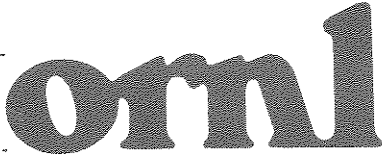


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OAK RIDGE
NATIONAL
LABORATORY



Environmental Monitoring Report
United States Department of Energy
Oak Ridge Facilities
Calendar Year 1984

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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ORNL-6209

**Environmental Monitoring Report
United States Department of Energy
Oak Ridge Facilities**

Calendar Year 1984

Date Published: August 1985

**MARTIN MARIETTA ENERGY SYSTEMS, INC.
P.O. Box X
Oak Ridge, Tennessee 37831
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400**

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SUMMARY

The Environmental Monitoring Program for the Oak Ridge area includes sampling and analysis of air, water from surface streams, groundwater, creek sediments, biota, and soil for both radioactive and nonradioactive materials. This report presents a summary of the results of the program for CY 1984.

Surveillance of radioactivity in the Oak Ridge environment indicates that atmospheric concentrations at some stations were above background but would result in radiation exposures well within the applicable Environmental Protection Agency (EPA) guidelines. Levels of radioactivity in rain-water samples collected in the Oak Ridge areas were not significantly different from those collected at remote locations. Concentrations of radioactivity in the Clinch River and in fish collected from the river were similar to those of previous years.

Potential pathways of exposure to humans from radioactive effluents released by the operation of the Department of Energy (DOE) facilities in Oak Ridge were considered in the calculation of the maximum potential dose to the public. The exposure routes included direct radiation, inhalation of gaseous effluents, and consumption of milk, water, and fish. The total body dose resulting from direct radiation, assuming an exposure of 240 h per year, to a "hypothetical maximum exposed individual" at the site boundary location of maximum potential exposure was 5.9 millirem. This site is located along the Clinch River just below Clinch River Mile (CRM) 20.8. Airborne releases result in a committed dose equivalent of 15 millirem to the pulmonary tissues and a committed effective dose equivalent of 4.6 millirem to a member of the public receiving the highest exposure to plant effluents for 1984. The dose to pulmonary tissues is 20% of the EPA National Standard for Hazardous Air Pollutants of 75 millirem to the critical organ. Ingestion of 1 L of locally produced milk per day for one year from surrounding dairies would result in a maximum committed effective dose equivalent to an individual of <0.01 millirem and 0.07 millirem to the bone (endosteal cells). The annual dose from ingestion of 2.2 L of treated water per day for one year from the Kingston filtration plant would be 0.2 millirem for the committed effective dose equivalent and 0.5 millirem to the bone (endosteal cells). Consumption of 17 kg of bass muscle per year from CRM 20.8 gave the highest annual average effective dose equivalent (1.1 millirem) via the aquatic pathway. The annual dose equivalent to the endosteal cells from the consumption of an average bass sample from this location was 2.1 millirem. Consumption of 1 kg of carp patties (flesh and bone) containing the maximum amount of ⁹⁰Sr would result in a committed effective dose equivalent of 1.4 millirem and a committed dose equivalent to the bone (endosteal cells) of 15 millirem. One kilogram of patties containing average concentrations of ⁹⁰Sr found at CRM 20.8 would result in a committed effective dose equivalent of 0.4 millirem and a committed dose equivalent to the bone (endosteal cells) of 4.3 millirem.

For an Oak Ridge resident, the average committed dose equivalent was 1.6 millirem and the average dose commitment to the pulmonary tissues was calculated to be 5.4 millirem. The primary contributor to the dose was attributed to airborne releases of uranium from the Y-12 Plant. The calculated cumulative committed effective dose equivalent to the population within an 80-km radius of the area resulting from operation of the Oak Ridge facilities was 120 person-rem. This dose may be compared with 164,000 person-rem for the same population from natural background radiation.

The data on chemical water quality in surface streams obtained from the water sampling program indicated that average concentrations resulting from plant effluents during 1984 were in compliance with State Stream Standards for the protection of drinking water, fish and aquatic life, and

recreation classifications, except for cadmium, lead, mercury, nitrate, and zinc. The average concentrations of all chemicals analyzed in the processed water from the Oak Ridge Gaseous Diffusion Plant (ORGDP) sanitary water pumping station were within the Tennessee Water Quality Criteria for domestic water supply, except for mercury. Although no mercury was detected in any of the samples, the detection limit of the analytical procedure exceeded the criteria.

Sampling of groundwater in shallow wells in Oak Ridge National Laboratory (ORNL) solid waste storage areas (SWSAs) was continued during 1984. Several wells had high concentrations of many pollutants, including metals, organics, and radionuclides. Well contamination appears to be closely coupled with surface water flow. Because most of the groundwater movement occurs in the near-surface zone and the rate of movement is very slow, it is believed that no significant potential for groundwater contamination of the 16 public groundwater supplies within a 32.3-km radius of ORNL results from operations at ORNL.

There is evidence of migration of radionuclides from the SWSAs to White Oak Lake. The primary contributor to this migration is ^{90}Sr from SWSA 4. Studies have shown that surface water flows account for the majority of radionuclide transport from the SWSAs. To address this issue, ORNL installed storm water channels in SWSAs 4 and 5 to enhance drainage of storm water out of them. ORNL also installed a storm water diversion system above SWSA 4 to reroute the water to other pathways. A groundwater diversion drain in SWSA 6 has been proposed and funded to intercept the lateral movement of groundwater before it reaches waste trenches and routes it to natural drainage paths. Construction of an engineered groundwater barrier around trench 7 was initiated in FY 1984 and is scheduled for completion in late 1986.

ORNL has proposed and funded several projects to cap the disposal trenches and pits to reduce rainwater infiltration. In addition to these efforts, ORNL has excavated, decommissioned, and sealed off an abandoned waste transfer line.

During 1984 individual fish were sampled for mercury and polychlorinated biphenyls (PCBs). The highest mercury concentrations occurred at CRM 12.0, about where Poplar Creek enters the river. All average values were below 1000 ng/g, the Food and Drug Administration (FDA) action level. A single carp at CRM 12.0 had concentrations of mercury exceeding the FDA level. The FDA PCB tolerance limit for fish and shellfish was exceeded by the average concentration for two species (bluegill and carp) at CRM 5.0. Over all stations, carp had the highest PCB concentrations.

Samples of deer muscle were analyzed for total mercury. The average concentrations were not statistically different in deer taken from the Oak Ridge Reservation (ORR) and those collected off-site.

A new National Pollutant Discharge Elimination System (NPDES) permit was issued in February 1984 for ORGDP. New permits for the other plants are expected during 1985. Compliance with the existing permits is summarized in this report. ORNL achieved less than 60% compliance for ammonia at its sewage treatment plant. Two projects are planned or under construction that should bring ammonia levels into compliance.

No major spills of oil and grease, PCBs, or chemicals occurred during 1984. No major releases of any radionuclides occurred.

INTRODUCTION

Each year since 1972, a report has been prepared on the environmental monitoring activities for the DOE facilities in Oak Ridge, Tennessee, for the previous calendar year. Previously, the individual facilities published quarterly and annual progress reports that contained some environmental monitoring data. The environmental monitoring program for 1984 includes sampling and analysis of air, water from surface streams, groundwater, creek sediment, biota, and soil for both radioactive and nonradioactive (including hazardous) materials. Special environmental studies that have been conducted in the Oak Ridge area are included in this report, primarily as abstracts or brief summaries. The annual report for 1984 on environmental monitoring and surveillance of the Oak Ridge community by Oak Ridge Associated Universities (ORAU) is included as an appendix.

A brief description of the topography and climate of the Oak Ridge area and a short description of the three DOE facilities are provided below to enhance the reader's understanding of the direction and contents of the environmental monitoring program for Oak Ridge.

Oak Ridge is located in East Tennessee in a broad valley that lies between the Cumberland Mountains to the northwest and the Great Smoky Mountains to the southeast. The ORR is located in the valley-and-ridge physiographic province, which is characterized by parallel ridges of sandstone, shale, and cherty dolomite, separated by valleys of less weather-resistant limestone and shale. The ridges are oriented southwest-northeast. Topography of the area has resulted from differential erosion of severely folded and faulted rocks ranging in age from early Cambrian to early Mississippian. Elevations range from 226 to 415 m above mean sea level—a maximum relief of 189 m. The area includes gently sloping valleys and rolling-to-steep slopes and ridges. The Tennessee Valley Authority's (TVA's) Melton Hill and Watts Bar reservoirs on the Clinch River form the southern and western boundaries of the ORR, and the City of Oak Ridge (pop. ~28,000) forms the northern boundary.

The local climate is noticeably influenced by topography. Prevailing winds are usually either up-valley, from the west or southwest, or down-valley, from the east or northeast. During periods of light winds, daytime winds are usually southwesterly and nighttime winds usually northeasterly. Wind velocities are somewhat decreased by the mountains and ridges, and tornadoes rarely occur. In winter, the Cumberland Mountains have a moderating influence on the local climate by retarding the flow of cold air from the north and west. Temperatures of 38°C or higher and -18°C or below are unusual. Low-level temperature inversions occur during about 56% of the hourly observations. Winter and early spring are the seasons of heaviest precipitation, the monthly maximum normally occurring from January to March. The mean annual precipitation is about 137 cm.

