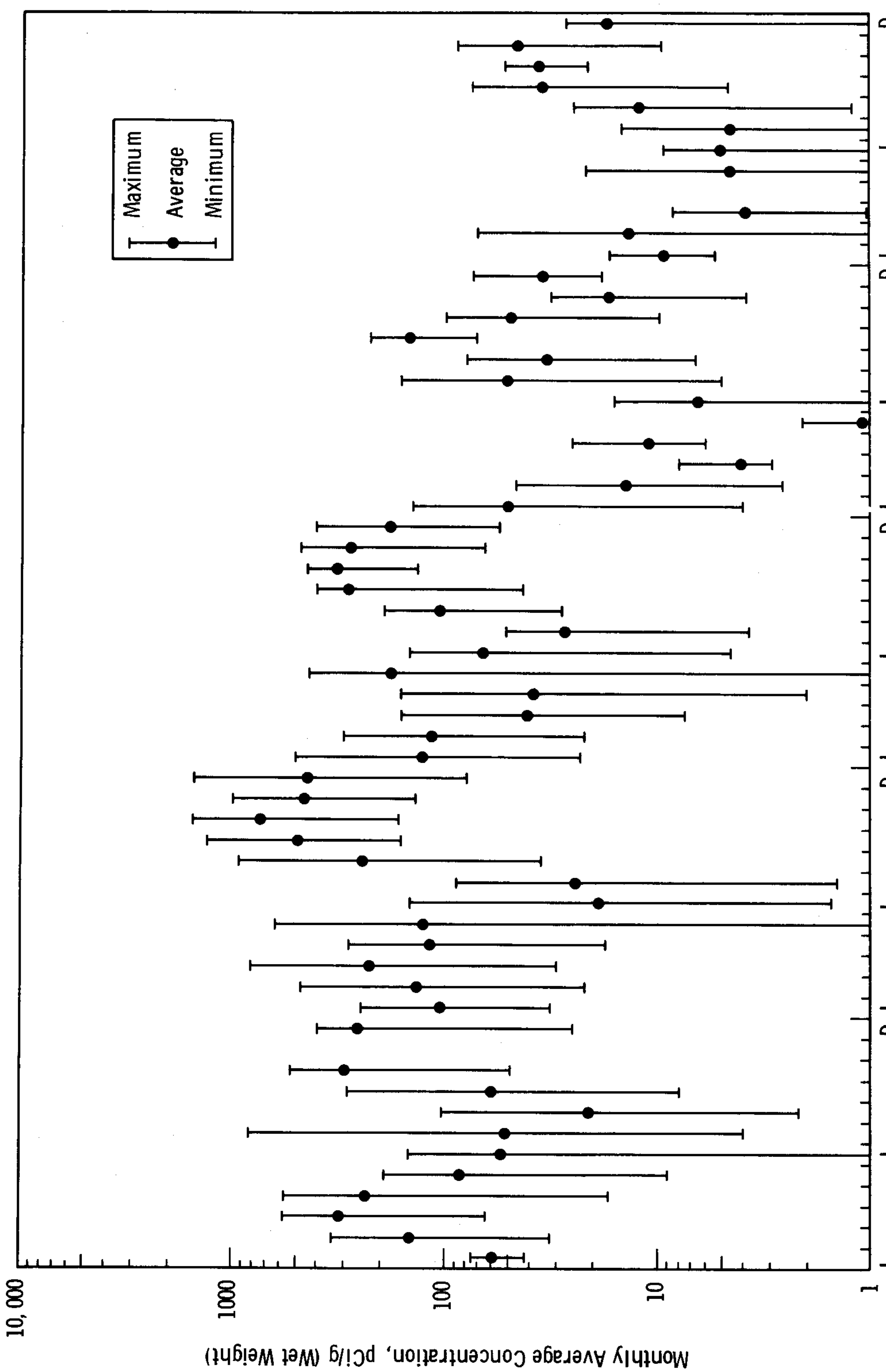


FIGURE 5. Monthly Average $^{32}P$ Concentrations in Flesh of Whitefish Caught in the Columbia River Between Ringold and Richland, 1966-1970

project, including sites within and near ground disposal and tank storage areas, to monitor the movement of radionuclides in the groundwater.

The radioactivity reaching the groundwater from the chemical separations areas is primarily $^{3}H$ and $^{106}Ru$; $^{60}Co$ and $^{99}Tc$ have also been found but at much lower concentrations. The more radiotoxic nuclides, such as $^{90}Sr$, have not been detected in groundwater except in the immediate vicinity of a few specific disposal sites.

Figures 6 and 7 show the probable extent of detectable $^{3}H$ and $^{106}Ru$ in groundwater beneath the Hanford project[11] as of December 31, 1970. The outer boundary of the contamination contours, i.e., 0.03% CG of $^{3}H$ and 2% CG for $^{106}Ru$, represent the detection levels routinely achievable for those radionuclides.

It is possible that some radionuclides from the chemical processing areas are presently entering the Columbia River. However, the concentrations of these nuclides are too low to be routinely measurable in the groundwater near the river or in the river itself, and any radiation dose to people from them is negligible. Tritium in the groundwater near the river in the vicinity of the N Reactor Area may have contributed to the small increase in tritium concentration observed in the river between Vernita and Richland in 1970 (as shown in Table 4), but any resulting dose from off-site drinking water would still be negligible.

A remote possibility exists that radioactive or process materials could penetrate to confined aquifers which generally underlie the Pasco Basin. Several farm wells on the east side of the Columbia River, which are believed to penetrate to those confined aquifers, are routinely sampled for tritium and nitrate ion. The data are not definitive, since contamination from the surface by nitrate from fertilizers and tritium from non-Hanford sources in recent precipitation can also occur. Samples from all five off-site wells during 1970 were at or less than the analytical limit (see Appendix D) for tritium and nitrate ion.

## RADIOACTIVITY IN DRINKING WATER

The city of Richland, about 75 km (47 miles) downstream from the Hanford reactors, is the first community below the project that uses the

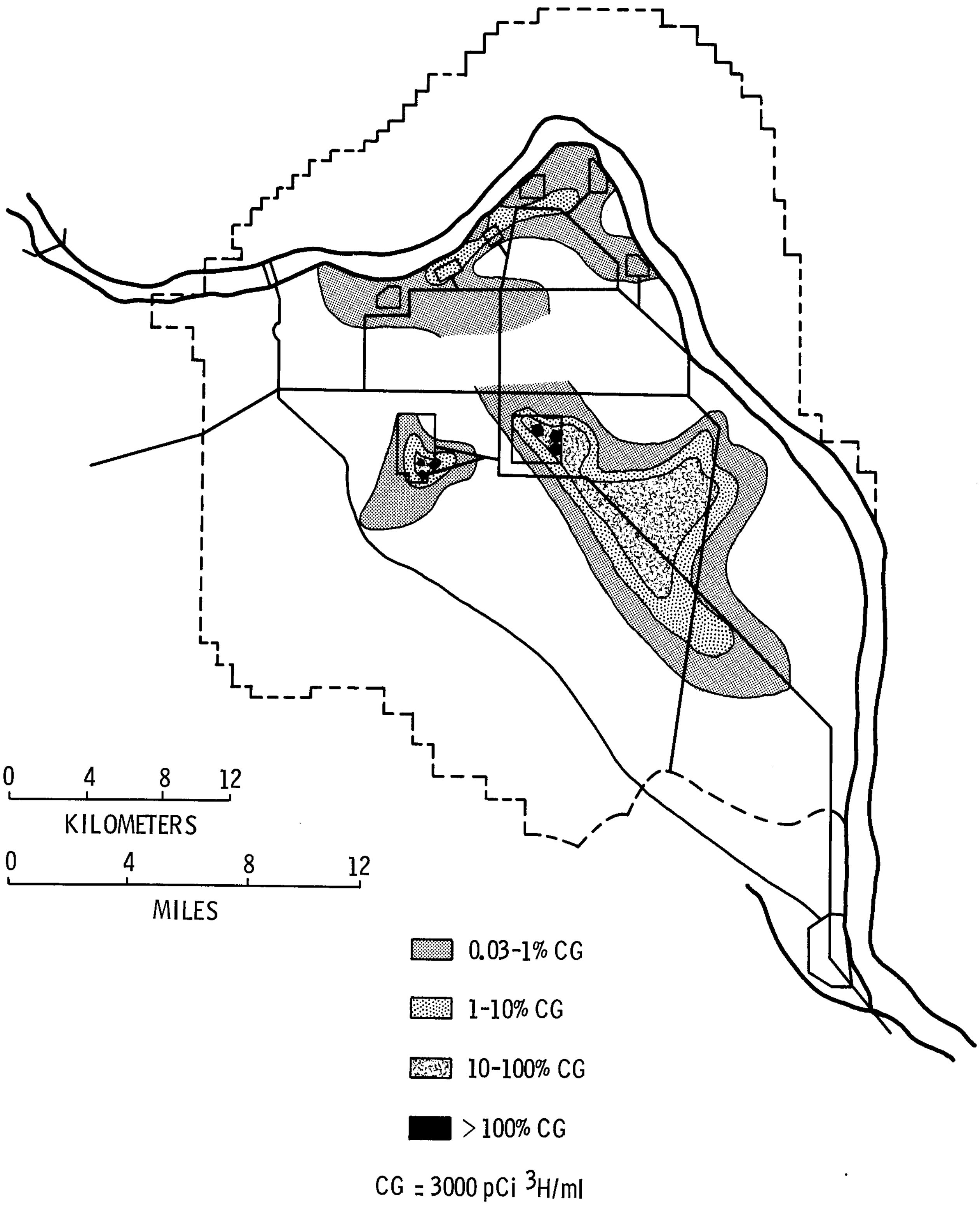


FIGURE 6. $^3$H Concentrations in Groundwater, July-December, 1970

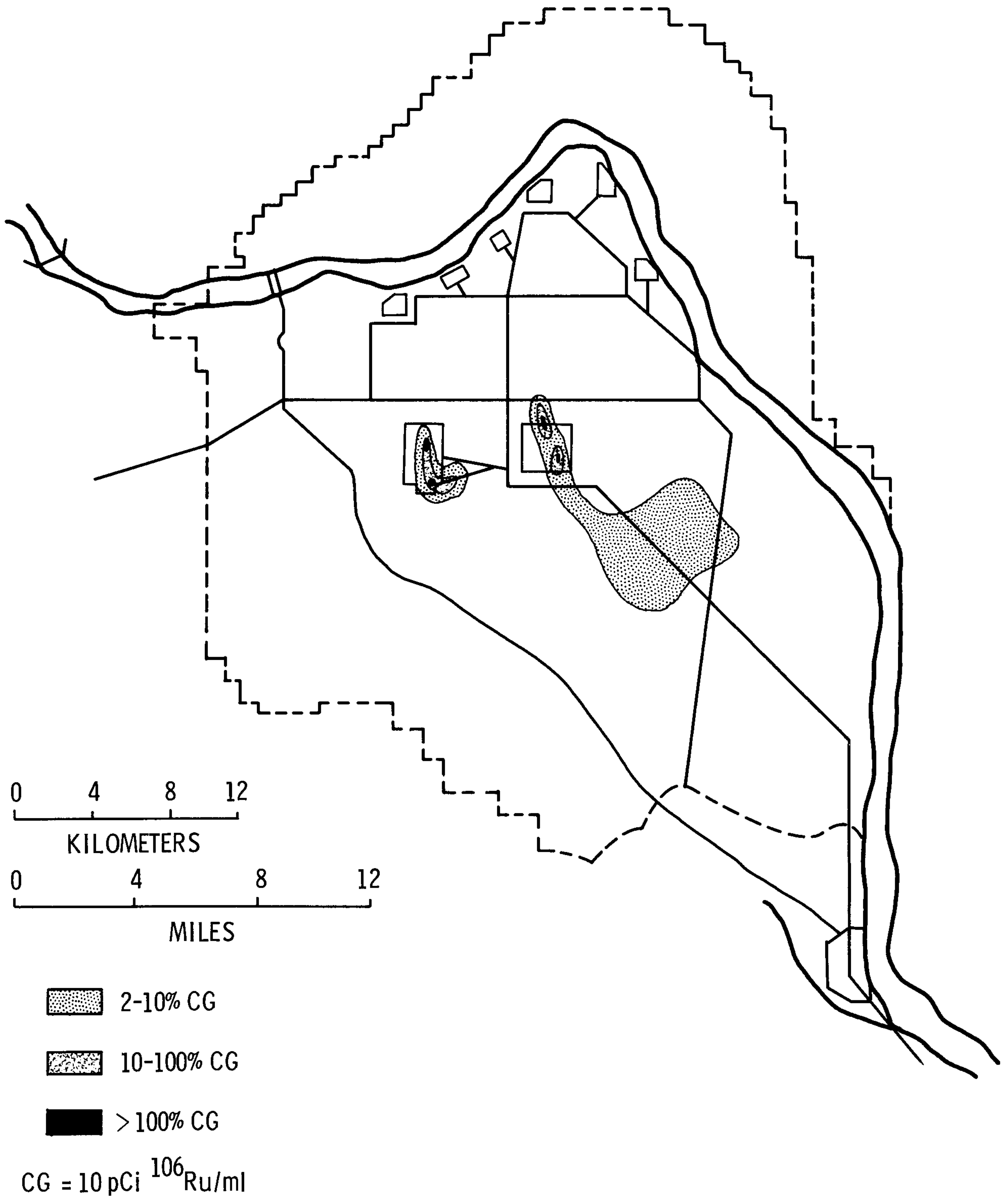


FIGURE 7. $^{106}$Ru Concentrations in Groundwater, July-December, 1970

Columbia River as a source of drinking water. Pasco and Kennewick, a few kilometers farther downstream, also use the river as a water source. The Richland and Pasco water plants use a modern flocculation-filtration treatment method; water for Kennewick is pumped from Ranney well collectors (infiltration pipes) laid in the riverbank.

During 1970, cumulative and periodic grab water samples were collected at both the Richland and Pasco water plants and analyzed for selected individual radionuclides and gross beta activity (Table 6). The Pasco sampling was discontinued at mid-year since the calculated dose-rate from drinking water was uniformly less than at Richland and was becoming less and less significant. At each plant, water was sampled after treatment and just prior to entering the city distribution system.

The concentrations of short-lived radionuclides in the water at the time it is consumed were less than shown in Table 6 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 nuclide showing the largest average percentage of its Concentration Guide in Richland drinking water during 1970 was $^{24}Na$, about 2%.

Annual average concentrations of radionuclides measured at the Richland water plant were used to calculate the doses from drinking water for comparison with past years. The correlation between the GI tract dose rate at the water plant (established by direct measurement of individual radionuclide concentrations) and the gross beta activity was determined monthly. This correlation used in conjunction with thrice-weekly measurements of gross beta activity at the water plant provided the basis for estimation of the GI tract dose. The estimated annual GI tract dose to Richland residents from the measured radionuclides in drinking water continued to decrease in 1970 (10 mrem) from 1969 (17 mrem). Figure 8 shows long-term trends in the GI tract dose from Pasco and Richland drinking water.