The topography of the Oak Ridge area is such that all drainage from the ORR flows into the Clinch River, which has its headwaters in southwestern Virginia and flows southwest to its mouth near Kingston, Tennessee. The Clinch River flow is regulated by several dams that provide reservoirs for flood control, electric power generation, and recreation. The principal tributaries through which liquid effluents from the plant areas reach the Clinch River are White Oak Creek, Bear Creek, East Fork Poplar Creek, and Poplar Creek.

Except for of the City of Oak Ridge, the land within 8 km of the ORR is predominantly rural, used largely for residences, small farms, and pasturage of cattle. Fishing, boating, water skiing, and swimming are favorite recreational activities in the area. The approximate location and population of the towns nearest the ORR are Oliver Springs (pop. 3600), 11 km to the northwest; Clinton (pop. 5400), 16 km to the northeast; Lenoir City (pop. 5400), 11 km to the southeast; Kingston

(pop. 4400), 11 km to the southwest; and Harriman (pop. 8300), 13 km to the west. Knoxville, the major metropolitan area nearest Oak Ridge, is located about 40 km to the east and has a population of about 183,000. A directional 80-km population distribution map, which is used to calculate population dose later in this report, is shown in Fig. 1.

The ORR contains three major operating facilities: ORNL, ORGDP, and the Y-12 Plant. In addition, two smaller DOE facilities are in the area: the Scarboro Facility (formerly the Comparative Animal Research Laboratory), and ORAU, both of which are operated by ORAU.

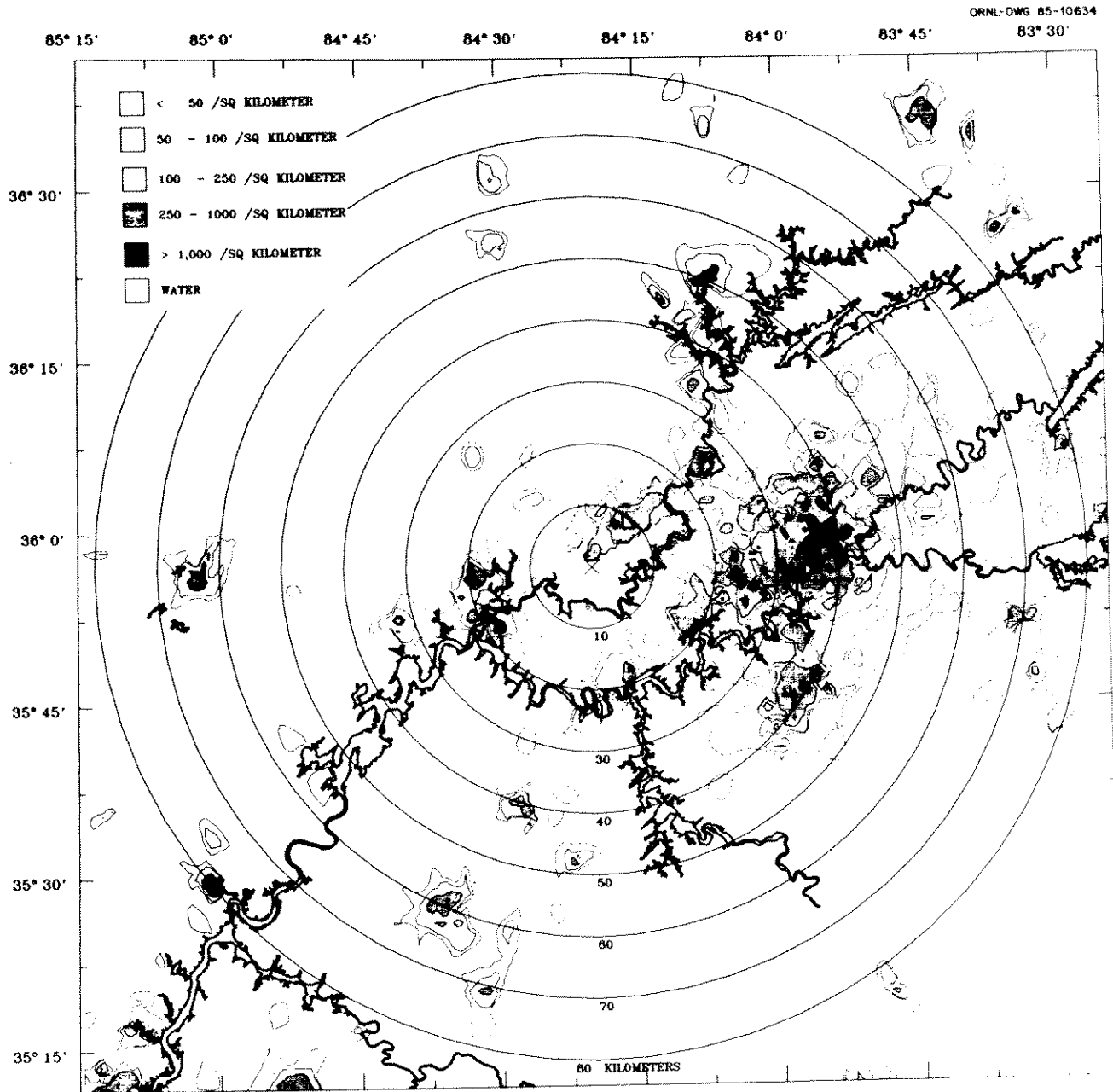


Fig. 1. Population densities from the center of the Oak Ridge Reservation based on 1980 census data.

ORNL, located toward the west end of Bethel Valley, is a large, multipurpose research laboratory whose basic mission is to expand knowledge, both basic and applied, in all areas related to energy. To accomplish this mission, ORNL conducts research in all fields of modern science and technology. ORNL's facilities include nuclear reactors, chemical pilot plants, research laboratories, radioisotope production laboratories, and support facilities.

ORGDP is a complex of production, research, development, and support facilities located west of the City of Oak Ridge. Although the primary function of ORGDP is the enrichment of uranium hexafluoride (UF_6) in the ^{235}U isotope, extensive efforts are also expended on research and development activities associated with the gaseous diffusion, gas centrifuge, and atomic vapor laser isotope separation (AVLIS) processes. Numerous other activities lend support to these primary functions and are essential to the operation of this plant.

The Oak Ridge Y-12 Plant, which is located immediately adjacent to the City of Oak Ridge, has five major responsibilities: (1) to produce nuclear weapons components, (2) to process source and special nuclear materials, (3) to provide support to the weapons design laboratories, (4) to provide support to other Martin Marietta Energy Systems, Inc., installations, and (5) to provide support to other government agencies. Activities associated with these functions include the production of lithium compounds, the recovery of enriched uranium from scrap material, and the fabrication of uranium and other materials into finished parts and assemblies. Fabrication operations include vacuum casting, arc melting, powder compaction, rolling, forming, heat treating, machining, inspection, and testing.

Operations associated with the DOE research and production facilities in Oak Ridge give rise to several types of waste materials. Radioactive wastes are generated from nuclear research activities, reactor operations, pilot plant operations involving radioactive materials, isotope separation processes, uranium enrichment, and uranium processing operations. Nonradioactive (including hazardous) wastes are generated by normal industrial-type support facilities and operations that include water demineralizers, air conditioning, cooling towers, acid disposal, sewage plants, and steam plants.

Nonradioactive solid wastes are buried in a centralized sanitary landfill or designated burial areas. Hazardous wastes are shipped off-site to approved disposal sites. Radioactive solid wastes are buried in SWSAs and placed in retrievable storage units either above or below ground, depending on the type and quantity of radioactive material present and the economic value involved.

Gaseous wastes generally are treated by filtration, electrostatic precipitation, and/or chemical scrubbing techniques before they are released to the atmosphere.

Liquid radioactive wastes are not released, but are concentrated and contained in tanks for ultimate disposal. After treatment, process water, which may contain small quantities of radioactive or chemical pollutants, is discharged to White Oak Creek, Poplar Creek, East Fork Poplar Creek, and Bear Creek, which are small tributaries to the Clinch River.

MONITORING DATA: COLLECTION, ANALYSIS, AND EVALUATION

Environmental monitoring data for CY 1984 are summarized in subsequent tables. In general, the tables give the number of samples collected at each station or location and maximum, minimum, and average values of substances detected. The 95% confidence coefficients were calculated from the standard deviation of the sample average, assuming a normal frequency distribution, and are an indication of how close the sample average is to the true average value.

Where possible, average values were compared with applicable guidelines, criteria, or standards as a means of evaluating the impact of effluent releases. Stream concentrations of nonradioactive pollutants have generally been compared with the most recent Tennessee Department of Health and Environment (TDHE) water quality criteria for fish and aquatic life in freshwater streams. Liquid effluent monitoring data have been compared with the limits specified in the NPDES permits issued to the Oak Ridge installations by the EPA. In the case of particulates in air, the geometric average and standard deviation were calculated because the applicable standards are based on the geometric average.

Data below the minimum detectable limit (MDL) are expressed as less than the MDL. In computing average values, sample results below the MDL were assigned the MDL, and the resulting average value is expressed as less than the computed value.

In the past, radionuclide concentrations in various media were compared with DOE concentration guides. EPA has not issued concentration guides or concentration standards. Instead, EPA recently issued radiation dose limits that apply to the dose received by the public as a result of airborne emissions from DOE facilities. EPA has also issued dose limits for the ingestion of drinking water. The EPA standards are more stringent than the guides issued by DOE because they are largely based on limiting public exposures to levels that were considered to be "as low as reasonably achievable" (ALARA). This ALARA concept is a part of the DOE regulations, but it is not specifically quantified. In this report, potential doses are calculated from the inhalation of air and ingestion of water, fish, and milk based on EPA's methodology.¹ Dose rates were compared with EPA standards when these were available. No specific standards or criteria are in general use for radionuclides in sediments, vegetation, fish, or other edibles. Acceptable levels may be determined, nevertheless, on the basis of ensuring that the applicable exposure limit is not exceeded through the sum of all pathways to individuals or to suitable samples of the exposed population. DOE is expected to promulgate, in the near future, new standards that will be consistent with the most recent recommendations of the National Council on Radiation Protection and Measurements.

Air

Radioactive

Most gaseous wastes are released to the atmosphere through stacks. Radioactivity may be present in waste streams as a solid (particulates), an absorbable gas (such as iodine), or as a nonabsorbable species (noble gas). Most gaseous wastes that may contain radioactivity are processed to reduce the radioactivity to acceptable levels before they are discharged. Stacks are monitored routinely for radionuclides of concern at each of the three Oak Ridge plants.

All noble gases originate from ORNL and are monitored with a real-time (continuous) monitor with an electronic integrator. The majority (about 99%) of the ^3H discharged during CY 1984 came from the isotope production facilities at ORNL and was released through stack 3039. The remaining ^3H comes from the ^3H target facility through stack 7025 at ORNL. Tritium is measured with a real-time monitor at stack 3039 and with silica gel samplers at stack 7025.

Alpha and beta particles are measured in filters and ^{131}I is absorbed onto charcoal samplers that are collected three times per week from stack 3039 and weekly from five other stacks at ORNL. Iodine-131 discharges come from the two main stacks at ORNL (3039 and 7911) and result from the processing of fuel elements and the production of medical isotopes.

Minor discharges of ^{220}Rn from stack 7911 at ORNL result from the storage of an irradiated radium sample. Although the source was sealed in 1983, some contamination still remains in the storage cell. Discharges of ^{220}Rn are estimated from particulate sample results.

The majority of the uranium discharged to the atmosphere comes from the Y-12 Plant. It is currently measured using particulate samplers. Several projects were initiated by the Y-12 Plant during 1984 to upgrade the monitoring of stack effluents, and further improvements are planned. For further discussion, see the "Special Studies" section. ORGDP also measures air discharges for uranium and ^{99}Tc using Boyce-Thompson bubblers.

In addition to monitoring stack discharges to the atmosphere, atmospheric concentrations of materials occurring in the general environment of East Tennessee are measured by several monitoring systems.

One system, the Perimeter Air Monitoring System, consists of ten stations (HP-32 through HP-41) that are, with one exception, outside the ORNL, Y-12, and ORGDP plant boundaries but inside the ORR boundary. These provide data for evaluating releases from Oak Ridge facilities to the immediate environment (Fig. 2). A second system, the Remote Air Monitoring System, consists of seven stations (HP-51 through HP-53 and HP-55 through HP-58) that are outside the ORR at distances of from 19 to 121 km (Fig. 3). This system provides background data to aid in evaluating local conditions and weapons fallout data.

Sampling for radioactive particulates was carried out by directing air continuously through filter papers. Filter papers from the perimeter and remote systems were evaluated weekly by gross beta- and alpha-counting techniques and composited quarterly by system for specific radionuclide analysis.

Airborne ^{131}I was monitored in the immediate environment at the perimeter stations (HP-32 through HP-41) by directing air continuously through cartridges containing activated charcoal. Gamma spectrometry was used to measure ^{131}I .

The Y-12 Plant's eleven air monitors surround the plant at the boundary fence (Fig. 4); these monitors are used to measure ambient uranium concentrations and other parameters of interest at the plant boundary. The results from the weekly samples were composited quarterly by station and evaluated for uranium.

Concentrations of radioactive materials in air and the quantities of radioactive materials released to the atmosphere via stacks in Oak Ridge and the surrounding areas for the last six years are given in Figs. 5-11. Tables 1 and 2 list concentrations of radionuclides at air monitoring stations for 1984. Table 3 summarizes the combined stack discharges from the three Oak Ridge plants.

The average gross beta concentrations for 1984 from particulates in air measured by both the perimeter and the remote monitoring systems have remained essentially constant since 1979, except

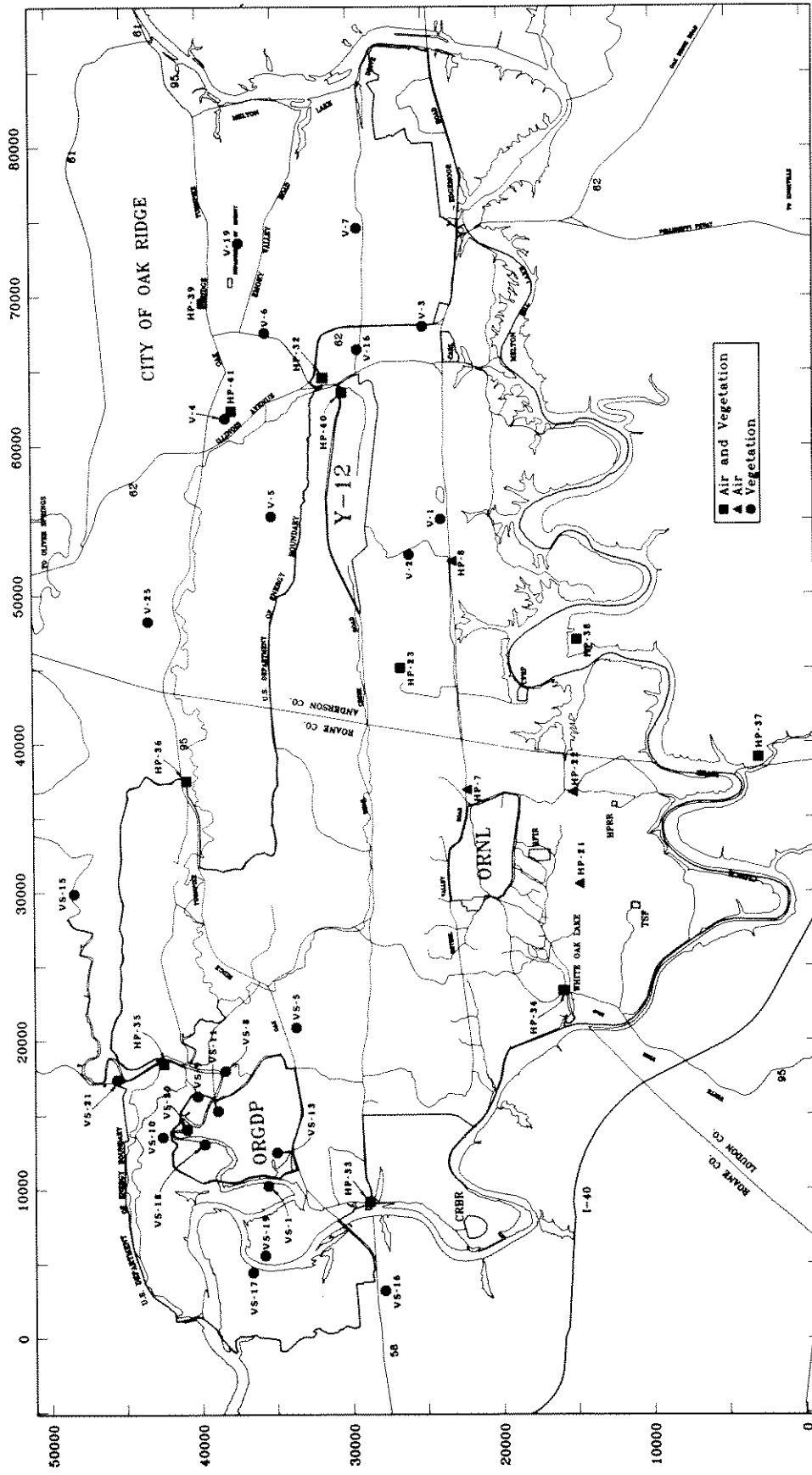


Fig. 2. Vegetation and air monitoring stations on the Oak Ridge Reservation.