## RADIONUCLIDES IN COLUMBIA RIVER FISH

The quantities and kinds of fish caught by local fishermen have been estimated previously from surveys carried out from 1961 to 1965 in cooper-

TABLE 6. Concentrations of Several Radionuclides in Richland Drinking Water[a] - 1970 ($10^{-9}$ μCi/ml)

| Radionuclide | Analytical Limit[b] | No. of Samples | Richland | Concentration Guide | % of C.G. |
|---|---|---|---|---|---|
| Total Beta (counts/min/ml) | 0.2 | 95 | 1.0 | 2,000,000[e] | <0.1 |
| $^{24}Na$ | 35 | 9 | 640 | 30,000 | 2.1 |
| $^{32}P$[d] | 6 | 52 | 16 | 20,000 | <0.1 |
| $^{51}Cr$ | 70 | 4 | 410 | 2,000,000 | <0.1 |
| $^{65}Zn$ | 20 | 52 | 20 | 100,000 | <0.1 |
| $^{76}As$ | 5 | 4 | 41 | 20,000 | 0.2 |
| $^{122}Sb$ | 5 | 4 | 42 | 30,000 | 0.1 |
| $^{131}I$[d] | 2 | 52 | 2.0 | 300 | 0.7 |
| $^{133}I$ | 10 | 9 | 13 | 1,000 | 1.3 |
| $^{239}Np$ | 10 | 9 | 220 | 100,000 | 0.2 |
| RE + Y[c] | 5 | 4 | 26 | 40,000[e] | <0.1 |

(a) Measured at the water plants.
(b) See Appendix D.
(c) Rare Earths plus Yttrium fraction.
(d) Results based on cumulative samples.
(e) Calculated from isotopic ratios.

ation with the Washington State Game Department. The maximum estimate of consumption by the fishermen interviewed was 200 meals per year of panfish species (crappie, bass, and perch) taken from the Columbia River. Additional dietary data[12] collected during 1966 and 1967 from household questionnaires and interviews also showed individual consumption estimates as high as 200 meals of fish per year. The primary fishing locations for the catch of these fish were Burbank, Hover-Finley, and Island View (see Figure 2). The average percentage of the maximum annual consumption by species was 73% crappie, 16% bass, and 11% perch.

Based on data collected during 1970, the average concentration of $^{32}P$ in such a mixture of panfish was about $5 \times 10^{-6}$ μCi/g, and that of $^{65}Zn$ was $2 \times 10^{-6}$ μCi/g. Gamma scans of samples showed no other nuclides present on the average above the analytical level. From this species distribution and radiochemical analyses of the specimens collected,[1] the Maximum Individual's estimated intakes during 1969 were 0.20 μCi of $^{32}P$ and 0.08 μCi of $^{65}Zn$, or less than one-half the corresponding intakes during 1969. The calculated dose to the bone of the Maximum Individual for 1970 from this source was 38 mrem or about 2.5% of the standard of 1500 mrem per year.

The average consumption of Columbia River fish by Richland residents was estimated from diet questionnaires[3] completed by Hanford plant employees. Assuming the same mixture of species as for the Maximum Individual, the Average Richland Resident's intake during 1970 was estimated to be 0.002 μCi of $^{32}P$ and 0.001 μCi of $^{65}Zn$. These intakes correspond to a bone dose of about 0.5 mrem or about 0.1% of the standard of 500 mrem per year for the population average.

## RADIOACTIVITY IN SHELLFISH

$^{65}Zn$ and $^{32}P$ are the only radionuclides from Hanford reactor effluents that have been found in sufficient abundance in seafoods collected beyond the mouth of the Columbia River to be of significance to human radiation exposure. Oysters have been found to contain higher concentrations of $^{65}Zn$ than other common seafoods.[3] Oyster samples were obtained during 1970 from commercial sources at Willapa Bay, Washington. This area is a major regional commercial source of oysters and, because of prevailing ocean

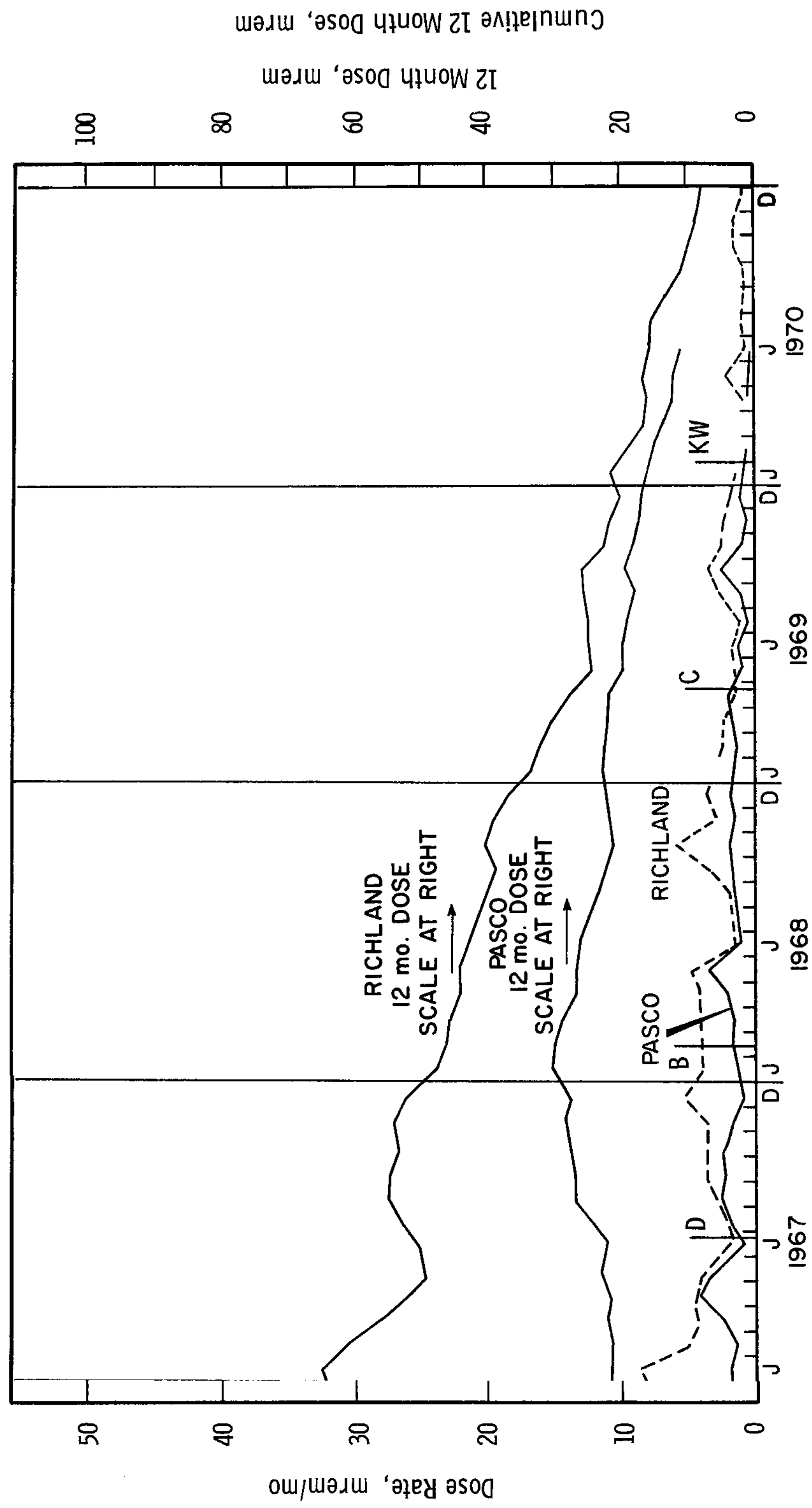


FIGURE 8. Doses to the GI Tract from Richland and Pasco Drinking Water, 1967-1970 (1.86 liter/day intake rate)

currents, a likely location for maximum concentrations of Hanford nuclides in shellfish.

Monthly average concentrations of $^{32}P$ and $^{65}Zn$ in oysters grown commercially in the Willapa Bay area, are shown in Figure 9 for the years 1969-1970. A normal seasonal minimum for $^{32}P$ occurs in the late summer. The $^{65}Zn$ data for 1970 show a decrease through the year approximating the radioactive half-life. The annual average concentrations for 1970 were $1.3 \times 10^{-5}$ $\mu Ci$ $^{65}Zn$ per gram and $0.6 \times 10^{-7}$ $\mu Ci$ $^{32}P$ per gram. Detailed analytical results for 1970 are tabulated in the Addendum.

Fresh shellfish are not an important item in the average Tri-Cities diet, but residents of some coastal areas may consume more than the reference value of 50 g/day.(14) For such individuals, shellfish are assumed to be their only source of radionuclides of Hanford origin. Consumption of oysters containing the 1970 average concentrations of $^{32}P$ and $^{65}Zn$ at the rate of 50 g/day would result in annual doses of about 2.5 mrem to the GI tract, 1.6 mrem to the whole body, and 2.9 mrem to the bone of a Standard Man.(8) This calculated whole body dose is about 0.3% of the appropriate dose standard of 500 mrem per year.

## RADIOACTIVITY IN GAMEBIRDS

Waterfowl and other gamebirds utilizing the river downstream from the reactors or open low-level waste disposal sites within the plant boundaries may injest $^{32}P$, $^{65}Zn$, and other radionuclides with their intake of insects, algae, vegetation, and water containing these radionuclides. Although the spring and fall migrations bring a temporary influx of great numbers (up to 200,000 birds), some waterfowl remain in this general area throughout the year. The river also provides cover, food, and water for a local population of pheasant, quail, and other upland gamebirds. The concentrations of radionuclides in the flesh of gamebirds at the time of consumption are dependent upon the bird species, the geographical locations from which the birds are taken, their residence time in the vicinity, their current feeding habits, and the elapsed time between killing and consumption of the birds.

Table 7 shows radionuclide concentrations in the muscle (the edible protion) of gamebirds collected along the river within the Hanford project

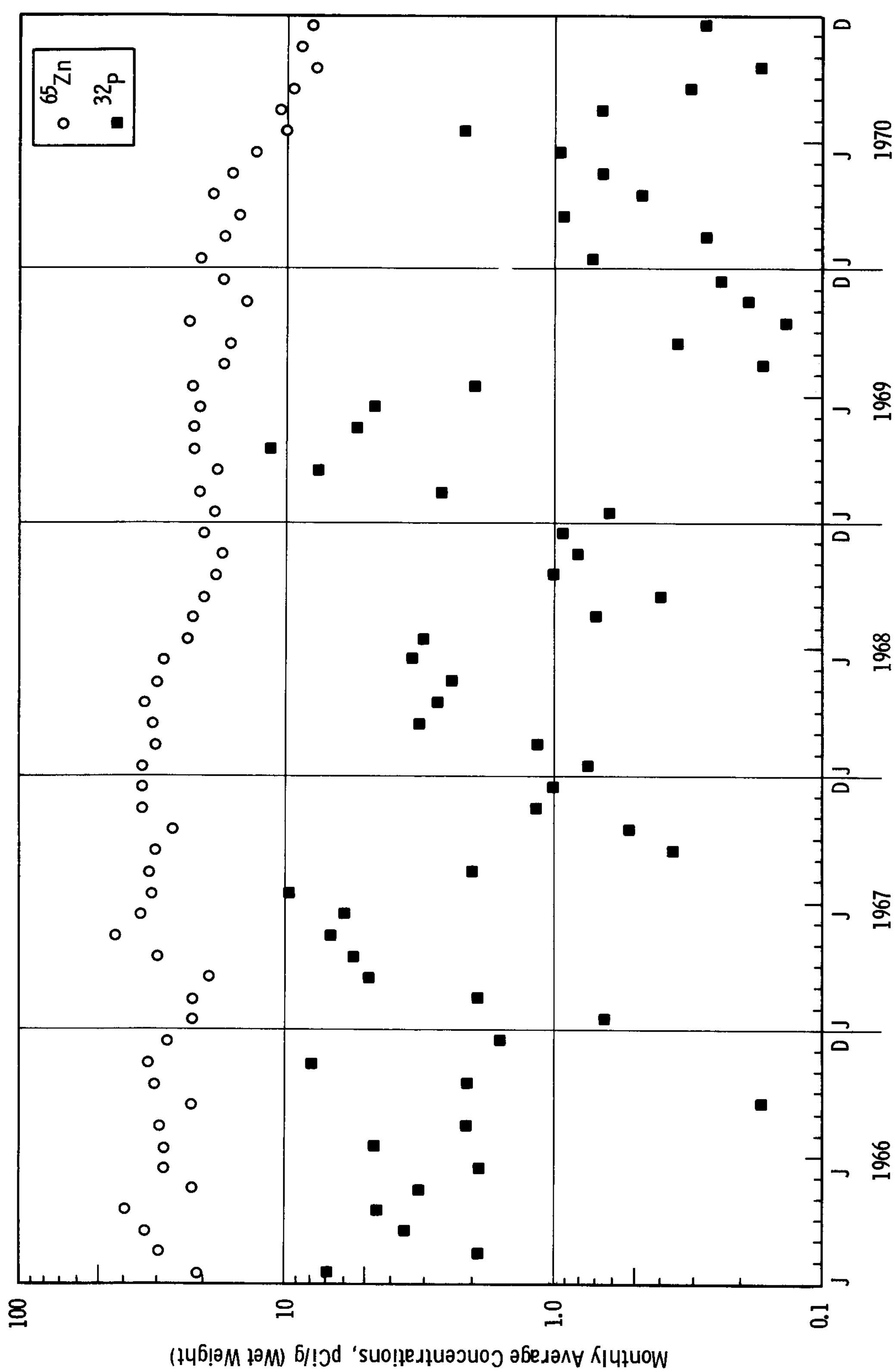


FIGURE 9. $^{32}P$ and $^{65}Zn$ Concentrations in Willapa Bay Oysters, 1966-1970

TABLE 7. Radionuclide Concentrations in Gamebirds, 1970

($10^{-6}$ μCi/gm)

| | | $^{32}P$ | | | $^{60}Co$ | | | $^{65}Zn$ | | | $^{137}Cs$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Analytical Limit | | 1.0 | | | 0.15 | | | 0.2 | | | 0.1 | | |
| Species | No. of Samples | Max. | Min. | Avg. | Max. | Min. | Avg. | Max. | Min. | Avg. | Max. | Min. | Avg. |
| Geese (river)[a] | 18 | 49 | * | 13 | 150 | * | 8.3 | 9.0 | 0.23 | 3.2 | 0.31 | * | 0.14 |
| Duck (river)[a] | 79 | 170 | * | 7.1 | 0.16 | * | * | 9.2 | * | 1.6 | 0.25 | * | 0.04 |
| Pheasant[b] | 34 | 26 | * | 3.1 | 0.41 | * | * | 8.4 | * | 2.1 | 0.31 | * | 0.09 |
| Quail[b] | 23 | 17 | * | 2.0 | * | * | * | 4.0 | * | 1.0 | 2.4 | * | 0.18 |

(a) Collected on the Columbia River within the Hanford boundary.
(b) Collected with 5 km (3 miles) of the Columbia River and within the Hanford boundary.
* Less than the analytical detection limit (see Appendix D).

for the environmental monitoring program during hunting seasons in 1970. The maximum concentration in such birds during 1970 was $1.7 \times 10^{-4}$ μCi $^{32}P$ per gram; for comparison the maximum observed in 1969 was $5.1 \times 10^{-4}$ μCi $^{32}P$ per gram for birds collected in the same area.

Data from a dietary survey of Hanford employees,[3] from a special survey of local hunters,[15] and from the radionuclide concentration data for the various species have been combined to estimate the species mix and the radionuclide content of an average local gamebird meal, as shown in Table 8. About 30% of the gamebird meals consumed by local hunters were reported to be birds shot within about 5 km (3 miles) of the Columbia River between Ringold and McNary Dam. Past analyses have shown that pheasants collected beyond this distance contain little, if any, radioactivity of Hanford origin. About 44% of all birds eaten were reported to have been placed in frozen storage, which would permit appreciable decay of any $^{32}P$ before consumption.

TABLE 8. Contribution of Each Species to 100 Grams of an Average Gamebird Meal[a] - 1970

| Species | Weight, g | Radionuclide Content ($10^{-6}$ μCi) | |
|---|---|---|---|
| | | $^{32}P$ | $^{65}Zn$ |
| Duck | 23 | 46 | 10 |
| Goose | 6 | 16 | 10 |
| Quail | 12 | 5 | 2 |
| Pheasant | 47 | 26 | 36 |
| Other | 13 | 2 | 1 |
| TOTAL | 100 | 95 | 59 |

[a] Weighted for location of kill by using measured concentrations for river birds and assuming no $^{32}P$ or $^{65}Zn$ in other birds. Also weighted for frozen storage by assuming complete decay of $^{32}P$ but no significant decay of $^{65}Zn$ during frozen storage of 44% of the birds.

The maximum total gamebird consumption by adults reported to date is 100 meals per year, or an estimated 23 kg/yr. Consumption of this weight of the "average gamebird meal" (Table 8) would result in intakes of 0.022 μCi of $^{32}P$ and 0.014 μCi of $^{65}Zn$, implying a dose of 4.2 mrem to the skeleton, or less than 0.4% of the standard for individual members of the population. Consumption of 1.24 kg/yr, the estimated annual intake for the Average Richland Resident, would result in a total dose of about 0.2 mrem to the skeleton, less than 0.1% of the appropriate standard of 500 mrem/yr.

The dose calculations shown above do not include four ducks collected at the K and N Reactor area trenches between the last week in December, 1969 and the first week in March, 1970. Muscle tissue from these four birds, of 15 collected at these locations during this period, showed concentrations from 0.03 to 0.14 μCi $^{32}P$ per gram, compared to a maximum in birds collected along the river of 0.00017 μCi $^{32}P$ per gram. Analysis of gizzard contents indicated some feeding on filamentous algae present in the water in the trenches. Steps were taken to prevent further access by waterfowl, including partial backfilling and screening the remaining open areas of the trenches.

Immediate consumption of 230 g (one-half pound---a normal meal) of flesh with the highest concentration, with consequent ingestion of about 30 μCi of $^{32}P$, would have resulted in a calculated skeletal-bone dose to an adult of about 6 rem, four times the applicable annual dose standard. The associated whole body dose, including a contribution from $^{65}Zn$, would have been about 250 mrem, or about 15% of the applicable annual dose standard.

Even were such a bird to be shot by a hunter, delays between the time a bird left a trench and the time of shooting, and as a result of the frequent practice of freezing gamebirds for later consumption would have permitted significant radioactive decay. This would further reduce the probability of consuming flesh containing the higher concentrations of $^{32}P$. For the bird with the maximum concentration that has been considered here, any delays in consumption of more than four weeks would have reduced the skeletal bone dose to less than 1500 mrem (the annual standard).

The consumption of such a bird by any member of the public, however, is considered highly improbable in view of the facts that: (a) very few birds (out of some 200,000 in the area at that time) would have been likely to spend sufficient time on the trenches near the reactor areas to accumulate such large amounts of radioactive materials, and (b) concentrations of this magnitude have never been found in hundreds of birds sampled along the river for over 20 years. In our judgment, ducks collected on swamps, trenches, or ponds are not representative of those available to the general population, and dose estimates derived therefrom are not pertinent for inclusion in comparisons with the established dose standards.

## RADIOACTIVITY IN MILK AND FOODSTUFFS

Irrigation with river water containing radionuclides can contribute radioactivity to local milk and locally-grown farm produce, as can deposition of airborne materials from weapons test fallout and from Hanford sources. Chemical separations facilities would generally be the principal local source of airborne radionuclides other than fallout, although unusual radioactivity releases could occur from ventilation stacks of reactor or laboratory facilities.

The farming area closest to the separations facilities is at Ringold about 21 km (13 miles) away. Much of the land east and south of the project boundary (see Figure 2) is under cultivation and may be in the path of airborne releases. Most irrigated farms near the Hanford plant obtain water from the Yakima River or from the Columbia River above the plant. However, two small irrigated areas using Columbia River water taken downstream from the reactors are the Ringold farms and the Riverview district west of Pasco. These are 40 and 65 km (25 and 40 miles), respectively, downstream from the operating reactors.

The milk surveillance program maintained during 1970 included samples from local farms and dairies and from commercial supplies available to people in the Tri-Cities. Milk from local farms irrigated with water drawn from the river downstream from the reactors contained $^{32}P$ and $^{65}Zn$ as well as fission products from fallout and possibly Hanford sources. Commercial milk distributed in the Tri-Cities normally does not contain detectable $^{32}P$

and $^{65}Zn$, because only a small fraction of the milk is produced on farms irrigated with water drawn from the Columbia River below the Hanford reactors.

Figure 10 shows the monthly average concentrations of $^{32}P$ and $^{65}Zn$ in milk from river-irrigated farms for 1966-1970. Table 9 gives concentrations for an expanded list of radionuclides in milk and foodstuffs for 1970.

During 1970, the annual average concentrations of $^{32}P$ and $^{65}Zn$ for the Riverview farm were $2.1 \times 10^{-7}$ and $1.2 \times 10^{-7}$ μCi/ml compared to 1969 averages of $1.6 \times 10^{-7}$ and $1.1 \times 10^{-7}$ μCi/ml, respectively, for the same farm. Seasonal fluctuations in concentrations of both $^{32}P$ and $^{65}Zn$, caused primarily by irrigation and feeding practices, followed expected trends. Adult residents consuming milk (1 liter/day) obtained from the Riverview area could have received an annual dose from $^{32}P$ and $^{65}Zn$ of about 15 mrem to the bone (1% of the applicable dose standard).

$^{131}I$ concentrations in both farm milk and commercial milk during 1970, were consistently less than the analytical limit of $2 \times 10^{-9}$ μCi/ml. The maximum $^{131}I$ concentration of $21 \times 10^{-9}$ μCi/ml for the period was measured in a sample of commercial milk collected in December and was attributed to atmospheric weapons testing.

The concentrations of other fallout nuclides, $^{90}Sr$ and $^{137}Cs$, in the local environs are usually below the national average because of the low rainfall. Concentrations of $^{90}Sr$ in locally produced farm and commercial milk (Table 9) were similar in 1970 to those in commercial milk produced in other areas remote from the Hanford plant.

Fresh produce, meat, and eggs from local sources were sampled periodically for radioanalysis during the 1970 growing season and compared with samples from commercial sources. Results of these measurements were as expected lower than those of previous years, and indicated that only small quantities of radionuclides from Hanford were present in locally-grown produce. However, a resident of a local farm, consuming eggs and one-half pound per day of beef raised on pasture irrigated with water taken from the river downstream of the reactors, could have received a bone dose up to 30 mrem for the year, 2% of the applicable standard.

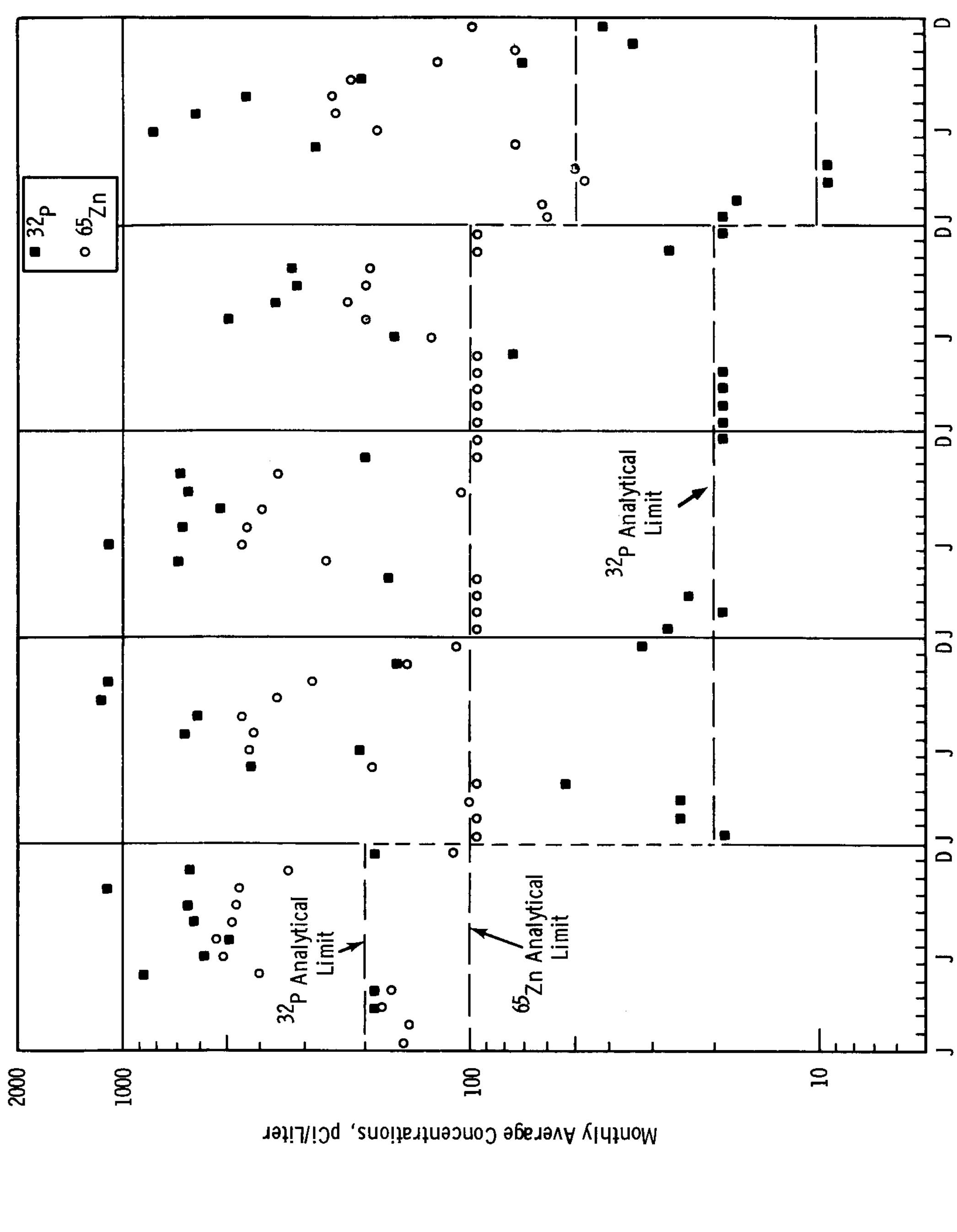


FIGURE 10. Monthly Average $^{32}P$ and $^{65}Zn$ Concentrations in Milk from River-Irrigated Farms, 1966-1970

## TABLE 9. Radionuclide Concentrations in Local Milk and Foods, 1970

($10^{-9}$ μCi/ml of Milk)

A. MILK

| Location | $^{131}I$ No. of Samples | $^{131}I$ Max. | $^{131}I$ Avg. | $^{131}I$ % of C.G. | $^{32}P$ No. of Samples | $^{32}P$ Max. | $^{32}P$ Avg. | $^{32}P$ % of C.G. |
|---|---|---|---|---|---|---|---|---|
| Concentration Guide[(a)] | 100 | | | | 20,000 | | | |
| Analytical Limit | 2 | | | | 6 | | | |
| Riverview | 52 | 3.6 | 0.84 | 0.3 | 52 | 1200 | 210 | 1 |
| Benton City & West Richland Composite | 62 | 10 | 1.3 | 0.4 | | | | |
| Benton City | 11 | 3.2 | 1.2 | 0.4 | | | | |
| Columbia Basin Composite No. 2 | 27 | 2.5 | 1.1 | 0.4 | 27 | 74 | 23 | 0.1 |
| Columbia Basin Composite No. 3 | 88 | 4.4 | 0.92 | 0.3 | | | | |
| Commercial | 56 | 21 | 0.83 | 0.3 | | | | |

MILK (Continued)

| Location | $^{65}Zn$ No. of Samples | $^{65}Zn$ Max. | $^{65}Zn$ Avg. | $^{65}Zn$ % of C.G. | $^{90}Sr$ Max. | $^{90}Sr$ Min. | $^{90}Sr$ Avg. | $^{90}Sr$ % of C.G. | $^{137}Cs$ Max. | $^{137}Cs$ Avg. | $^{137}Cs$ % of C.G. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Concentration Guide[(a)] | 100,000 | | | | 300 | | | | 20,000 | | |
| Analytical Limit | 50 | | | | 2 | | | | 30 | | |
| Riverview | 52 | 300 | 120 | 0.1 | 9.1 | 2.9 | 5.0 | 1.6 | 49 | 7.8 | <0.1 |
| Benton City & West Richland Composite | 39 | 60 | 28 | <0.1 | | | | | 25 | 5.8 | <0.1 |
| Benton City | 11 | 82 | 50 | <0.1 | 4.6 | 3.5 | 4.1 | 1.3 | 27 | 18 | <0.1 |
| Columbia Basin Composite No. 2 | 27 | 64 | 32 | <0.1 | 4.6 | * | 2.2 | 0.7 | 31 | 7.2 | <0.1 |
| Columbia Basin Composite No. 3 | 38 | 83 | 36 | <0.1 | | | | | 44 | 9.7 | <0.1 |
| Commercial | 24 | 77 | 35 | <0.1 | 9.5 | * | 3.6 | 1.2 | 34 | 14 | <0.1 |

*Less than the analytical limit (see Appendix D).

(a) Concentration Guide for water for Maximum Individual taken from AEC Manual Chapter 0524, Appendix, Table II. Implies a continued intake of 2.2 liters/day if no other source of intake.

Where no minimum value is shown, all minimum values were less than the analytical limit.