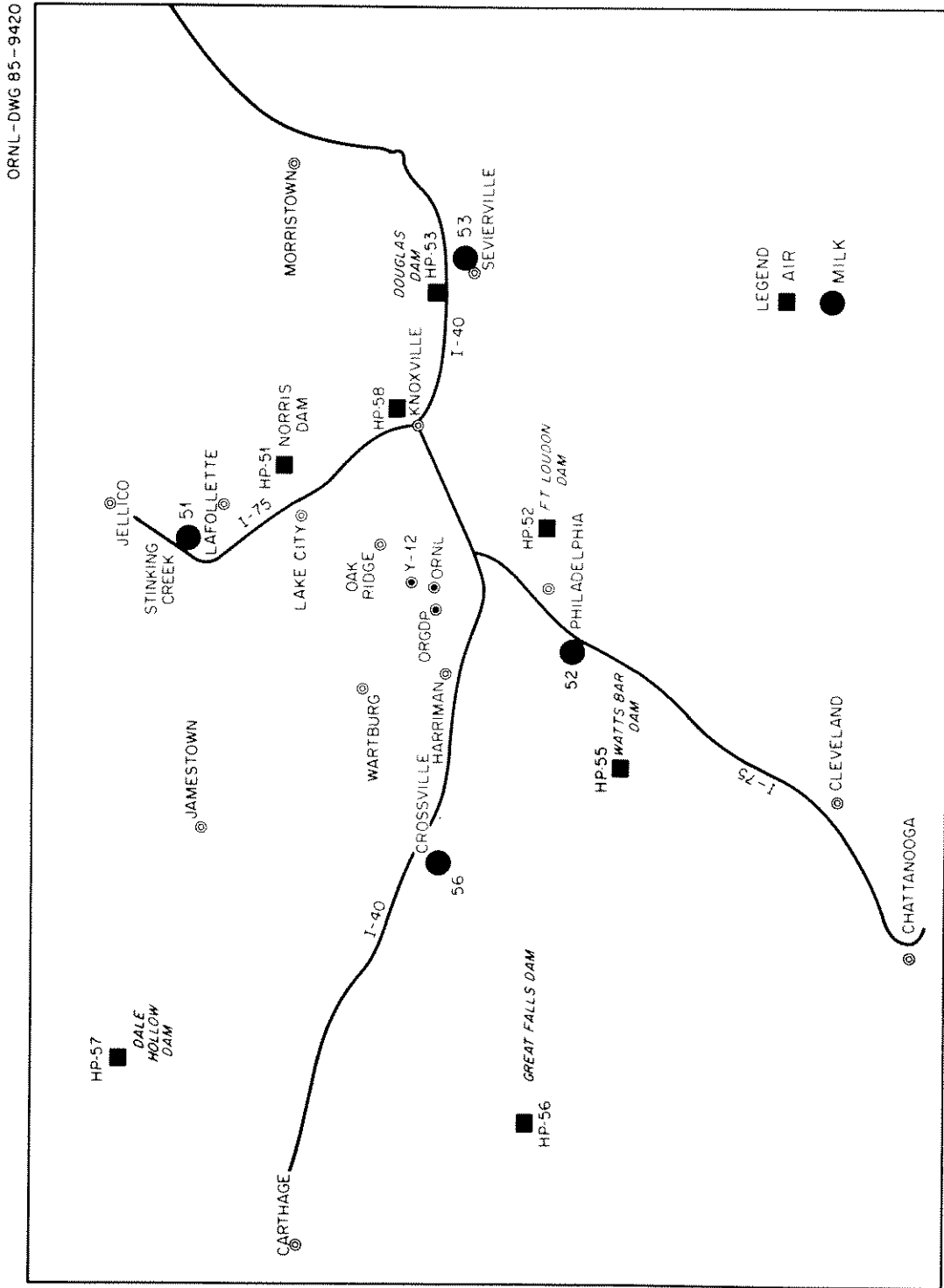


Fig. 3. Remote air monitoring and milk sampling stations.

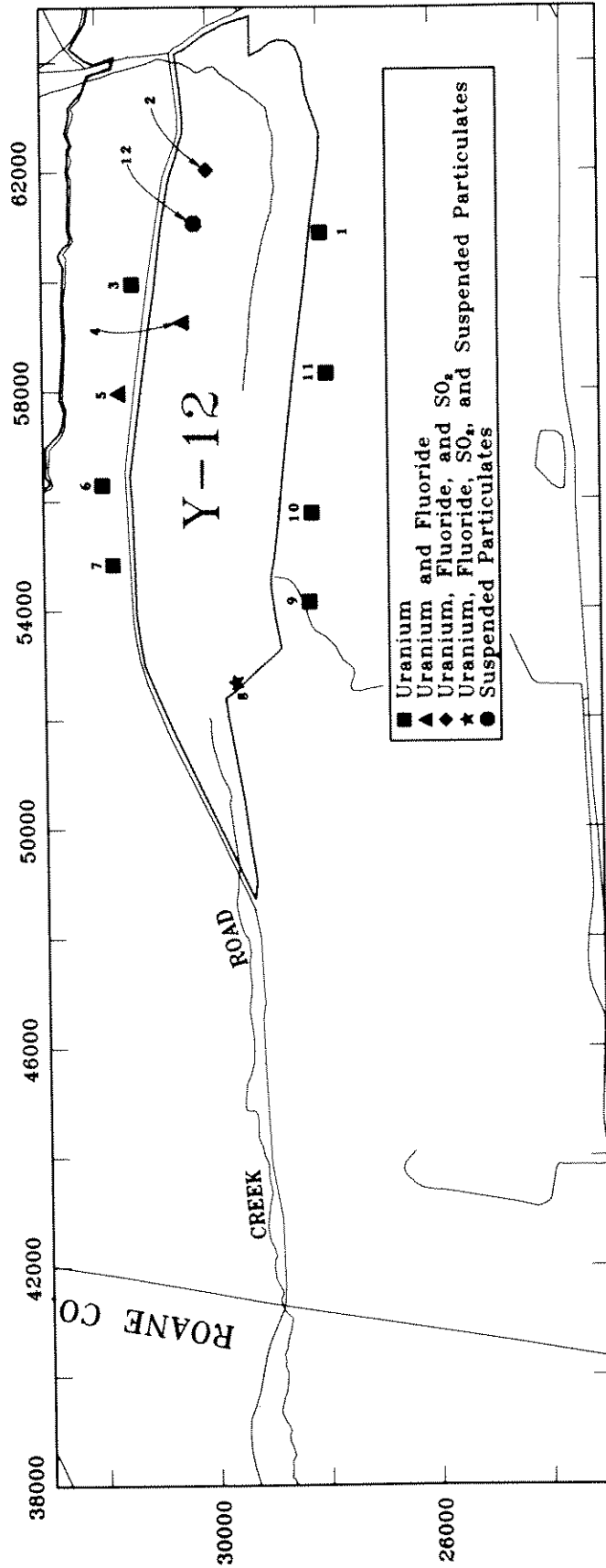


Fig. 4. Air monitoring stations around Y-12.

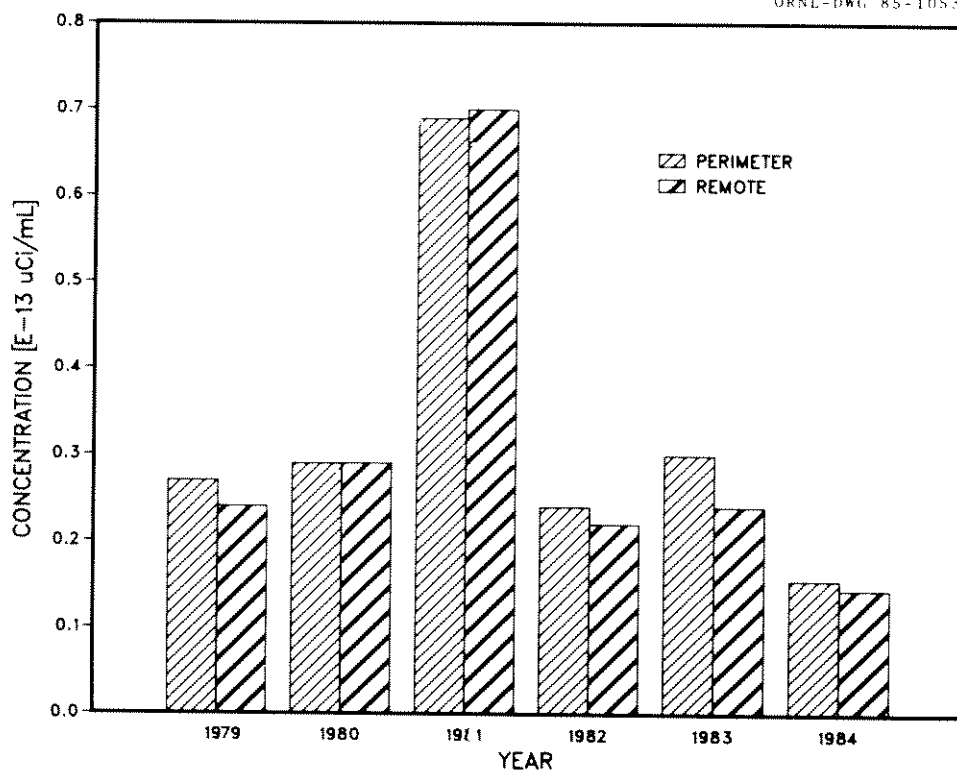


Fig. 5. Long-lived gross beta activity in air.

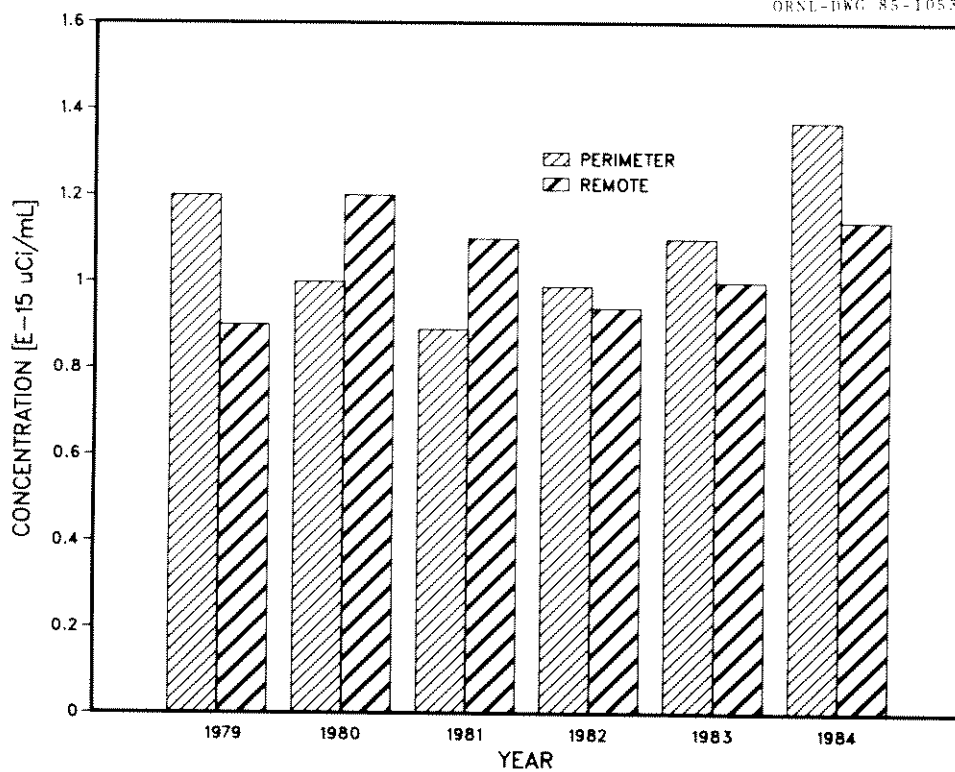


Fig. 6. Long-lived gross alpha activity in air.