TABLE 9. Radionuclide Concentrations in Local Milk and Foods, 1970
($10^{-6}$ μCi/gm of Food)

B. FOODSTUFFS

| Samples | $^{32}P$ No. of Samples | $^{32}P$ Max. | $^{32}P$ Avg. | $^{65}Zn$ No. of Samples | $^{65}Zn$ Max. | $^{65}Zn$ Min. | $^{65}Zn$ Avg. | $^{89}Sr$ Max. | $^{89}Sr$ Avg. | $^{90}Sr$ Max. | $^{90}Sr$ Min. | $^{90}Sr$ Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Analytical Limit | | 1.0 | | | 0.05 | | | 0.02 | | 0.002 | | |
| Farm Meat | 5 | 2.5 | 1.6 | 8 | 4.6 | 1.5 | 2.4 | | | | | |
| Commercial Meat | 13 | 2.0 | 0.31 | 27 | 0.12 | * | 0.04 | | | 0.013 | * | 0.005 |
| Commercial Poultry | | | | 1 | * | * | * | | | | | |
| Farm Poultry | 7 | 0.22 | 0.08 | 7 | 1.0 | * | 0.55 | * | * | * | * | * |
| Commercial Eggs | | | | 4 | 0.042 | * | * | | | | | |
| Farm Eggs | 16 | 5.6 | 1.2 | 16 | 2.5 | * | 0.54 | 0.011 | 0.006 | 0.002 | * | 0.0015 |
| Farm Fruit | 9 | 0.15 | 0.036 | 11 | 0.14 | * | 0.078 | | | 0.025 | * | 0.008 |
| Farm Leafy Vegetables | 7 | 0.49 | 0.28 | 9 | 0.60 | * | 0.28 | 0.004 | 0.003 | 0.06 | 0.01 | 0.039 |
| Farm Other Vegetables | 9 | 0.18 | 0.06 | 11 | 0.21 | * | 0.09 | | | 0.68 | 0.005 | 0.13 |
| Commercial Leafy Vegs. | 6 | 0.49 | 0.12 | 6 | 0.12 | * | * | 0.033 | 0.012 | 0.031 | * | 0.017 |
| Commercial Fruit and Vegetable Composite | 4 | 0.07 | * | 4 | 0.12 | 0.06 | 0.09 | | | 0.008 | 0.006 | 0.006 |

FOODSTUFFS (Continued)

| Samples | No. of Samples | $^{95}ZrNb$ Max. | $^{95}ZrNb$ Avg. | $^{106}Ru$ Max. | $^{106}Ru$ Avg. | $^{131}I$ Max. | $^{131}I$ Avg. | $^{137}Cs$ Max. | $^{137}Cs$ Avg. | $^{144}CePr$ Max. | $^{144}CePr$ Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analytical Limit | | 0.03 | | 0.6 | | 0.05 | | 0.02 | | 1.0 | |
| Farm Meat | 8 | 0.04 | 0.01 | * | * | * | * | 0.04 | 0.02 | * | * |
| Commercial Meat | 27 | * | * | * | * | * | * | 0.066 | 0.027 | * | * |
| Commercial Poultry | 1 | * | * | * | * | * | * | * | * | * | * |
| Farm Poultry | 7 | * | * | * | * | * | * | 0.038 | 0.020 | * | * |
| Commercial Eggs | 4 | * | * | * | * | * | * | * | * | * | * |
| Farm Eggs | 16 | * | * | * | * | * | * | 0.025 | * | * | * |
| Farm Fruit | 11 | 0.025 | * | * | * | * | * | 0.036 | 0.013 | * | * |
| Farm Leafy Vegetables | 9 | 0.71 | 0.16 | 0.89 | 0.17 | 0.41 | 0.04 | 0.170 | 0.056 | 1.3 | 0.41 |
| Farm Other Vegetables | 11 | * | * | * | * | * | * | 0.062 | 0.011 | * | * |
| Commercial Leafy Vegs. | 6 | 0.26 | 0.06 | * | * | * | * | * | * | * | * |
| Commercial Fruit and Vegetable Composite | 4 | * | * | * | * | * | * | 0.038 | * | * | * |

*Less than the analytical limit (see Appendix D).
Where no minimum value is shown, all minimum values were less than the analytical limit.

RADIOACTIVITY IN THE ATMOSPHERE

Gaseous effluents from the Hanford chemical separations facilities are released to the atmosphere through tall stacks after passage through high-efficiency filters. Laboratory stacks, reactor-building stacks, and stacks from waste storage facilities may also release small amounts of particulate radioactive materials. The reactors release some noble gases, mostly $^{41}Ar$, to the atmosphere under normal operating conditions.

During 1970, measurements of airborne $^{131}I$, gross beta, and total alpha were routinely made at 23 locations off-site and around the Hanford reservation boundary; locations are shown in Figure 11. Figure 12 shows (for a five-year period) the monthly average particulate beta radioactivity in the atmosphere, both from nearby locations in the direction of the prevailing wind (Southeast Quadrant) and from more distant perimeter communities. Airborne data concentrations followed the annual cycle observed in previous years and showed about the same maximum and minimum values as for 1969.

Tables 10 and 11 present a more detailed review of the 1970 airborne radioactivity data. Analyses for $^{90}Sr$ and total plutonium alpha were made quarterly on composited filters from several locations. The results are given in Table 11, with average total alpha and gross beta concentrations for comparison. Locations within each group are given in Table 10. The data show that plutonium alpha accounted for less than 1% of the total alpha activity and $^{90}Sr$ for about 2% of the gross beta activity. The radioactivity measured is believed to be essentially all of natural origin or from regional fallout.

Insufficient isotopic data was available to determine appropriate Concentration Guides for gross alpha and beta. However, the average airborne total alpha and gross beta concentrations at the Hanford boundary locations were the same as the average at more distant sampling locations, indicating that Hanford operations did not contribute measurably to off-site airborne radioactivity.

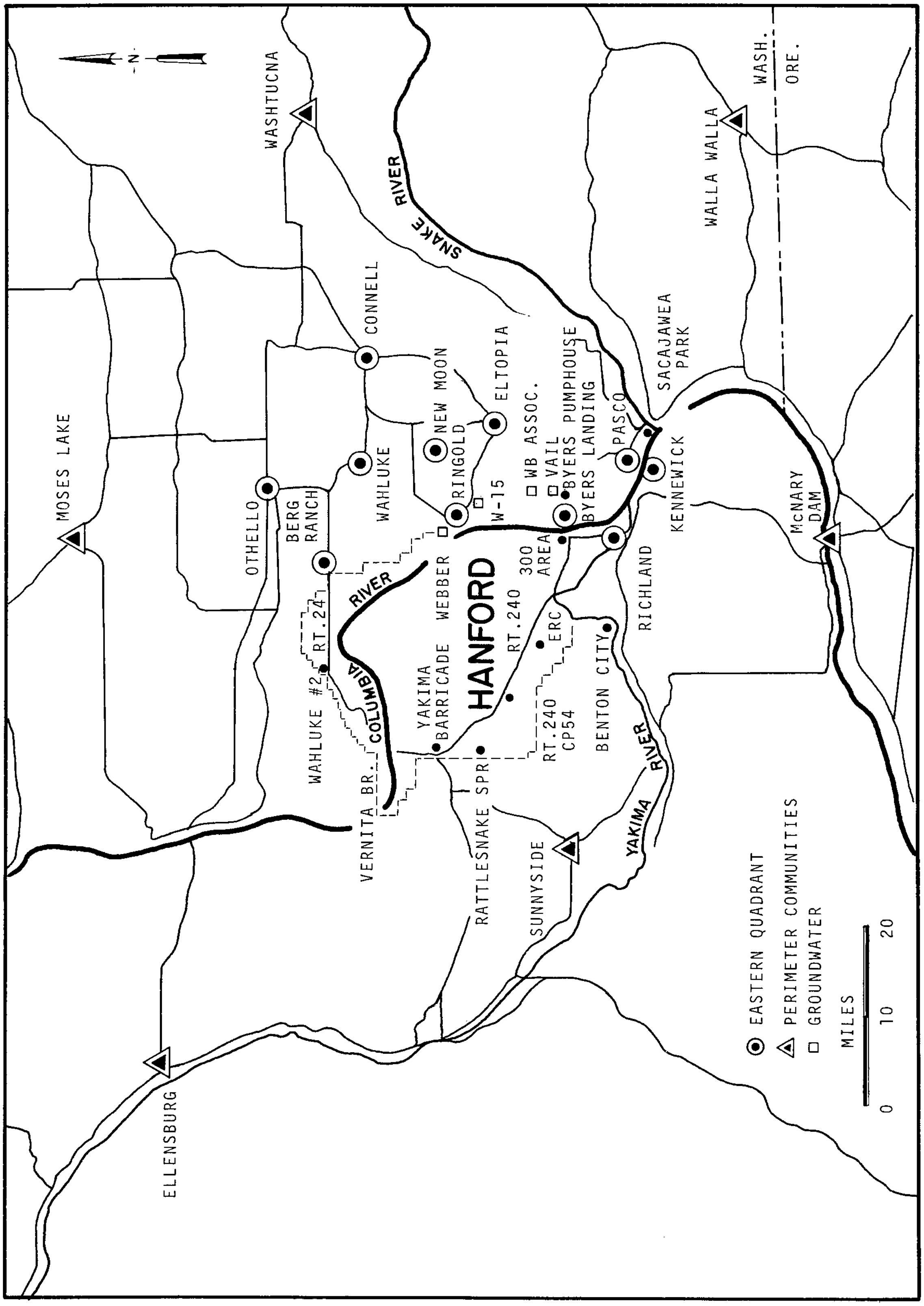


FIGURE 11. Off-Site Air Sampling Locations

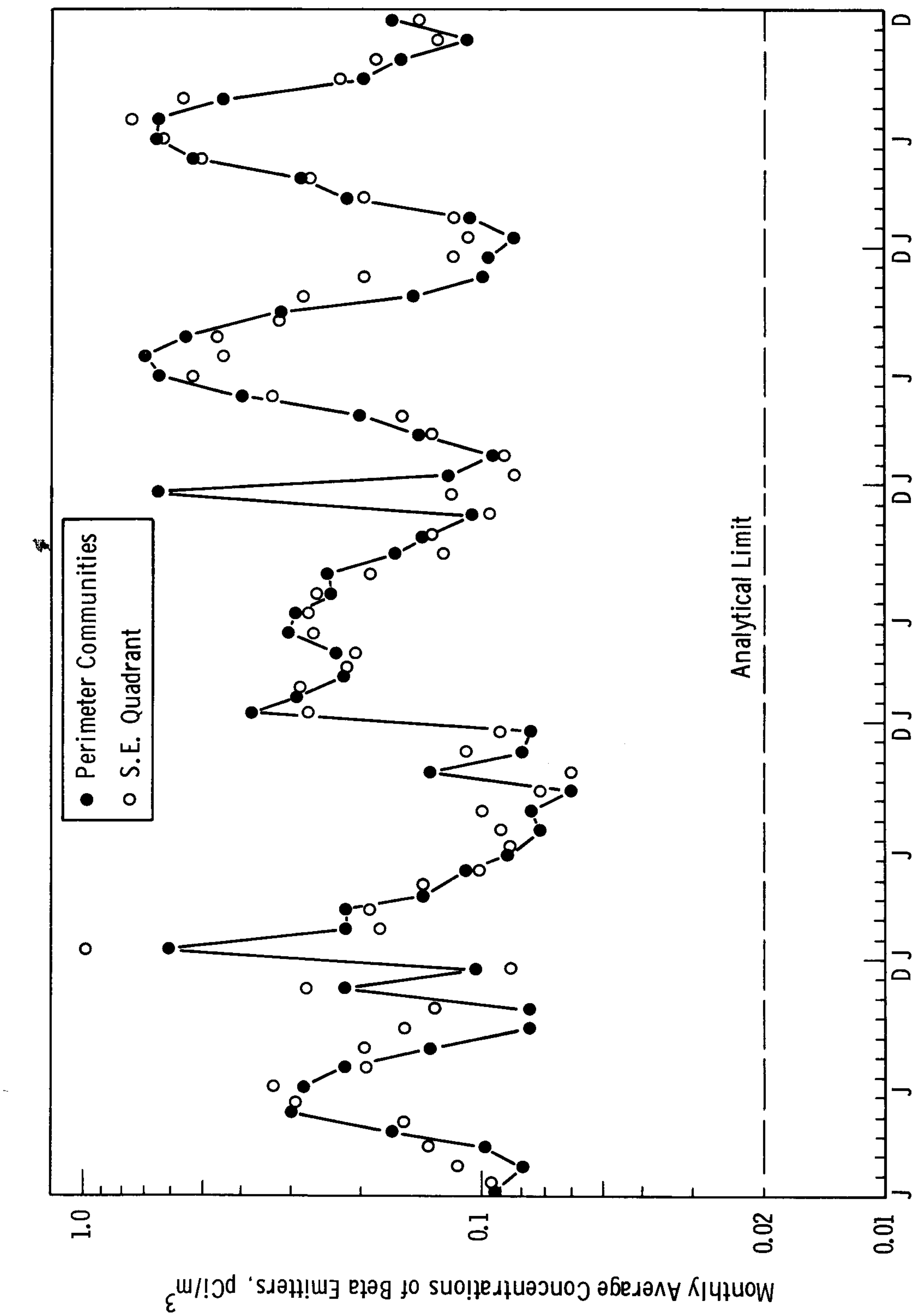


FIGURE 12. Monthly Average Particulate Total Beta Concentrations in the Air of Hanford Environs, 1966-1970

## TABLE 10. Radioactivity in Air - 1970
$(10^{-12}\ \mu Ci/ml)$

| | | Total Alpha | | | Gross Beta | | | $^{131}I$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Analytical Limit | | 0.001 | | | 0.02 | | | 0.02 | | | | 0.07 | | | |
| Concentration Guide | | | | | | | | 100 | | | | 100 | | | |
| | | | | | | | | January-June 1970 | | | | July-December 1970 | | | |
| Southeast Quadrant | No. of Samples | Max. | Min. | Avg. | Max. | Min. | Avg. | Max. | Min. | Avg. | % CG | Max. | Min. | Avg. | % CG |
| Berg Ranch | 39 | 0.042 | 0.001 | 0.011 | 0.99 | 0.05 | 0.27 | 0.029 | * | 0.011 | 0.01 | 0.39 | * | 0.12 | 0.1 |
| Wahluke Watermaster | 13 | | | | 0.84 | 0.10 | 0.31[a] | | | | | 0.28 | * | 0.096 | 0.1 |
| Wahluke Slope #2 | 21 | | | | 1.1 | 0.03 | 0.41 | * | * | 0.010 | 0.01 | | | | |
| New Moon | 39 | 0.032 | 0.003 | 0.010[a] | 0.88 | 0.03 | 0.26 | 0.051 | * | 0.012 | 0.01 | 0.25 | * | 0.048 | 0.05 |
| Eltopia | 39 | | | | 1.0 | 0.03 | 0.34 | | | | | | | | |
| Ringold | 39 | 0.027 | 0.001 | 0.011 | 1.3 | 0.06 | 0.31 | 0.45 | * | 0.016 | 0.02 | 0.26 | * | 0.10 | 0.1 |
| Byers Landing | 39 | 0.038 | 0.001 | 0.012 | 1.4 | 0.02 | 0.35 | 0.033 | * | 0.008 | 0.01 | 0.21 | * | 0.059 | 0.06 |
| Richland | 39 | 0.044 | 0.001 | 0.013 | 1.3 | 0.06 | 0.37 | 0.026 | * | 0.007 | 0.01 | 0.18 | * | 0.068 | 0.07 |
| Pasco | 39 | 0.045 | 0.005 | 0.016[a] | 1.3 | 0.02 | 0.37 | 0.026 | * | 0.009 | 0.01 | 0.16 | * | 0.076 | 0.08 |
| Kennewick | 12 | 0.039 | 0.002 | 0.014 | 0.50 | 0.02 | 0.23[a] | | | | | 0.12 | * | 0.029 | 0.03 |
| Benton City | 39 | 0.046 | 0.001 | 0.012 | 0.92 | 0.04 | 0.32 | 0.028 | * | 0.009 | 0.01 | 0.12 | * | 0.043 | 0.04 |
| S.E. Quadrant Avg. | | | | 0.012 | | | 0.32 | | | 0.010 | 0.01 | | | 0.071 | 0.07 |
| Perimeter Communities | | | | | | | | | | | | | | | |
| Walla Walla | 39 | 0.078 | 0.002 | 0.018[a] | 1.5 | 0.03 | 0.33 | | | | | | | | |
| McNary Dam | 39 | | | | 1.0 | 0.06 | 0.33 | | | | | | | | |
| Washtucna | 37 | | | | 1.2 | 0.02 | 0.38 | | | | | | | | |
| Moses Lake | 31 | | | | 1.0 | 0.02 | 0.31 | | | | | | | | |
| Ellensburg | 26 | | | | 1.2 | 0.04 | 0.21 | | | | | | | | |
| Sunnyside | 41 | | | | 1.0 | 0.01 | 0.33 | | | | | | | | |
| Othello | 13 | 0.033 | 0.002 | 0.014[a] | 0.54 | 0.02 | 0.26[a] | | | | | | | | |
| Connell | 11 | | | | 0.57 | 0.06 | 0.24[a] | | | | | | | | |
| Perimeter Avg. | | | | 0.016 | | | 0.30 | | | | | | | | |

* Less than the analytical limit. See Appendix D.
(a) 6 months of data only

No entry indicates that no analysis was made.

TABLE 11. Radioactivity in Air - Quarterly Average, 1970
($10^{-12}$ μCi/ml)

| | Average Gross Beta | $^{90}Sr$ | % C.G. | Average Total Alpha | Pu-Alpha | % C.G. |
|---|---|---|---|---|---|---|
| Concentration Guide | 100 | 10 | | 0.03 | 0.02 | |
| Southeast Quad. | | | | | | |
| Jan-March | 0.15 | | | 0.004 | | |
| April-June | 0.48 | | | 0.017 | | |
| July-Sept. | 0.52 | 0.005 | 0.05 | 0.021 | 0.00004 | 0.2 |
| Oct-Dec. | 0.15 | 0.0027 | 0.03 | 0.009 | 0.00003 | 0.15 |
| Annual or 6-Mo. Avg. | 0.32 | 0.004 | 0.04 | 0.014 | 0.000035 | 0.2 |
| Perimeter Communities | | | | | | |
| Jan-March | 0.14 | | | | | |
| April-June | 0.50 | | | | | |
| July-Sept. | 0.44 | 0.015 | 0.15 | 0.017 | 0.00003 | 0.15 |
| Oct-Dec. | 0.15 | 0.001 | 0.01 | 0.014 | 0.00004 | 0.2 |
| Annual or 6-Mo. Avg. | 0.31 | 0.008 | 0.08 | 0.015 | 0.000035 | 0.2 |

No entry indicates no analysis was made.

## EXTERNAL RADIATION

### Land Measurements

Prior to June, 1970, ionization chambers (100 ml nominal volume) were used at a limited number of locations for basic gamma radiation measurements. Pocket ionization chambers (gamma pencils) were also used at all air sampler locations in order to distinguish major changes in gamma radiation levels. Table 12 shows measurements of an on-site and off-site location over a five-year period. The upward trend is believed to be due to increased deposition from weapons test fallout, as essentially all of the population expsoure at Richland is from natural background and worlwide fallout from nuclear testing.

TABLE 12. Average External Radiation Exposure Rates, 1966-1970 (mR/day)

| Location | 1966 | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|---|
| Hanford Test Location | 0.35 | 0.35 | 0.36 | 0.37 | 0.39 |
| Richland | 0.28 | 0.26 | 0.28 | 0.30 | 0.34 |

The chambers, however, have a limited response range (2 mR), and are prone to erroneous readings from mechanical shock, moisture, and dust. The best estimates of environmental gamma radiation dose based on chamber readings are, therefore, apt to be high. In June, 1970, thermoluminescent dosimeters (TLD-200*) in an experimental shielded package, were installed at all air sampling locations to measure the gamma radiation exposure at one meter above ground level. Table 13 shows the average exposure rates for the same location groups used in Table 10, the perimeter communities being the more distant locations. The difference of 0.01 mR/day between the two location groups is not statistically significant. The indicated annual expo-

*Harshaw Chemical Company, $CaF_2$(Dy).

sure of about 60 mR/year implied by the data in Table 13 is believed to be low but the data are considered valid for comparative purposes.

TABLE 13. Average External Radiation Exposure Rates - TLD, July-December, 1970
(mR/day)

| Location | Max. | Min. | Avg. |
|---|---|---|---|
| Perimeter Communities | .32 | .10 | .16 |
| Southeast Quadrant | .24 | .11 | .17 |

## Columbia River Shoreline

Estimates of the external radiation dose received from recreational use of the Columbia River shoreline in the vicinity of the Hanford project have been based on routine measurements along the shoreline at Vernita (upstream of the reactor), at Richland, and at Sacajawea Park (where the Snake River enters the Columbia). The exposure rate measured at the shoreline may include components from radioactivity accumulated in sediment deposits and algae growth at the river's edge as well as from any radioactive material in the water. The average exposure rates at the three shoreline locations (Figure 13) were measured with a 40-liter ionization chamber, one meter back from the water's edge and centered one meter above the ground; this approximates the dose rate to the gonads of a person standing on the riverbank. Average shoreline exposure rates (Table 14) at these two locations were 0.43 mR/day at Richland and 0.53 mR/day at Sacajawea Park, or 160 and 190 mR/yr., respectively. The average exposure rate at Vernita, upstream of the Hanford plant, was 0.38 mR/day, indicating a small dose increment from Hanford. The maximum recreational user of the river is estimated from local fishermen interviews to spend not more than 500 hours per year along the river shoreline.(12)

TABLE 14. Gamma Exposure Rates at the Columbia River Shoreline - 1970

| Location | (mR/day) Max. | (mR/day) Min. | (mR/day) Avg. | (mR/year) Avg. |
|---|---|---|---|---|
| Vernita | 0.98 | 0.24 | 0.38 | 140 |
| Richland | 0.86 | 0.14 | 0.43 | 160 |
| Sacajawea Park | 1.0 | 0.31 | 0.53 | 190 |

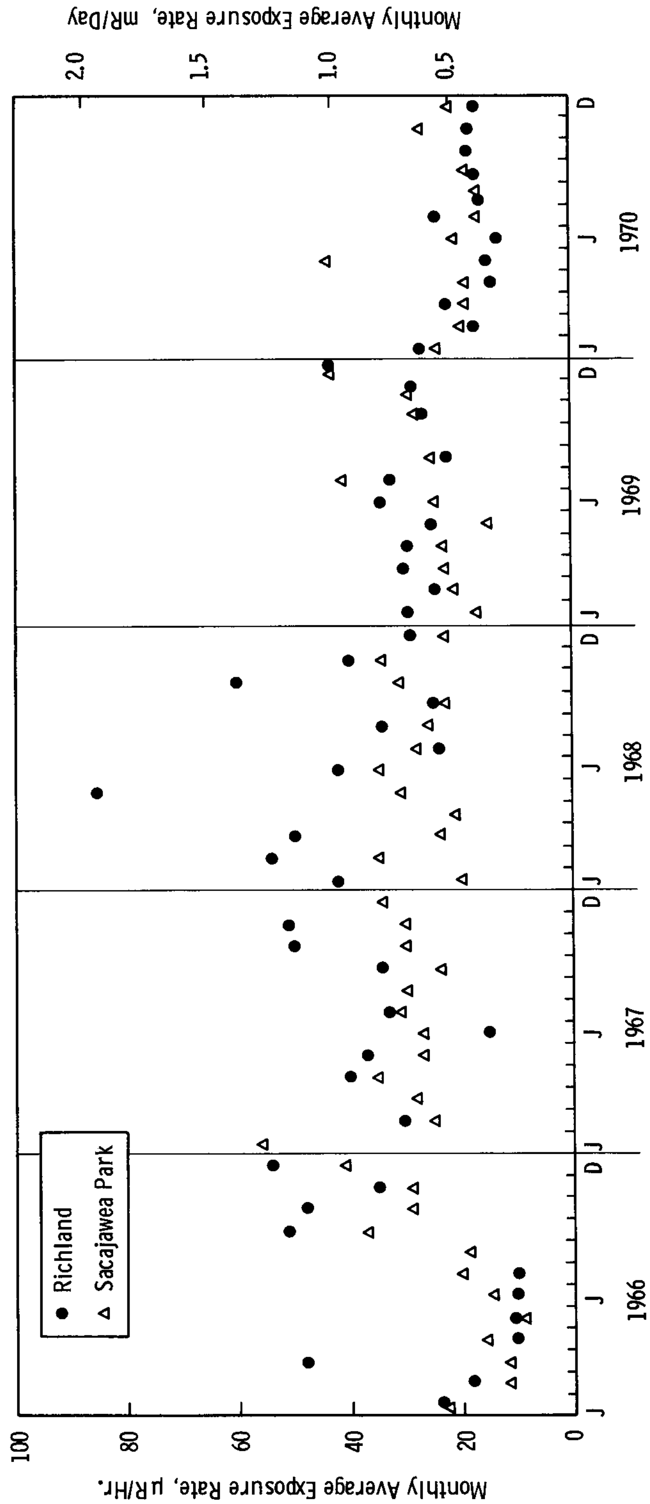


FIGURE 13. Monthly Average External Gamma Exposure Rates at the Columbia River Shoreline at Richland and at Sacajawea Park - 1966-1970

## Immersion Dose

The immersion dose received by Tri-City swimmers is based on April through October exposure rates at Richland. Thermoluminescent dosimeters, positioned about one meter below the surface of the Columbia River, were substituted for pocket ionization chambers beginning June, 1970. Measured immersion exposure rates were due to gamma emitters in the river from all sources, including Hanford reactors. In the vicinity of Richland, the average measured immersion exposure rate for 1970 was 0.42 mR/day. For comparison, the immersion exposure rate measured upstream at Vernita was 0.16 mR/day.

Teenagers are the major recreational users of the Columbia River locally. A survey of 430 Richland teenagers in 1968 indicated an average exposure time of about 115 hours in or along the river for members of this group. About one-third of the time was probably immersion and about two-thirds was shoreline exposure.[16] Using the annual average shoreline exposure rate and the April through October average immersion exposure rate at Richland, the average exposure to the teenage population was estimated to be about 0.5 mR during 1970.

The average whole body dose received by the Richland population from recreational use of the Columbia River can be estimated by assuming that other age groups use the river less than teenagers, but with the same proportion of immersion and shoreline exposure times. For the average exposure of the Richland population, an annual Columbia River (recreation) time of 32 hours was assumed.[16] Based on 11 hours of immersion and 21 hours of shoreline exposure in the vicinity of Richland, the whole body dose received by the Average Richland Resident during 1970 was estimated to be less than 0.1 mrem.

## Surface Measurements

Roads and land surfaces in the vicinity of Hanford were periodically surveyed for possible radionuclide deposition resulting from Hanford operations. Locations of control plots and routes of road and aerial surveys are described in Appendix B.

Eleven small areas, called control plots, are located around the Hanford boundaries. These plots, measuring 3m x 3m (10' x 10'), were surveyed monthly or semi-monthly with a GM survey meter for deposited radioactive material. No surface radioactivity of Hanford origin was detected on the control plots during 1970.

Public Highway 240, which traverses the Hanford reservation, was surveyed monthly with a bioplastic scintillation detector attached to the bumper of a truck positioned about 0.6 meters (2 ft.) above the edge of the road surface. This road monitor has been described in document BNWL-62.(17) During 1970, no radioactivity was detected by these surveys.

Aerial surveys can be used to detect contamination which is spread over a large area. Like road and control plot surveys, aerial surveys are only qualitative in nature, but through routine use of this technique a capability for rapid assessment of an emergency situation is maintained. Aerial surveys at Hanford are conducted at an altitude of 150 meters (500 ft.) using a three-inch by five-inch thallium-activated sodium iodide scintillation crystal detector. Aerial survey slight patterns used during 1970 were:

1. Near the Hanford project perimeter.
2. Fifteen to forty miles beyond the project perimeter.
3. Following the Columbia River from the Vernita Bridge (upstream of the Hanford reactors) downstream to McNary Dam.

During 1970, no significant changes were seen in previously observed patterns.

## FALLOUT FROM NUCLEAR WEAPONS TESTS

Measurements of fallout radiation, like measurements of natural background radiation, are all of interest for comparison with the radiation doses resulting from Hanford operations. Dose increments received by residents of the Hanford environs from the fallout nuclides $^{3}H$, $^{90}Sr$, and $^{137}Cs$ have been estimated routinely although they are not included in the assessment of dose attributable to Hanford operations. The concentrations of fallout nuclides in the local environs are below the national average because of the low rainfall.

Several positive analyses for $^{131}I$ concentrations in milk samples during 1970 were attributed to fallout from weapons testing. Estimates of fallout $^{3}H$ intakes from drinking water were based on upstream concentrations measured in river water (Table 4). Concentrations of $^{90}Sr$ and $^{137}Cs$ in locally produced farm and commercial milk (Table 9) were similar to those in commercial milk produced in areas remote from the Hanford plant,[18] and worldwide fallout was assumed to be the sole source of $^{90}Sr$ and $^{137}Cs$ in milk.

Assuming that 40% of an individual's total $^{90}Sr$ intake is obtained from milk,[19] the intake of $^{90}Sr$ for 1970 was estimated to be 0.0051 μCi for the Maximum Individual and 0.0012 μCi for the Average Richland Resident. The total intake of $^{137}Cs$ during 1970 was about 0.022 μCi for the Maximum Individual and 0.0052 μCi for the Average Richland Resident.

Table 15 shows a summary of the estimated annual dose commitments from fallout nuclides present in the Hanford environs in 1970. The estimated $^{90}Sr$ annual intake for the Maximum Individual and for the Average Adult Richland Resident, evaluated in terms of the Federal Radiation Council guides,[7] both correspond to 2% of the upper end of Range II ($2x10^{-4}$ μCi/day for the average intake by a suitable sample of the exposed population, and $6x10^{-4}$ μCi/day for individuals).