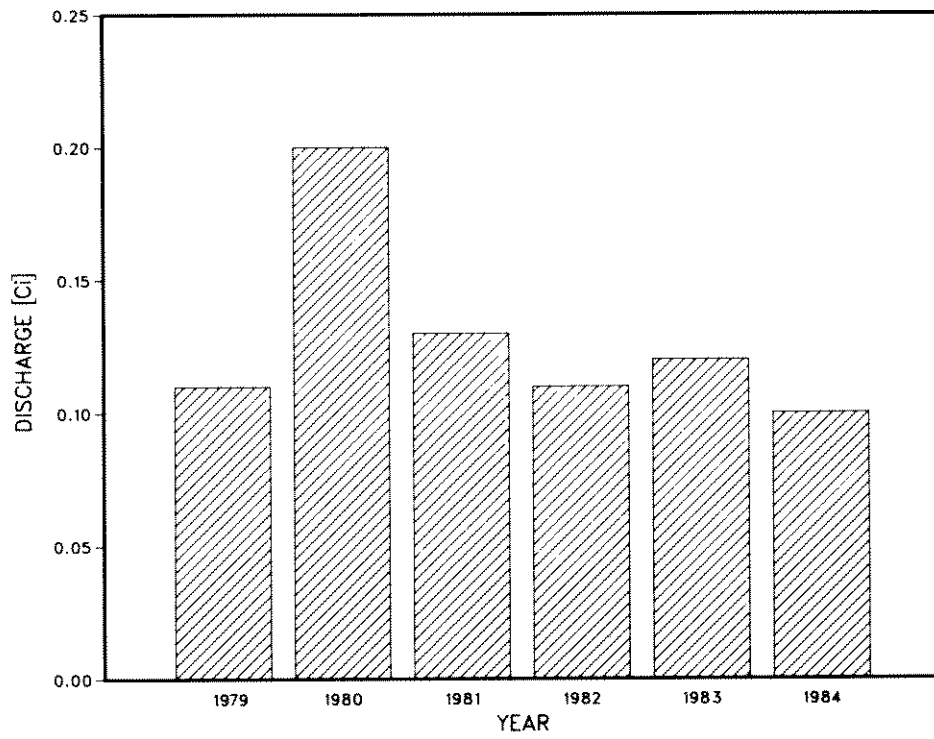


Fig. 7. Discharges of uranium to the atmosphere.

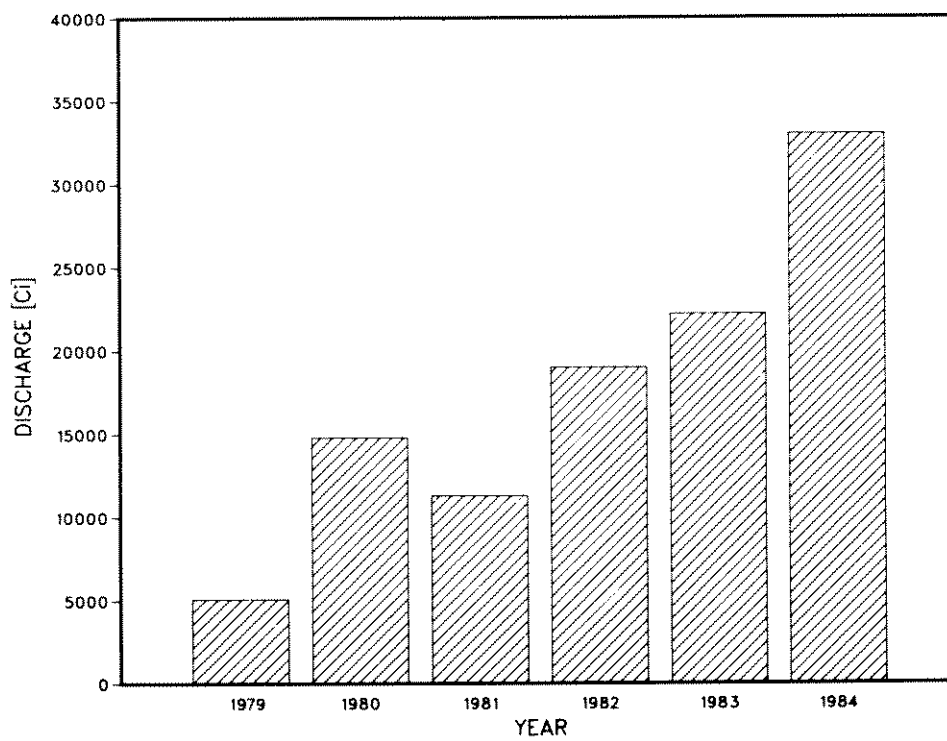


Fig. 8. Discharges of ^3H to the atmosphere.

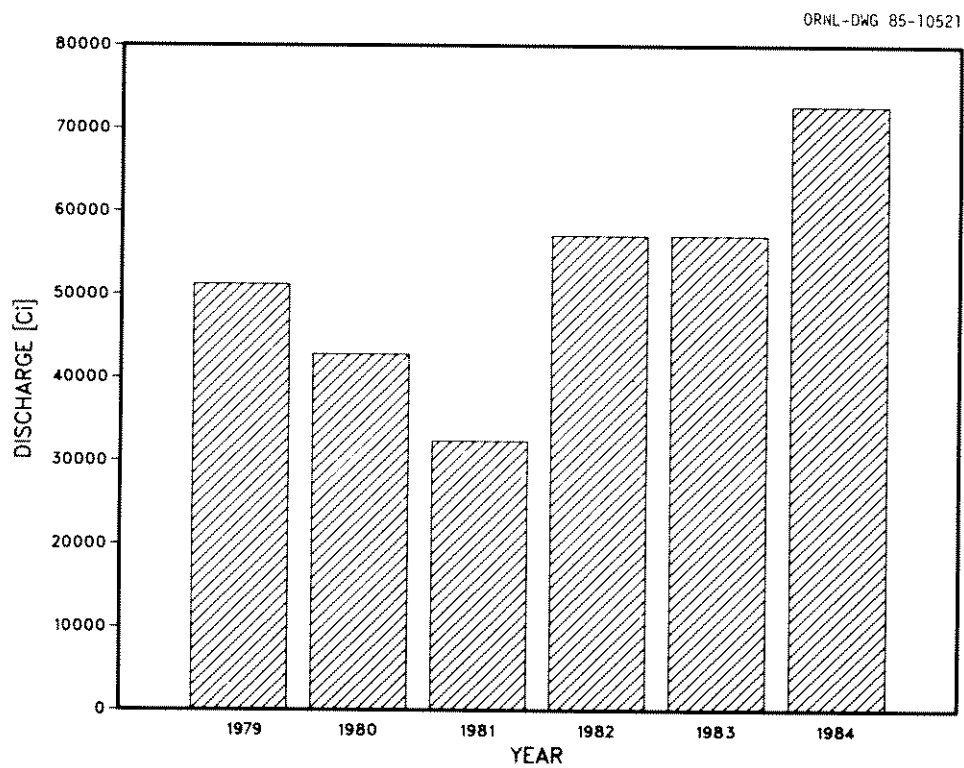


Fig. 9. Discharges of ^{133}Xe to the atmosphere.