## COMPOSITE ESTIMATES OF RADIATION DOSE

### THE MAXIMUM INDIVIDUAL

Experience accumulated from the environmental surveillance program and associated research studies has indicated that those individuals receiving the greatest percentage of permissible radiation dose standards from Hanford sources consumed some combination of the following: fish caught locally in the Columbia River, gamebirds shot near the river, foodstuffs produced on local farms irrigated with Columbia River water drawn from below the reactors, and municipal water with the Columbia River as its source. A hypothetical Maximum Individual has been assigned assumed dietary habits (see Appendix E) which are identical to those used in the 1966 through 1969 annual reports.[1,2,3,20] The consumption rates of most foods for this hypothetical Maximum Individual were compiled from intake rates described in published dietary surveys and have been documented separately in detail.[21,22]

TABLE 15. Radiation Dose Commitments[a] from Ingestion of Individual Fallout Nuclides - 1970

(mrem)

| Maximum Individual | $^{3}H$ | $^{90}Sr$ | $^{137}Cs$ | Total |
|---|---|---|---|---|
| Bone | | 49.[b] | 1.6 | 51 |
| Whole Body | <1 | 4.6[b] | <1[c] | 5 |
| GI Tract | | <1 | <1 | <1 |
| **Average Adult Richland Resident** | | | | |
| Bone | | 12.[b] | <1 | 12 |
| Whole Body | <1 | 1.1[b] | <1[c] | 1 |
| GI Tract | | <1 | <1 | <1 |

[a] Not included in dose summaries presented elsewhere.

[b] The radiation dose commitments shown for bone and whole body represent the dose received over a period of 50 years based on ICRP methods.[8,9] Only a few percent of the total dose commitment from $^{90}Sr$ intake is received during the first year for each of these organs.

[c] For the whole body dose commitment from ingestion of $^{137}Cs$ by an adult, the FRC dose conversion factor of 0.06 rem/μCi was used.[23]

No entry indicates no analysis was made.

The composite doses estimated for this Maximum Individual for 1970 are shown graphically in Figure 14 and summarized in Table 16. Major decreases from the 1969 values were noted for all estimated organ doses.

1970 dose estimates for bone, whole body, and GI tract of the Maximum Individual continued to be predominantly from external exposure while fishing plus the consumption of Columbia River fish. The relative contributions from other pathway were greater than in the past, as radioactivity in the river declined with successive reactor shutdowns. The Maximum Individual thyroid dose declined even more sharply in 1970 due to the reduction in radioiodines released to the river in reactor effluents. The composite annual doses for 1967 through 1970 are shown in Table 17.

TABLE 16. Summary of Annual Radiation Doses[(a)] in the Hanford Environs, 1970

| Organ | Dose Standard, mrem | Calculated Dose - mrem | % of Standard |
|---|---|---|---|
| Maximum Individual | | | |
| Bone | 1500 | 94 | 6 |
| Whole Body | 500 | 12 | 2 |
| GI Tract | 1500 | 27 | 2 |
| Thyroid (Infant) | 1500 | 30 | 2 |
| Average Richland Resident | | | |
| Bone | 500 | 9 | 2 |
| Whole Body | 170 | 2 | 1 |
| GI Tract | 500 | 12 | 2 |
| Thyroid (Infant) | 500 | 8 | 2 |

(a) Doses from fallout and natural background not included.

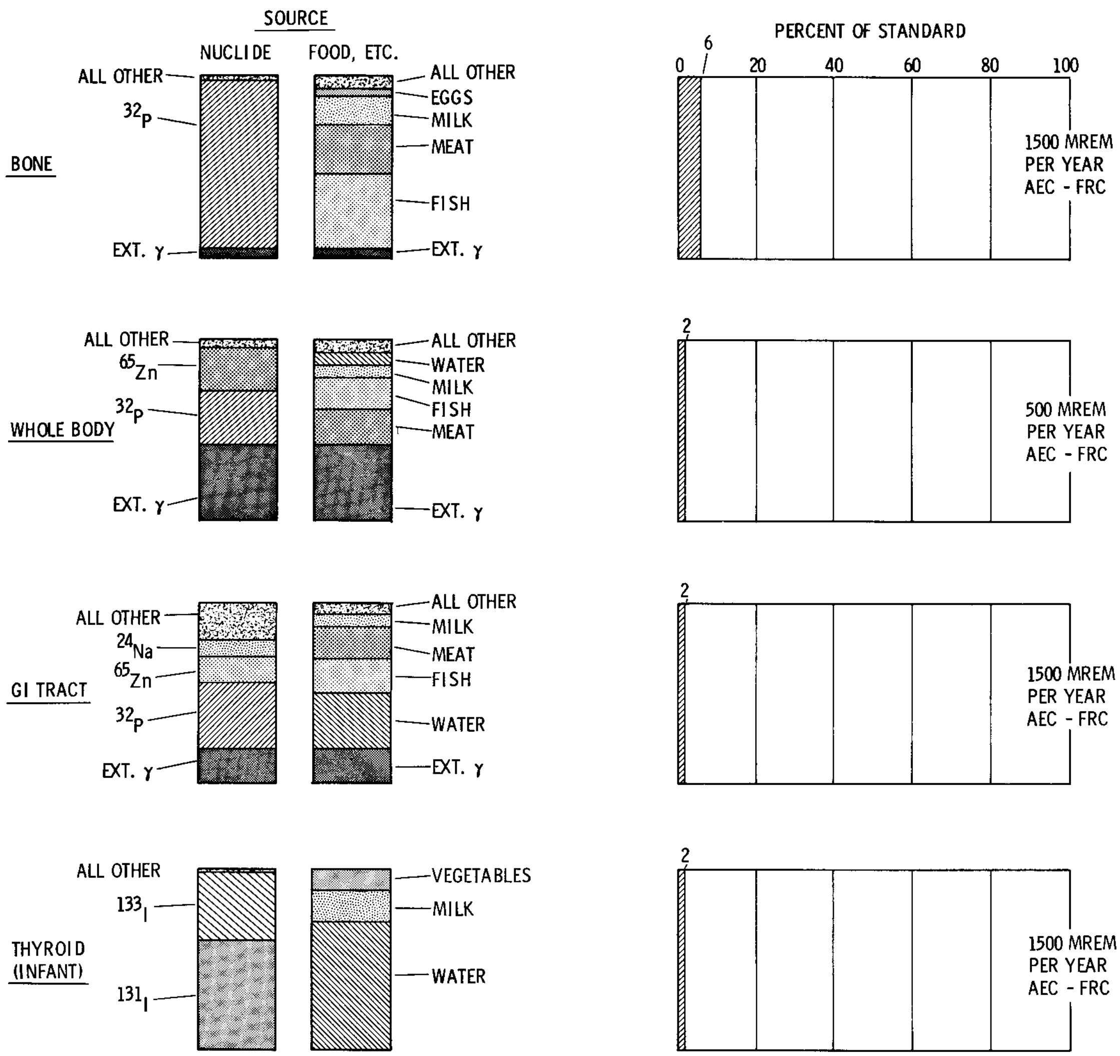


FIGURE 14. Estimated Doses to the Maximum Individual - 1970

THE AVERAGE RICHLAND RESIDENT

Estimates of average consumption rates of several food items were obtained for Richland adults from analysis of dietary questionnaires completed by plant employees. The program and the data have been discussed in previous reports.[3,22] Appendix E includes a summary of the diet for the Average Richland Resident. Not only are quantities consumed smaller than for the hypothetical Maximum Individual, sources of food, milk, and water based on the survey data indicate much greater dependence on commercial sources.

In computing doses for the Average Richland Resident, the assumed sources were Richland drinking water (with average concentrations adjusted for radioactive decay and dilution), Columbia River fish (with the average species composition of fish ingested by the Maximum Individual, but a much smaller quantitiy), an average species mix of gamebirds, and average amounts of milk, meat, and produce from local stores.

Because no significant contribution from Hanford operations to the ambient radiation levels in Richland has been discerned in the past, the external dose to the Average Richland Resident was assumed to result only from recreational use of the Columbia River. An estimated annual dose increment of 2 mrem from immersion in the river and activities along the shoreline was included in the GI tract, whole body, and bone doses. No such increment was included in the thyroid dose, calculated for an infant, because of the limited use of the river by this age group.

The composite doses estimated for the Average Richland Resident for 1970 are displayed in Figure 15 and summarized in Table 16. All 1970 doses estimated for the Average Richland Resident, like those for the Maximum Individual, decreased significantly with reduced radioactivity in the river and associated pathways.

For the Average Richland Resident, consumption of drinking water was by far the most important source of radiation dose. Because of the broad spectrum of radionuclides in the drinking water, however, no one nuclide predominated as a dose contributor to all organs.

The trend of exposure to the Average Richland Resident over the 1967-1970 period is also shown in Table 17.

TABLE 17. Comparable Dose Estimates[a] for Maximum Individual and Average Richland Resident - 1968-1970

| | Percent of Standard | | | | Dose Standard |
|---|---|---|---|---|---|
| Maximum Individual | 1967 | 1968 | 1969 | 1970 | (mrem/yr) |
| Bone | 26 | 17 | 9 | 6 | 1500 |
| Whole Body | 6 | 5 | 4 | 2 | 500 |
| GI Tract | 5 | 4 | 3 | 2 | 1500 |
| Thyroid (Infant) | 6 | 7 | 4 | 2 | 1500 |
| Average Richland Resident | | | | | |
| Bone | 5 | 3 | 3 | 2 | 500 |
| Whole Body | 3 | 2 | 2 | 1 | 170 |
| GI Tract | 6 | 5 | 4 | 2 | 500 |
| Thyroid (Infant) | 8 | 8 | 5 | 2 | 500 |

[a] Not including contributions from fallout or natural background radiation.

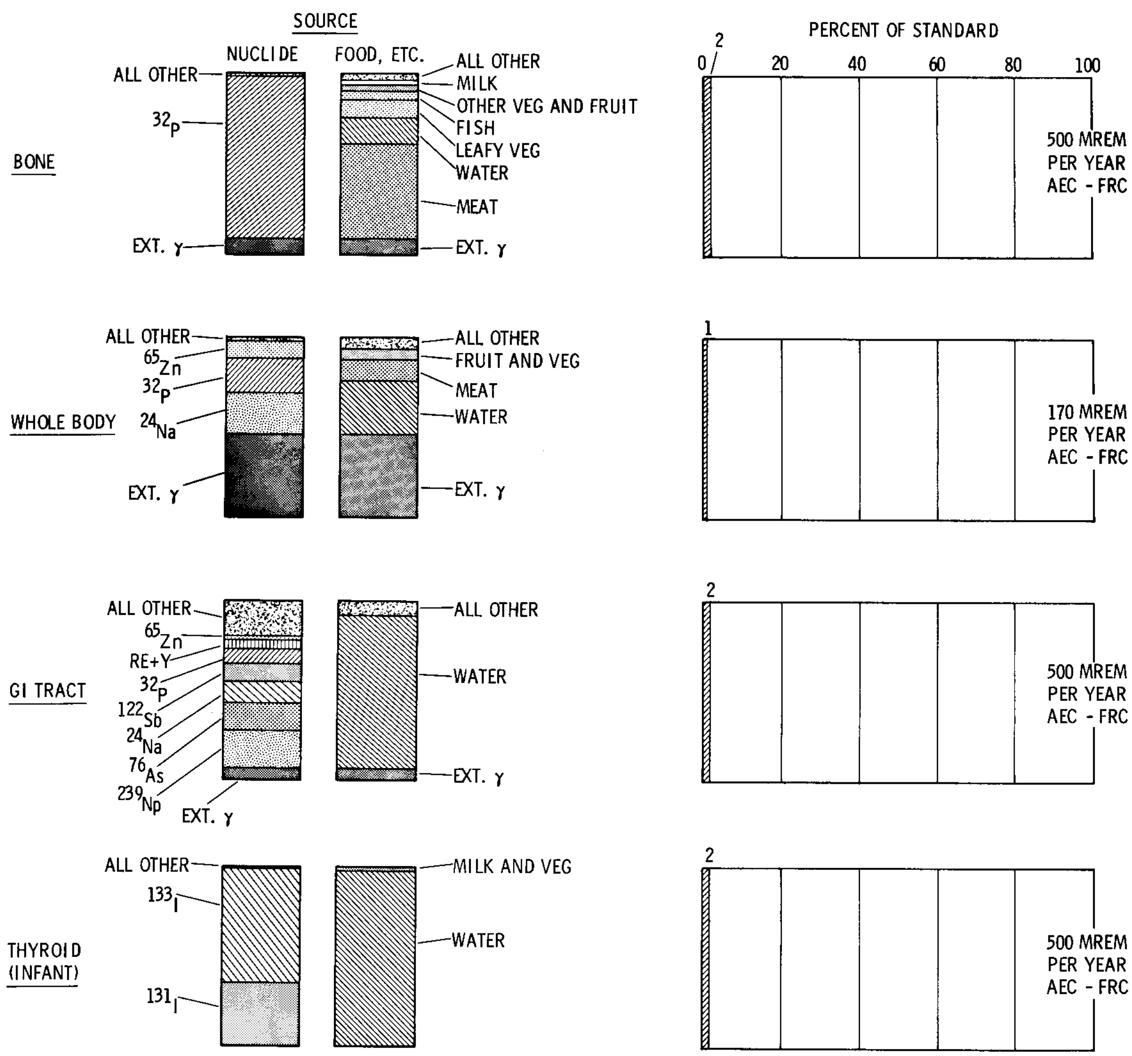


FIGURE 15. Estimated Doses to the Average Richland Resident - 1970

# AIR AND WATER QUALITY

## COLUMBIA RIVER WATER QUALITY

Measurements of water quality parameters other than radioactivity are routinely made on Columbia River water in order to:

(a) Detect any impact of Hanford waste disposal practices on river water quality.

(b) Demonstrate continued compliance with Washington State Water Quality Standards for the Columbia River and Public Health Service recommendation for sources of drinking water.

Standards[24] applicable to the local river reaches are abstracted in Appendix C. In accordance with these, routine measurements were made either at Richland or the Laboratory (300) Area, approximately 8 km (5 miles) upstream from the Richland water plant, for the parameters for which quantitative criteria are given. These are pH, turbidity, dissolved oxygen, coliform organisms, and temperature (Tables 18/19). Enterococci measurements were made to clarify the types of coliforms present. In addition, those parameters most likely to be affected by Hanford operations, temperature and nitrate ion, were measured both upstream at Priest Rapids or Vernita and downstream at Richland. Other chemical characteristics of the river water measured primarily for reactor process information, were also made available by Douglas-United Nuclear staff.

Analysis of Columbia River water for biological quality, shown in Table 18, indicated an increase of coliform organisms between the Vernita and Richland measurement points. These additions are believed to be related to drainage from farming and animal husbandry activities not associated with Hanford operations. Additionally, this section of the river is heavily populated by waterfowl which may contribute to the biological load. All data showed compliance with the Washington State Water Quality Standards.