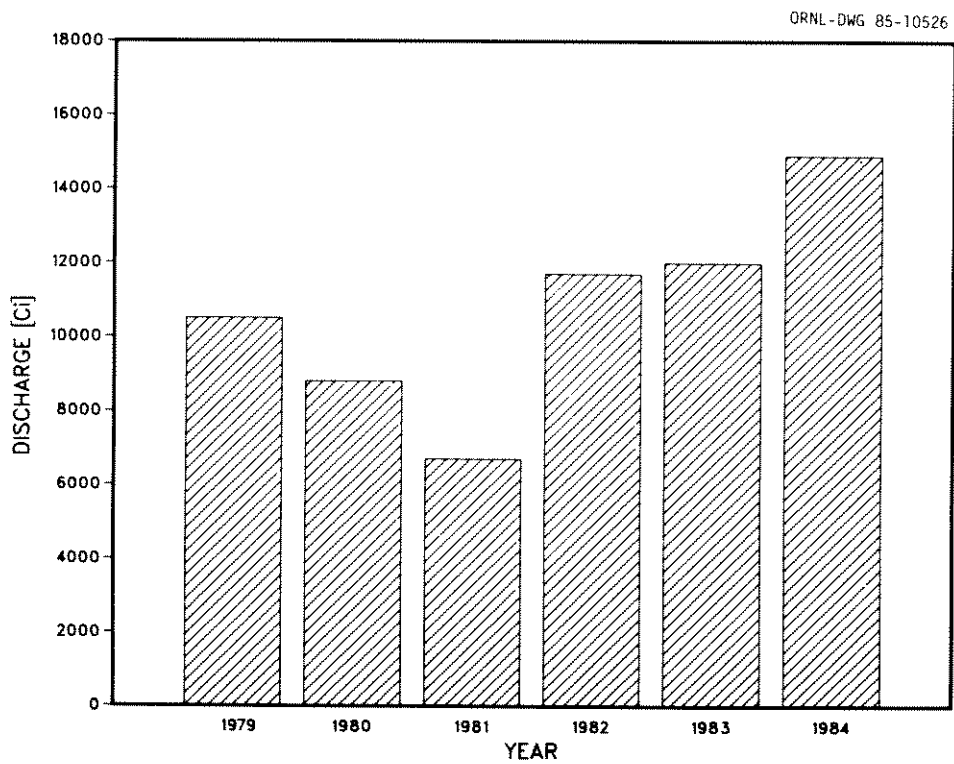


Fig. 10. Discharges of ^{85}Kr to the atmosphere.

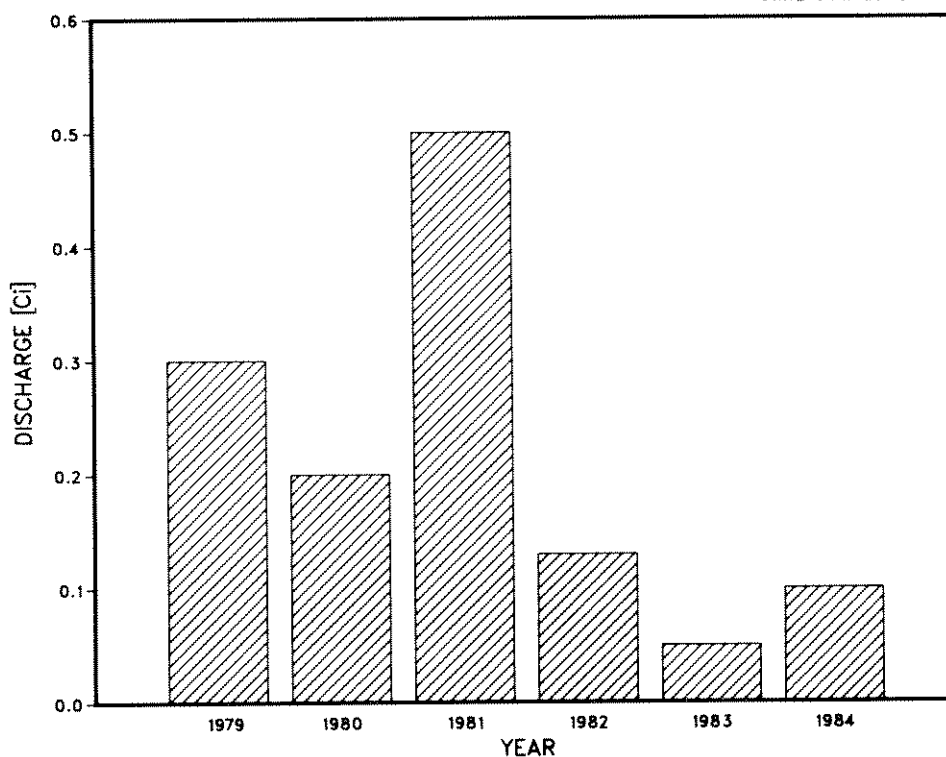


Fig. 11. Discharges of ¹³¹I to the atmosphere.

Table 1. 1984 continuous air monitoring data for specific radionuclides
(Composite samples)

Radionuclide	Concentration (E-15 μ Ci/mL)					
	Perimeter stations ^a			Remote stations ^b		
	Quarterly max	Quarterly min	Yearly av	Quarterly max	Quarterly min	Yearly av
⁹⁰ Sr	0.22	< 0.0049	< 0.069	0.11	0.0023	0.049
¹³⁷ Cs	0.17	< 0.015	< 0.074	0.11	< 0.023	< 0.057
²³⁰ Th	0.049	0.014	0.033	0.067	0.022	0.045
²³² Th	0.047	0.017	0.030	0.059	0.028	0.040
²³⁴ U	1.1	0.51	0.71	0.39	0.059	0.16
²³⁵ U	0.11	0.052	0.076	0.023	0.0028	0.015
²³⁸ U	0.25	0.11	0.16	0.085	0.035	0.054
²³⁸ Pu	0.0017	< 0.0004	< 0.001	0.0005	< 0.0003	< 0.0004
²³⁹ Pu	0.009	< 0.0002	< 0.0051	0.0008	< 0.0003	< 0.0005

^aSee Fig. 2.

^bSee Fig. 3.

**Table 2. 1984 Y-12 Plant air monitoring data for uranium
(Composite samples)**

Station ^a	Concentration (E-15 μ Ci/mL)			Yearly dose ^b (millirem)
	Quarterly max	Quarterly min	Yearly av	
1	8.6	1.0	5.9	1.5
2	19	3.1	8.2	2.1
3	48	8.6	20	5.1
4	37	11	21	5.3
5	36	13	21	5.3
6	24	5.4	15	3.8
7	15	4.1	10	2.5
8	13	4.7	7.9	2.0
9	17	4.8	12	3.0
10	13	2.3	8.1	2.0
11	23	3.1	11	2.8

^aSee Fig. 4.

^bSeventy-year committed dose equivalent to a worker as a result of breathing the air for 250 8-h days per year, based on the yearly average concentrations. May be compared with the DOE guide of 5000 millirem maximum permissible exposure to the total body of a worker.

**Table 3. 1984 discharges of radionuclides
to the atmosphere**

Radionuclide	Discharge (Ci)
Uranium ^a	0.104
¹³¹ I	0.06
³ H	33,400
¹³³ Xe ^b	72,700
⁸⁵ Kr ^b	14,900
⁹⁹ Tc	0.024
Alpha ^c	< 9.6 E-6
²²⁰ Rn	310

^aUranium of varying enrichments/ curie quantities calculated using the appropriate specific activity for material released.

^bUpper limit values based on direct radiation measurements in the stack gas stream and an assumed mixture of noble gases.

^cUnidentified alpha.

for the first half of 1981 (Fig. 5). The increase in activity measured during 1981 was attributed to the presence of weapons-test debris in the atmosphere. The average gross alpha concentrations in the perimeter and remote monitoring systems have remained fairly constant since 1979 (Fig. 6).

The results of specific radionuclide analyses of composited filters are given in Table 1. In general, activity levels were the same as those in 1983, except for ^{234}U levels, which were higher at both the remote and perimeter stations. Concentrations of ^{131}I measured by the perimeter air monitoring system have remained essentially unchanged since 1980.

The results of uranium analysis of the composited filters from the air monitoring stations around the Y-12 Plant are given in Table 2. The highest uranium concentrations were found in the prevailing-wind direction. Average concentrations were about two times greater during 1984 than in 1983. Seventy-year committed effective dose equivalents to a worker are given in Table 2. Doses were calculated based on the assumption of breathing the yearly average air concentration at the station for 8 h/d for 250 d per year. All the committed doses were <0.2% of the DOE guide of 5000 millirem maximum permissible exposure to the total body of a worker.

Total discharges of uranium to the atmosphere have remained fairly constant since 1981 (Fig. 7). The discharges of ^3H , ^{133}Xe , and ^{85}Kr to the atmosphere have increased since 1981 (Figs. 8–10). The discharge of 33,400 Ci of ^3H in 1984 represents a 46% increase over the 22,000 Ci released in 1983. This increase is the result of additional ^3H isotope work going on at ORNL. Some of the differences in ^3H discharges may be the result of the measurement method. CY 1984 was the first year ^3H was measured; previously, discharges were estimated from inventories. The number of curies of ^{133}Xe also increased in 1984, about 26% over the 1983 value (Fig. 9), as did the discharge of ^{85}Kr , 25% over 1983 (Fig. 10). The apparent increases in the noble gases discharged may be the result of changes in the measurement method. Previously, a manual integration from a strip chart was done to calculate discharge. During 1984 new equipment was installed and the integrations were done electronically. In addition, the contamination of a monitor at stack 7911 during 1984 may have exaggerated the total discharges. Discharges of ^{131}I decreased during 1982 and have remained fairly constant since then (Fig. 11). Apparent decreases in ^{131}I are probably not real and are a result of improved analytical techniques. During 1984 more sensitive sample counting techniques were employed that resulted in lower detection limits. This resulted in an overall decrease in the average values (Fig. 11).

Nonradioactive

Environmental air samples were taken for the determination of fluorides and suspended particulates around ORGDP and Y-12 and for SO_2 around Y-12. Fluorides, suspended particulates, and SO_2 are not monitored around ORNL because no operations are under way that require it under the Clean Air Act. No permit is required because ORNL releases of particulates are <0.9 t and releases of SO_2 are <4.5 t.

Fluoride sampling locations around ORGDP are indicated in Fig. 12 by F-1 through F-5 and by F-6, which is about 8 km from ORGDP upwind of the predominant wind direction; however, samples were not collected at location F-3 during 1984 because of mechanical problems with air samplers. Four fluoride monitoring stations (Fig. 4) were operated continuously for 7 d each month by Y-12.

Suspended particulates were measured in the ORGDP area at locations SP-1 through SP-4 (Fig. 12). Two suspended particulate monitors at the Y-12 Plant—one at the west end and one at

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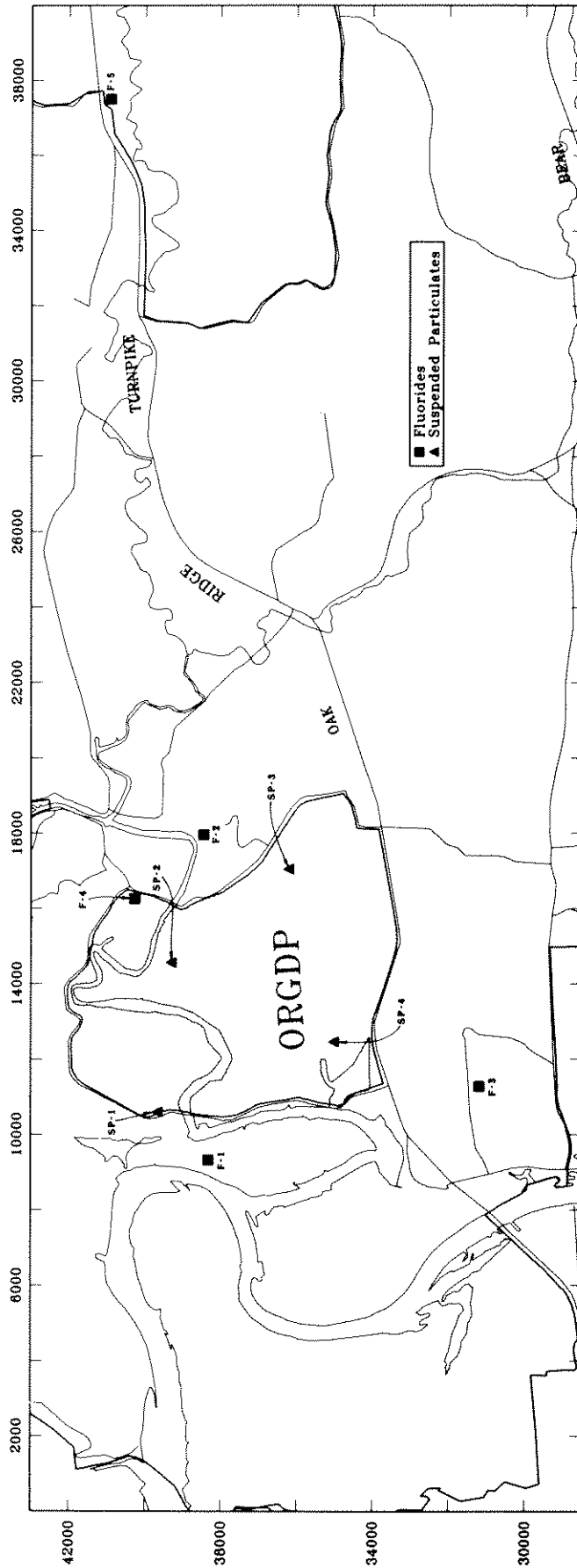


Fig. 12. Air monitoring stations around ORGDP.

the east end—provided samples (Fig. 4). Particulates were collected by drawing air through preweighed filter paper for 24 h every 6 d. At the end of the 24-h period, the filter paper was allowed to equilibrate in a humidity-controlled atmosphere and then was reweighed. From the weight of particulates, sampling time, and the air flow rate, the particulate concentration (expressed in micrograms per cubic meter) was calculated.

Continuous monitors located at each end of the Y-12 Plant (Fig. 4) provided SO₂ data. Each station consists of a pulsed ultraviolet fluorescence analyzer and recording unit in a temperature-controlled shelter. Concentrations of SO₂ were read hourly and averaged for 3-h, 24-h, monthly, and annual periods. The highest values at either station for SO₂ were only about 30% of the standards.

Air monitoring data for fluorides, suspended particulates, and SO₂ are presented in Tables 4–6. The data indicate that measured environmental concentrations of fluorides and SO₂ were in compliance with applicable standards.² However, suspended particulates at the Y-12 Plant have exceeded applicable standards.

The major source of increased suspended particulates is the fly ash from the Y-12 steam plant. To correct this problem, baghouse filter systems are being installed under a Federal Facilities Compliance Agreement between the DOE and the EPA signed in April 1982. The compliance agreement schedule calls for completion of the project in December 1985.

Table 4. 1984 air monitoring data for fluorides^a

Location	No. of samples ^b	Max concentration for averaging interval (μg/m ³)		Number of times standard exceeded ^b		Annual av (μg/m ³)	95% CC ^d
		7 d	30 d	7 d	30 d ^c		
F-1 ^e	52	0.1	0.05	0	0	< 0.4	0.01
F-2 ^e	51	0.1	0.1	0	0	< 0.5	0.01
F-4 ^e	41	0.2	< 0.1	0	0	< 0.5	0.02
F-5 ^e	44	0.2	0.1	0	0	< 0.4	0.01
F-6 ^f	39	0.1	< 0.1	0	0	< 0.4	0.01
2 ^g	12	< 0.1		0		< 0.1	0.01
4 ^g	12	< 0.1		0		< 0.1	0.01
5 ^g	12	< 0.1		0		< 0.1	0.01
8 ^g	12	< 0.1		0		< 0.1	0.01

^aData are not amendable to comparison with 12-h or 24-h standard. Six-day or seven-day sample period compared to seven-day averaging interval. See text for method of measurement.

^bSamples are continuous; analyses are conducted on 7-d composites.

^cTennessee Air Pollution Control (gaseous) for averaging intervals: 1.6 μg/m³ for 7-d and 1.2 μg/m³ for 30-d. All values are maximum—not to be exceeded more than once per year.

^d95% confidence coefficient about the average.

^eSee Fig. 12.

^fStation F-6 approximately 8 km from ORGDP, upwind of the prevailing wind direction; may be considered representative of general ambient background concentration.

^gSee Fig. 4.

Table 5. 1984 air monitoring data for suspended particulates

Location ^a	No. of samples	Concentration ($\mu\text{g}/\text{m}^3$)				Percentage of Standard ^c
		Max	Min	Geometric		
				Av	95% CC ^b	
SP-1	33	180	11	61	1.3	81
SP-2	39	152	< 0.05	< 27	2.0	< 36
SP-3	38	229	0.28	46	1.7	61
SP-4	48	193	< 0.06	< 29	1.7	< 39
12 ^d	44	160	1.6	62 ^e	1.3	82
8 ^d	47	400	3.2	76 ^e	1.3	100

^aSee Fig. 12.

^b95% confidence coefficient about the geometric average.

^cTennessee Primary Ambient Air Standards for annual geometric average is $75 \mu\text{g}/\text{m}^3$. The geometric average is calculated as a percentage of the standard.

^dSee Fig. 4.

^eThree samples for location 12 and four samples for location 8 showed zero concentrations because of filter media loss. These values were excluded from the average.

Table 6. 1984 air monitoring data for sulfur dioxide^a

Month	Max 24-h av (mg/L)		Monthly av (mg/L)	
	Station 2 ^b	Station 8 ^b	Station 2 ^b	Station 8 ^b
January	0.016	0.006	0.006	0.003
February	0.040	0.010	0.010	0.004
March	0.033	0.019	0.008	0.006
April	0.031	0.018	0.012	0.005
May	0.040	0.012	0.021	0.005
June	0.009	0.004	0.004	0.003
July	0.013	0.003	0.005	0.003
August	0.014	0.005	0.005	0.003
September	0.011	0.007	0.005	0.003
October	0.018	0.008	0.005	0.003
November	0.029	0.012	0.009	0.007
December	0.023	0.007	0.005	0.002
Annual arithmetic average			0.008	0.004

^aTennessee Ambient Air Standards are 0.14 mg/L for the maximum 24-h average and 0.03 mg/L for the annual arithmetic average. All maximum 24-h averages were < 30% of the standard.

^bSee Fig. 4.

The increase in activity at the fire training center, the clearing of vegetation on the north slope of Chestnut Ridge, and the increased travel on dirt roads in the vicinity of Station 8 on the west end of the Plant have all contributed to high suspended particulate levels. Because of the increased activity around Station 8, it is no longer considered to be an appropriate location for ambient air monitoring. In 1985 this monitor will be relocated to a more appropriate site.

External Gamma Radiation

External gamma radiation measurements are made to confirm that routine radioactive effluents from the Oak Ridge facilities are not significantly increasing external radiation levels above normal background. Measurements are also made in the few relatively small areas that are accessible to the public where current or past operations cause radiation levels to be elevated. In addition, the monitoring network could be used to assess the impact of unusual occurrences.

For purposes of measuring external radiation, the perimeter air monitoring system stations were divided into two groups: those around the perimeter of ORNL (HP-7, HP-8, HP-21, HP-22, and HP-23) and those that monitor the rest of the ORR (Fig. 2). This differentiation made it possible to determine if levels around ORNL and ORGDP (Fig. 13) were significantly higher than those throughout the ORR or in remote areas (Fig. 3). External gamma radiation measurements are made routinely at the ORNL, ORGDP, and ORR perimeter air monitoring stations and at the remote monitoring stations using thermoluminescent dosimeters (calcium fluoride at ORNL and ORR perimeter stations and lithium fluoride at ORGDP) suspended 1 m above the ground. Two dosimeters are placed in a container at the ORR perimeter and remote sites, and three are placed in each container at the ORNL and ORGDP sites. Dosimeters at the ORR perimeter stations were collected and analyzed monthly; those at the remote stations and the ORNL perimeter stations, semiannually; and those at ORGDP, quarterly.