TABLE 18. Columbia River Biological Analyses, 1970

| | Coliform (N/100 ml) | | Enterococci (N/100 ml) | | BOD (ppm) | |
|---|---|---|---|---|---|---|
| Recommended Standard | 240 | | None | | None | |
| | Vernita | Richland | Vernita | Richland | Vernita | Richland |
| # Samples | 12 | 12 | 12 | 12 | 11 | 11 |
| Max. | 75 | 180 | 86 | 210 | 4.6 | 4.6 |
| Min. | 1.0 | 2.0 | * | 2.0 | 0.95 | 1.0 |
| Avg. | 24 | 44 | 13 | 33 | 3.2 | 2.8 |

*Less than the analytical limit (see Appendix D).

Nitrate ion and hexavalent chromium ($Cr^{+6}$) concentrations, showed (Table 19) small increases across the plant reach of the river. Nitrate ion probably entered the river in groundwater from agricultural sites as well as plant sites. $Cr^{+6}$ was added to reactor cooling water in small concentrations. Neither ion approached recommended standards. pH, turbidity, and dissolved oxygen measurements were made only at 300 Area; the range of these measurements is believed to be of natural origin not associated with Hanford operations and all are well within state standards.

Other chemical characteristics of Columbia River water during 1970 are shown in Table 20. Slight increases of no real signficance were seen in most measurements between the upstream (Vernita) and the downstream (100-F Area) locations.

There was a small net increase in average Columbia River temperature between Priest Rapids and Richland for 1970, as indicated in Table 20. Reactors were not operating during the period when upstream river temperature exceeded the Washington State water quality criteria.

## RICHLAND DRINKING WATER QUALITY

The Hanford Environmental Health Foundation, as a contractor to the Atomic Energy Commission, makes routine measurements for coliform bacteria

TABLE 19. Columbia River Water Quality Measurments - 1970

| | pH | Turbidity (JTU)[a] | Dissolved Oxygen (ppm) | $NO_3$ (ppm) | | $Cr^{+6}$ (ppm) | | Temperature (°C) | |
|---|---|---|---|---|---|---|---|---|---|
| Standard | 6.5 to 8.5 | 5 + Bg | 8.0 min. | 45 | | 0.05 | | (b) | |
| | 300 Area | 300 Area | 300 Area | Vernita | Richland | Vernita | Richland | Priest Rapids | Richland |
| No. Samples | 214 | 215 | 185 | 51 | 52 | 47 | (c) | (c) | (c) |
| Maximum | 8.7 | 4.7 | 14.2 | 1.3 | 2.1 | 0.014 | 0.0023 | 20.7 | 21.6 |
| Minimum | 7.2 | 0.5 | 8.1 | * | * | * | * | 3.4 | 3.8 |
| Average | 8.2 | 1.8 | 11. | 0.28 | 0.50 | * | 0.0008 | 11.0 | 11.6 |

*Less than the analytical limit (see Appendix D).
(a) Standard is given as an increase in turbidity not to exceed 5 Jackson Turbidity Units (JTU).
(b) Special formula (see Appendix A).
(c) Continuous measurement.

TABLE 20. Chemical Characteristics of Columbia River - 1970
(parts per million)

| Location | No. of Samples | Mg | Fe | Cu | Ca | $SO_4$ | $PO_4$ | Cl | Diss. $O_2$ | Phth. Alk. | M.O. Alk. | Hardness | Total Solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vernita | 22 | 4.8 | 0.03 | 0.006 | 21 | 16 | 0.04 | 0.36 | 10 | 1.9 | 66 | 72 | 88 |
| 100-F Area | 22 | 5.0 | 0.04 | 0.006 | 22 | 16 | 0.04 | 0.40 | 10 | 1.8 | 68 | 74 | 90 |

Data furnished by Douglas-United Nuclear, Inc.

and specific chemical ions at the 300 Area treatment plant and the City of Richland municipal treatment plant. The objective of the program is to monitor the bacteriological and chemical quality of the plant drinking water, in part obtained from the City of Richland. The secondary objective is the monitoring of any effect of Hanford operations on the city water.

Annual average concentrations of nitrate and hexavalent chromium (Table 21) in treated water at the Richland water treatment plant were 0.19 and 0.002 ppm, <1% and 4% of the respective standards. All bacteriological measurements were negative.

## AIR QUALITY

Small atmospheric releases of oxides of nitrogen occur intermittently from Hanford process facilities, and coal-fired steam plants on the project release oxides of sulfur and particulates. The Hanford Environmental Health Foundation, as a contractor to the Atomic Energy Commission, routinely measured the concentrations of nitrogen dioxide, sulfur dioxide, and suspended particulates in the atmosphere at several off-site locations in the vicinity of Hanford during 1970. These data, reported in quarterly summary reports by the Hanford Environmental Health Foundation, have been summarized in Table 22.

$NO_2$ and $SO_2$ samples were collected using 24-hour sequential samplers operated at ground level monitoring stations. The highest average $NO_2$ concentration for any location was 0.007 ppm, 14% of the current Federal Air Quality Standards.[5] All $SO_2$ sample results were less than the detection level of 0.005 ppm, 20% of the Washington State Standard. Suspended particulates, measured at Richland, varied over a wide range due to heavy dust storms typical of the area. Measured fluctuations of nitrogen dioxide and particulates were attributed to non-plant sources.

TABLE 21. Chemical Analyses of Richland Drinking Water, 1970

(parts per million)

| | | $NO_3$ | | | | $Cr^{+6}$ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Analytical Limit | | 0.05 | | | | 0.001 | | | |
| Standard | | 45. | | | | 0.05 | | | |
| Location | No. of Samples | Max. | Min. | Avg. | % Std. | Max. | Min. | Avg. | % Std. |
| Richland Treatment Plant | 51 | 0.85 | * | 0.19 | <1 | 0.006 | 0.001 | 0.002 | 4 |

*Less than the analytical limit (see Appendix D).

Data by Hanford Environmental Health Foundation.

TABLE 22. Air Quality Measurements in Hanford Environs, 1970

| | $NO_2$ (ppm) | | | | Suspended Particulates $\mu g/m^3$ | | | |
|---|---|---|---|---|---|---|---|---|
| Location | No. of Samples | Max. | Min. | Avg. | No. of Samples | Max. | Min. | Avg. |
| Richland (747 Building) | | | | | 31 | 400 | 2 | 110 |
| Opposite Richland | 359 | 0.020 | * | 0.0070 | | | | |
| Opposite North Richland | 310 | 0.020 | * | 0.0065 | | | | |
| Opposite 300 Area | 365 | 0.029 | * | 0.0048 | | | | |
| Ringold | 365 | 0.020 | * | 0.0052 | | | | |
| White Bluffs | 365 | 0.018 | * | 0.0053 | | | | |

*Less than analytical limit (see Appendix D).
No entry indicates no analysis was made.

Data by Hanford Environmental Health Foundation.

## ACKNOWLEDGMENTS

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Pasco, Washington

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Richland, Washington

Roza Irrigation District
Sunnyside, Washington

Sitko Motors
Washtucna, Washington

U.S. Army Corps of Engineers
McNary, Oregon
Bonneville, Oregon

Washington State Department of Game
Olympia,Washington

Washington State Dept. of Highways
Ellensburg, Washington/Wenatchee, Washington

Washington State Patrol
Yakima, Washington

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# APPENDIX A

## APPLICABLE STANDARDS

# APPENDIX A

## APPLICABLE STANDARDS

I. Extracts from Washington State Water Quality Standards for Interstate Waters, 1967:(6)

"A. Water Quality Criteria

1. Class A Excellent

a. General Characteristics

Water quality of this class exceeds or meets the requirements for all or substantially all uses.

b. Characteristic uses

Characteristic uses include, but are not limited to, the following:

Water supply (domestic, industrial, agricultural)
Wildlife habitat, stock watering
General recreation and aesthetic enjoyment (picnicking, hiking, fishing, swimming, skiing and boating)
Commerce and navigation
Fish and shellfish reproduction, rearing and harvest

c. Water Quality Standards

Total Coliform Organisms shall not exceed median values of 240 (FRESH WATER) with less than 20% of samples exceeding 1,000 when associated with any fecal source or 70 (MARINE WATER) with less than 10% of samples exceeding 230 when associated with any fecal source.

Dissolved Oxygen shall exceed 8.0 mg/l (FRESH WATER) or 6.0 mg/l (MARINE WATER).

Temperature No measurable increases shall be permitted within the waters designated which result in water temperatures exceeding $65^{o}F$ (FRESH WATER) or $61^{o}F$ (MARINE WATER) nor shall the cumulative total of all such increases arising from nonnatural causes be permitted in excess of $t = 90/(T-19)$ (FRESH WATER) or $t = 40/(T-35)$ (MARINE WATER); for purposes hereof "t" represents the permissive increase and "T" represents the resulting water temperature.

1. Class A Excellent (Continued)

c. Water Quality Standards (Continued)

pH shall be within the range of 6.5 to 8.5 (FRESH WATER) or 7.8 to 8.5 (MARINE WATER) with an induced variation of less than 0.25 units.

Turbidity shall not exceed 5 JTU (Jackson Turbidity Units - Standard Candle) over natural conditions

Toxic, Radioactive or Deleterious Material Concentrations shall be below those of public health significance, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.

Aesthetic Values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch or taste.

B. Classification

Interstate and coastal waters of the State of Washington are classified as follows:

1. Columbia River Class A

Washington-Oregon border (River Mile 309) to Grand Coulee Dam (River Mile 595)

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

## II. Air and Sanitary Water Quality Standards

### A. Air Quality Standards

1. Sulfur dioxide: 24-hour average: 0.10 ppm
   Annual Average: 0.02 ppm

   Ref: Washington State Department of Ecology Chapter 18-56, Sulfur Oxide Standards, April 1970.

2. Nitrogen dioxide: Annual arithmetic mean 100 $\mu g/m^3$; 24 hour average - not to exceed 250 $\mu g/m^3$ more than once per year.

   Ref: Environmental Protection Agency[5]

3. Suspended particulates: annual mean - concentration not to exceed 60 micrograms per cubic meter of air (less background east of the Cascades).

   Ref: Washington State Department of Ecology Chapter 18-40, Suspended Particulate Standards, April 1970.

### B. Bacteriological and Chemical Quality Criteria for Sanitary Water

1. Bacteriological quality - no coliform organisms shall be present in any sanitary water samples.

   Ref: Hanford Standard HW-4966-S[25]

2. Chemical Quality

   a. Fluorides: with a mean average of maximum daily air temperatures = 64.8°F for this area, the recommended control limit is 1.2 mg/liter. A concentration of greater than 1.4 mg/liter shall constitute grounds for rejection of the water supply.

      Ref: Public Health Service[24]

   b. Nitrates: 45 mg/liter

      Ref: Public Health Service[24]

c. Mercury: No current standards exist for allowable mercury content in sanitary water. However, 5.0 ppb is an accepted limit pending revision of Public Health Service Drinking Water Standards.

## III. RADIATION STANDARDS

The basic radiation standards for population dose in use at Hanford are given in the following extract from AEC Manual Chapter 0524, Appendix:[4]

" TABLE II: Radiation Protection Standards for External and Internal Exposure

| | Annual Dose or Dose Commitment (rem) | |
|---|---|---|
| Type of Exposure | Based on Dose to Critical Individuals at Points of Maximum Probable Exposure | Based on an Average Dose to a Suitable Sample of the Exposed Population[1] |
| Whole body, gonads, or bone marrow | 0.5 | 0.17 |
| Other organs[2] | 1.5 | 0.5 |

(1) See Paragraph 5.4, FRC Report No. 1, for discussion on concept of suitable sample of exposed population.

(2) An acceptable alternate standard for bone for individuals is the ICRP standard of 0.003 μg of radium-226 or its biological equivalent. The alternate standard for populations would be one-third this ICRP standard."

[Concentration Guides for air and water, given in Table II of the Appendix, also apply to maximum exposures to individuals.]

# APPENDIX B

## ROUTINE SURVEILLANCE SCHEDULE

# APPENDIX B

## ROUTINE SURVEILLANCE SCHEDULE

### Frequency Symbols Used

D - Daily
SW - Semi-Weekly
W - Weekly
BW - Bi-weekly
SM - Semi-monthly
M - Monthly
M Comp. - Monthly Composite
BM - Bi-monthly
Q - Quarterly
SA - Semi-annually
A - Annually

## I. WATER SAMPLES

### A. Columbia River Raw Integrated

| Location | Frequency | Measurement |
|---|---|---|
| Richland | W | P-32, Sc-46, Cr-51, Zn-65, I-131, Gamma Scan |
| | M Comp. | H-3, Sr-90, Alpha |
| | Q | Pu |
| Bonneville Dam | BW Comp. | P-32, Cr-51, Zn-65 |

### B. Columbia River Raw Grab

| Location | | |
|---|---|---|
| Vernita | SM | Mg, Fe, Cu, Ca, $SO_4$, $PO_4$, Cl, Diss. $O_2$, Phth. Alk., M.O. Alk., Hardness, Solids |
| | M | Coliform, Enterococci, BOD, Turbidity |
| | W | $NO_3$-, $Cr^{+6}$ |
| | M. Comp. | H-3, Sr-90, Alpha |
| | Q | Pu |

B. Columbia River Raw Grab (Continued)

| Location | Frequency | Measurement |
|---|---|---|
| 300 Area | D | pH, DO, Turbidity |
| North Richland | M | Coliform, Enterococci, BOD, Turbidity |
| Richland | M | Na-24, Cr-51, Mn-56, Cu-64, Zn-69m, As-76, Sb-122, Np-239, RE+Y, Beta |
| | W | $NO_3^-$ |

C. Sanitary Water Integrated

| Location | | |
|---|---|---|
| Richland | W | P-32, Zn-65, I-131 |

D. Sanitary Water Grab

| Location | | |
|---|---|---|
| Richland Water Plant | W | Beta |
| | M | Na-24, I-131, I-133, Beta |

E. Groundwater

Off-Plant Wells

| Location | | |
|---|---|---|
| Webber Ranch | SA | H-3, $NO_3^-$ |
| W-15 | SA | H-3, $NO_3^-$ |
| White Bluffs | SA | H-3, $NO_3^-$ |
| Vail Ranch | SA | H-3, $NO_3^-$ |
| Hildebrandt | SA | H-3, $NO_3^-$ |

## II. AIR SAMPLES

### A. Radioactivity

| Location | Frequency | Measurement |
|---|---|---|
| Yakima Barricade | BW | Beta, alpha |
| Vernita Bridge | BW | Beta |
| ERC | BW | Beta |
| Rattlesnake Springs | BW | Beta |
| | | I-131 |
| Benton City | BW | Beta, alpha |
| | | I-131 |
| Wahluke Slope #2 | BW | Beta |
| Berg Ranch | BW | Beta, alpha |
| | | I-131 |
| Othello | BW | Beta, alpha |
| | | I-131 |
| Connell | BW | Beta |
| | | I-131 |
| New Moon | BW | Beta, alpha |
| | | I-131 |
| Wahluke Water Master | BW | Beta |
| | | I-131 |
| Eltopia | BW | Beta |
| Ringold | BW | Beta, alpha |
| | | I-131 |
| Byers Landing | BW | Beta, alpha |
| | | I-131 |
| Pasco | BW | Beta, alpha |
| | | I-131 |
| Kennewick | BW | Beta, alpha |
| | | I-131 |
| Richland | BW | Beta, alpha |
| | | I-131 |
| Sunnyside | BW | Beta |

A. Radioactivity (Continued)

| Location | Frequency | Measurement |
|---|---|---|
| Ellensburg | BW | Beta |
| Moses Lake | BW | Beta |
| Washtucna | BW | Beta |
| Walla Walla | BW | Beta, alpha |
| McNary Dam | BW | Beta |

B. Composite Analyses

| Perimeter Communities | South East Quadrant |
|---|---|
| McNary | Benton City |
| Walla Walla | Richland |
| Washtucna | Kennewick |
| Moses Lake | Pasco |
| Ellensburg | Byers Landing |
| Sunnyside | Eltopia |
| | Ringold |
| | New Moon |
| | Connell |
| | Othello |
| | Berg Ranch |
| | Wahluke Water Master |

| South East Quadrant | Frequency | Measurement |
|---|---|---|
| | M | Gamma scan |
| | Q | Pu-239, Sr-90 |
| Perimeter Communities | | |
| | M | Gamma scan |
| | Q | Pu-239, Sr-90 |

C. Air Quality

| Location | Frequency | Measurement |
|---|---|---|
| Richland | D | $NO_2$, $SO_2$ |
| | BW | Particulate |
| Opposite Richland | D | $NO_2$, $SO_2$ |
| Opposite N. Richland | D | $NO_2$, $SO_2$ |
| Opposite 300 Area | D | $NO_2$, $SO_2$ |
| Ringold | D | $NO_2$, $SO_2$ |

| III. MILK | Location | Frequency | Measurement |
|---|---|---|---|
| Lucerne | Tri-City | M | I-131, Gamma scan |
| | | Q | Sr-90 |
| Darigold-Arden | Tri-City | SM | I-131 |
| | | Q | Sr-90 |
| Hulbert (Raw) | Kiona | SM | I-131, Gamma scan |
| | | Q | Sr-90 |
| Col. Basin Comp. (Raw) | Esser, Robinson, Bleazard | BW | P-32, I-131, Gamma scan Sr-90 |
| Col. Basin Comp. Comp. #3 (Raw) | Taylor, New Moon, Kinne, Monson | BW | I-131 Gamma scan |
| West Richland-Benton City Comp. (Raw) | Dinneen, Atterberry | BW | I-131, Gamma scan |
| [Riverview] River Irrigated (Raw) | Harris | W | P-32, I-131 Gamma scan |
| | | Q | Sr-89, Sr-90 |

| IV. FISH | Location | Frequency | Measurement |
|---|---|---|---|
| Whitefish (muscle) | Ringold to Richland | SM | P-32 |
| (5 fish/sample) | | SM Comp. | Gamma scan |

| IV. FISH (Cont.) | Location | Frequency | Measurement |
|---|---|---|---|
| Bass | Island View | *SM Comp.<br>M Comp. | P-32<br>Gamma scan |
| | Burbank | *SM Comp.<br>M Comp. | P-32<br>Gamma scan |
| | Hover | *SM Comp.<br>M Comp. | P-32<br>Gamma scan |
| Perch | Island View | SM Comp.<br>M. Comp. | P-32<br>Gamma scan |
| | Burbank | SM Comp.<br>M Comp. | P-32<br>Gamma scan |
| | Hover | SM Comp.<br>M Comp. | P-32<br>Gamma scan |

| V. WILD FOWL | Location | Frequency | Measurement |
|---|---|---|---|
| River Ducks | | | |
| 80 birds/yr | 100-K to Savage Island | Oct-Jan | P-32, gamma scan (muscle) |
| River Geese | | | |
| 20 birds/yr | 100-K to Savage Island | Oct-Jan | P-32, gamma scan (muscle) |
| Pheasant and Quail | | | |
| 20 birds/yr of each species | Rivershore, 100-K to 300 Area | Oct-Jan | P-32, gamma scan (muscle) |

* Bass will be routinely collected during April-November only.

## VI. FOODSTUFFS

### A. Meat, Chicken, Eggs

| | Location | Frequency | Measurement |
|---|---|---|---|
| Farm meat, lean beef | Riverview - river irrigated | M | P-32, gamma scan |
| Commercial meat, pork | Tri-Cities Stores | BM | Gamma scan |
| Commercial meat, calves liver | Tri-Cities Stores | Mar, Jun, Sept | Gamma scan |
| Commercial meat, ground round | Tri-Cities Stores | BM | Gamma scan |
| Commercial meat, chicken | Tri-Cities Stores | Mar, Jun, Sept | Gamma scan |
| Commercial eggs | Tri-Cities | Q | Gamma scan |
| Commercial meat, lean beef | Pasco Meat Packers | M | P-32, Sr-90 gamma scan |
| Commercial meat, pork roast | Pasco Meat Packers | Q | P-32, Sr-90 gamma scan |
| Farm eggs | Harris (Riverview) | M | P-32, gamma scan |
| | | Q | Sr-89, Sr-90 |
| Farm eggs | Kinne (Ringold) | M | P-32, gamma scan |
| Farm chicken | Harris (Riverview) | Q | P-32, Sr-89, Sr-90, gamma scan |
| Farm chicken | Kinne (Ringold) | Q | P-32, gamma scan |

### B. Produce

| | Location | Frequency | Measurement |
|---|---|---|---|
| Commercial leafy vegetables | Tri-Cities | *M | P-32, gamma scan, Sr-89, Sr-90 |
| Commercial vegetables & fruit | Tri-Cities | *M | P-32, gamma scan, Sr-90 |
| Farm leafy vegetables | Riverview river irrigated | *SM | P-32, gamma scan |
| | | *M | Sr-90 |
| Farm other vegetables | Riverview river irrigated | *SM | P-32, gamma scan |
| | | *M | Sr-90 |

* During the growing season, May-October only.

| B. Produce (Cont.) | Location | Frequency | Measurement |
|---|---|---|---|
| Farm fruit | Riverview river irrigated | *SM<br>*M | P-32, gamma scan<br>Sr-90 |
| Farm leafy vegetables | Benton City | *2 samples | Gamma scan<br>Sr-90 |
| Farm other vegetables | Benton City | *2 samples | Gamma scan<br>Sr-90 |
| Farm fruit | Benton City | *2 samples | Gamma scan<br>Sr-90 |
| C. Oysters | Willapa Bay | M | P-32, gamma scan |

VII. SURFACE CONTAMINATION

A. Control Plots

| Location | Frequency | Measurement |
|---|---|---|
| Wahluke Slope (8 locations) | M | Contamination-GM |
| Hanford Ferry (far shore) | M | Contamination-GM |
| 300-Area Parking Lot | W | Contamination-GM |

B. Road Surveys

| | | |
|---|---|---|
| Hanford Highway - Horn Rapids to Yakima Barricade & Route 6 | M | Gamma - Road Monitor |
| North Richland to 300 Area | Q | Gamma - Road Monitor |

VIII. AERIAL SURVEY

| Location | Frequency | Measurement |
|---|---|---|
| Project Perimeter | SA | Radiation |
| Richland-Ellensburg-Ritzville "triangle" | SA | Radiation |
| Columbia River-Vernita to McNary Dam | SA | Radiation |

*During the growing season, May-October only.

## IX. GAMMA DOSE RATE

### A. Columbia River

| Location | Frequency | Measurement |
|---|---|---|
| Vernita | M | Immersion dose-TLD |
| Powerline Crossing | M | Immersion dose-TLD |
| Richland Pumphouse | M | Immersion dose-TLD |

### B. Columbia River Shoreline

| | | |
|---|---|---|
| Vernita | M | Dose rate-40 liter chamber Contamination-GM |
| Richland - Plant Shore Above Water Plant | SW | Dose rate-40 liter chamber Contamination-GM |
| Sacajawea | BW | Dose rate-40 liter chamber Contamination-GM |

### C. Land Locations

| | | |
|---|---|---|
| Rte. 10, mile 1.6 | | Integrated gamma dose - Ionization chamber |
| Richland | | Integrated gamma dose - Ionization chamber |
| All air sample locations | M | Integrated gamma dose - TLD |

## X. INSTRUMENTS - CONTINUOUS MONITORING

### A. Radiation Monitors

| Location | Frequency | Measurement |
|---|---|---|
| 300-Area - ACRMS | Continuous | Gamma dose rate - Water surface |
| 300 Area - ACRMS | Continuous | I-131 concentration in river water |

### B. Temperature Monitors

| | | |
|---|---|---|
| Priest Rapids Gauge Station | Continuous | River temperature (by DUN) |
| Richland | Continuous | River temperature |

### C. Chemical Monitors

| | | |
|---|---|---|
| 300-Area - ACRMS | Continuous | $Cr^{+6}$ concentration in river water |

# APPENDIX C

# ROUTINE ANALYTICAL PROCEDURES

# APPENDIX C

## ROUTINE ANALYTICAL PROCEDURES

### Air

Alpha - Direct count of filter on gas flow alpha proportional counter.

Beta - Direct count of filter on gas flow beta proportional counter.

Sr-90 - Leach with HCl, fuming nitric precipitation, barium scavenge, carbonate precipitation, count with gas flow beta proportional counter.

Plutonium - Leach with HCl, precipitation with hydrofluoric acid, extraction with TTA in presence of aluminum nitrate and sodium nitrite, electrodeposition and alpha track counting on NTA film.

Gamma Emitters - Direct count of filter with sodium iodide well crystal. Routine radionuclides: Zr-Nb-95, Cs-134, Cs-137, Ru-Rh-106, Ce-Pr-144.

Iodine-131 - (a) Direct gamma count for iodine-131 on charcoal sample in sodium iodide well crystal.

(b) Precipitation with silver iodide from caustic solution. Direct count with beta proportional counter.

Nitrogen Dioxide - Collection with alkaline solution bubbler. Colorometric determination as azo dye, using sulfanilimide method.(26)

Sulfur Dioxide - Collection with bubbler solution of sodium tetrachloromercurate, with colorometric determination.(27)

Particulates - Collection on Gelman Type A glass fiber filter, with direct weighing for particulate loading.

### Water

Alpha - Extraction with diethylether. Count dried residue with gas flow alpha proportional count.

Beta - Count dried residue with gas flow beta proportional counter.

Tritium - After distillation, direct count with liquid scintillation spectrometer.

Phosphorus-32 - Ammonium phosphomolybdate precipitate and gas flow beta proportional counter.

Strontium-90 - Same as for air filters.

Iodine-131 - Same as for Air, Iodine-131 (b).

Uranium - Direct fluorometric measurement

Plutonium - Same as for air filters.

Gamma-Emitters - Same as for air filters. Routine radionuclides: Sc-46, Cr-51, Co-60, Zn-65, Cs-137.

Coliforms - (a) Membrane filter method,[28]
(b) Multiple tube fermentation method---48-hour test.[28]

Enterococci - Membrane filter method.[29]

B.O.D. - 5-Day B.O.D. procedure[28]

pH - Direct pH meter measurement.

Turbidity - Direct turbidimeter measurement

Dissolved Oxygen - Direct measurement with polarographic probe.

Nitrate Ion - Phenyldisulfonic method.[28]

Hexavalent Chromium - Continuous automated analyzer measurement (Technicon Autoanalyzer), based on diphenylcarbazide colormetric method.[28]

Milk

Phosphorus-32 - Ashed, precipitated as ammonium phosphomolybdate, reprecipitated as magnesium ammonium phosphate, beta counted with gas flow beta proportional counter.

Strontium-90 - Ashed, then same as for air filters.

Iodine-131 - Ion exchange whole milk sample. Resin direct gamma counted in sodium iodide well crystal.

Gamma Emitters - Same as for air. Routine radionuclides: K-40, Zn-65, Cs-137, I-131

Solid Foodstuffs and Vegetation

Phosphorus-32 - Same as for milk.

Strontium-90 - Same as for milk.

Plutonium - Ashed, HCl leach, ion exchange, TTA extraction in presence of aluminum nitrate and sodium nitrite, alpha spectroscopy.

Gamma Emitters - Same as for air filters. Routine radionuclides: Co-60, K-40, Zn-65, Co-58, Mn-54, Cs-137, I-131.

Soil

Strontium-90 - HCl leach, then same as for air filters.

Plutonium - HCl leach, then same as for Solid Foodstuffs and Vegetation.

Gamma Emitters - Same as for air filters. Routine radionuclides: K-40, Cs-137

# APPENDIX D

# ANALYTICAL LIMITS

# APPENDIX D

## ANALYTICAL LIMITS

Routine environmental radioanalyses for the Hanford program are performed by the U. S. Testing Company, Richland, Washington. Analytical limits are specified in a services contract between U. S. Testing and the Atomic Energy Commission. The term "analytical limit" is defined as the concentration at which the laboratory can measure a radionuclide with an accuracy (bias-precision composite) of ± 100% at the 90% confidence level. The detection limit for a specific radionuclide varies with sample type, sample size, counting time, and amounts of interfering radionuclides present. The "analytical limits" given represent upper bounds to these fluctuating detection limits.

The following rule has been applied for determining statistical detection levels for averaged data:

$$A.L._{ave} = \frac{A.L._i}{\sqrt{n}}$$

i.e., the laboratory analytical level is divided by the square root of the number of averaged results to obtain the estimated analytical level for the average, with the same confidence level and precision.

It is recognized that the value obtained will be approximate, since rigorously the variance of each result should be pooled. However, no simple method is available for estimating the variance of the average. The rule is applicable only when the actual net result is available for each sample including negative values. If the result is given only as less than some pre-determined value, it is not applicable.

# APPENDIX E

# DIETARY ASSUMPTIONS

# APPENDIX E

## DIETARY ASSUMPTIONS

| Foodstuffs | Maximum Individual | Average (Adult) Richland Resident |
|---|---|---|
| Water | 730 ℓ/yr | 680 ℓ/yr[a] |
| Milk | 380 ℓ/yr | 130 ℓ/yr[a] |
| Meat | 80 kg/yr | 74 kg/yr[a] |
| Chicken | 8 kg/yr | 5.4 kg/yr |
| Eggs | 30 kg/yr | 15 kg/yr |
| Seafood | 0 | 1.4 kg/yr[a,b] |
| Col. River Fish | 40 kg/yr | 0.48 kg/yr |
| Game Birds | 0 | 1.2 kg/yr[a] |
| Leafy Vegs. | 73 kg/yr[c] | 36.5 kg/yr |
| Other Vegs. & Fruits | 530 kg/yr[c] | 200 kg/yr |

| Foodstuffs | Maximum Individual | Average (Infant) Richland Resident |
|---|---|---|
| Water | 0.8 ℓ/day | 0.4 ℓ/day |
| Milk | 1.0 ℓ/day | 0.6 ℓ/day |
| Leafy Vegs. | 50 g/day | 25 g/day |

(a) Based on dietary questionnaires of Richland residents employed at Hanford.

(b) One-tenth of the total is assumed to be Willapa Bay oysters, the remainder free of radionuclides of Hanford origin.

(c) Fresh produce from the Riverview area is assumed to be available only during five months of the year.

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