Data on the average external gamma radiation for the perimeter and remote stations are given in Table 7 and for the ORGDP stations in Table 8. A considerable variation in background levels is normally experienced in East Tennessee, depending on elevation, topography, and geological character of the surrounding soil.³ Over the past five years (1980–1984), the average external gamma radiation background levels measured were 10 and 7.8 $\mu\text{R}/\text{h}$ at the ORR perimeter and remote monitoring stations, respectively. No statistically significant differences were apparent in the average radiation measurements at the ORNL perimeter stations, ORR perimeter stations, and remote stations. The average radiation measurements at ORGDP were statistically higher than those at the ORNL perimeter, ORR perimeter, and remote stations.

External gamma radiation background measurements were made along the stream course of East Fork Poplar Creek to evaluate potential external exposure from radioactivity that may be contained in the sediments as a result of effluent releases. Measurements were also made along the bank of the Clinch River from the mouth of White Oak Creek for several hundred yards downstream to evaluate gamma radiation levels resulting from effluent releases and "sky shine" from an experimental cesium plot located near the river bank. Measurements were made with thermoluminescent dosimeters suspended 1 m above the ground and/or with hand-held scintillation detectors. The average background level determined at the remote stations was subtracted from the measured gamma radiation levels to determine the incremental increases resulting from plant operations.

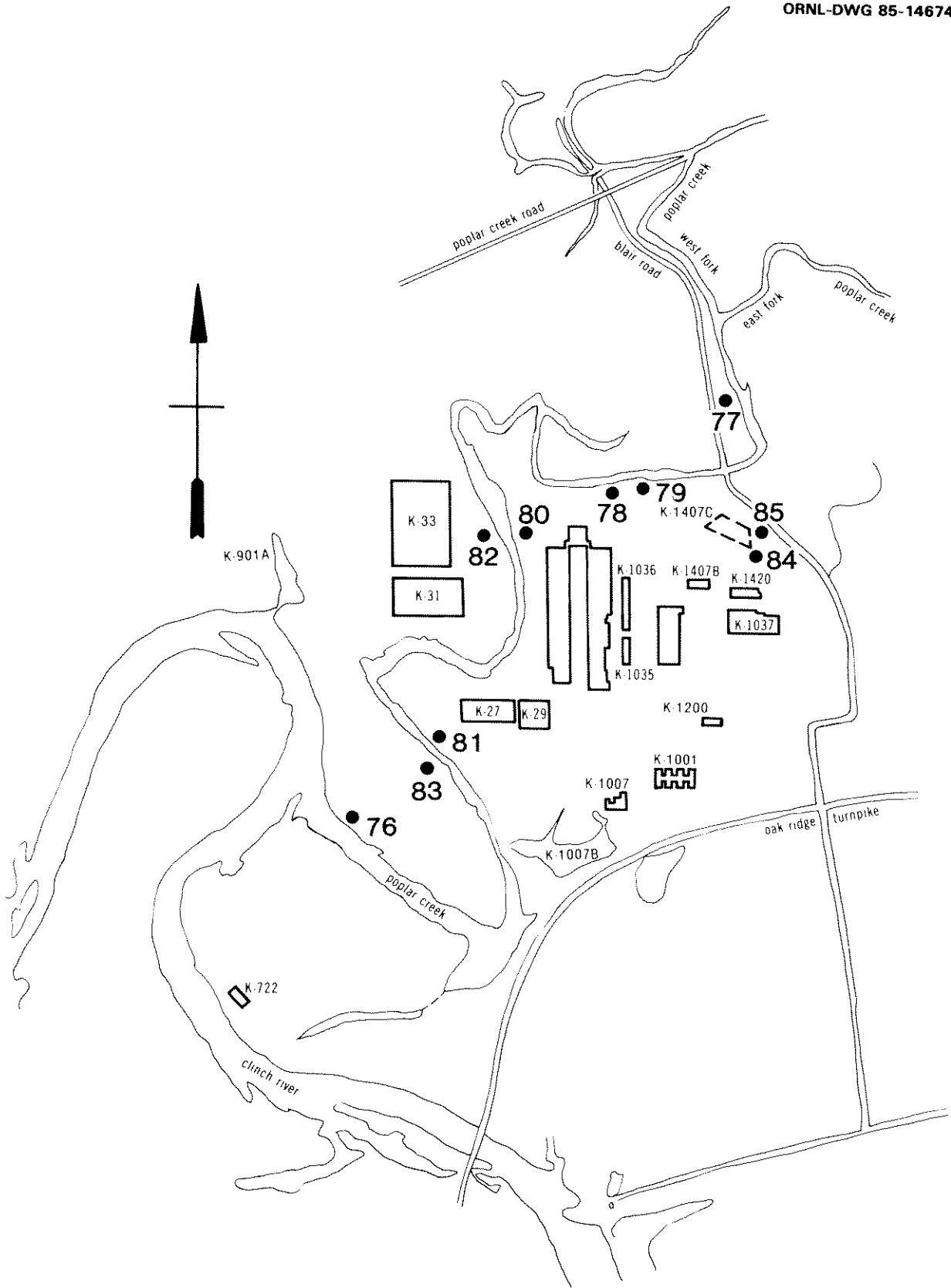


Fig. 13. ORGDP external gamma monitoring stations.

Table 7. 1984 external gamma radiation measurements

Station	No. of measurements ^a	$\mu\text{R/h}$	
		Av	95% CC ^b
<i>ORNL perimeter stations^c</i>			
HP-7	6	8.1	0.46
HP-8	6	8.2	1.2
HP-21	6	9.5	1.0
HP-22	6	13.0	0.34
HP-23	6	8.0	0.88
Overall	30	9.4	0.82
<i>Oak Ridge Reservation perimeter stations^c</i>			
HP-32	22	11	1.2
HP-33	22	8.4	0.76
HP-34	22	9.9	1.3
HP-35	22	7.9	0.72
HP-36	18	7.8	0.52
HP-37	22	7.3	0.68
HP-38	22	8.0	1.2
HP-39	22	7.6	0.86
HP-40	22	7.9	0.66
HP-41	22	10	0.76
Overall	216	8.6	0.34
<i>Remote stations^d</i>			
HP-51	4	6.8	0.20
HP-52	4	8.1	0.50
HP-53	4	9.1	0.84
HP-55	4	7.8	0.10
HP-56	4	6.4	1.7
HP-57	4	11	3.3
HP-58	4	11	1.0
Overall	28	8.7	0.86

^aTwo measurements are taken per station for each time interval except for the ORNL perimeter stations for which there are three measurements. Two or three dosimeters are placed in each container to obtain these measurements.

^b95% confidence coefficient about the average.

^cSee Fig. 2.

^dSee Fig. 3.

Table 8. 1984 external gamma radiation measurements at ORGDP

Location ^a	No. of samples	$\mu\text{R/h}$			95% CC ^b
		Max	Min	Av	
76	12	16	9.4	12	1.2
77	12	13	8.2	11	1.1
78	12	20	14	17	0.86
79	9	21	14	18	1.3
80	9	15	8.2	11	1.4
81	12	19	10	14	1.8
82	12	15	8.6	11	1.5
83	12	17	9.0	13	1.6
84	12	19	12	15	1.3
85	9	16	8.2	12	1.9
Overall	111	21	8.2	13	0.62

^aSee Fig. 13.

^b95% confidence coefficient about the average.

Gamma radiation levels along East Fork Poplar Creek ranged from 0 to 4.8 $\mu\text{R/h}$ above background. The external gamma radiation levels along the bank of the Clinch River ranged from 2 to 25 $\mu\text{R/h}$ above background. The impacts on the public from external radiation sources are minimal and are described in the section "Calculation of Potential Radiation Dose to the Public."

Surface Water

Radioactive

Surface streams. Flow proportional samples were composited weekly at the White Oak Dam Monitoring Station (W-2, Fig. 14). Water samples also were collected at the mouth of White Oak Creek (Station W-1), in the Clinch River at Melton Hill Dam (Station C-2) 3.7 km above the White Oak Creek outfall, at the ORGDP sanitary water outlet (Station C-3) 10 km downstream from the entry of White Oak Creek, at the ORGDP recirculating water outlet (Station C-4) downstream from the Poplar Creek outfall, and near Brashear Island (Station C-6). Processed water samples were collected from the water plant (Station C-5) near Kingston, Tennessee. Samples were collected continuously at Stations C-2, C-3, and W-1. A weekly 24-h composite sample was collected at Station C-4, and a weekly grab sample was collected at Station C-6. A daily grab sample was collected at Station C-5. Samples were composited for weekly, monthly, or quarterly analysis, depending on location.

Additional water samples were collected for uranium analyses (Fig. 14) at the outlet of New Hope Pond on East Fork Poplar Creek (Station E-1), in Bear Creek (Station B-1), and in Poplar Creek (Stations P-1 and P-2). Flow proportional samples were collected at Stations E-1 and B-1. Grab samples are collected weekly at Stations P-1 and P-2. All samples are composited for monthly analysis.

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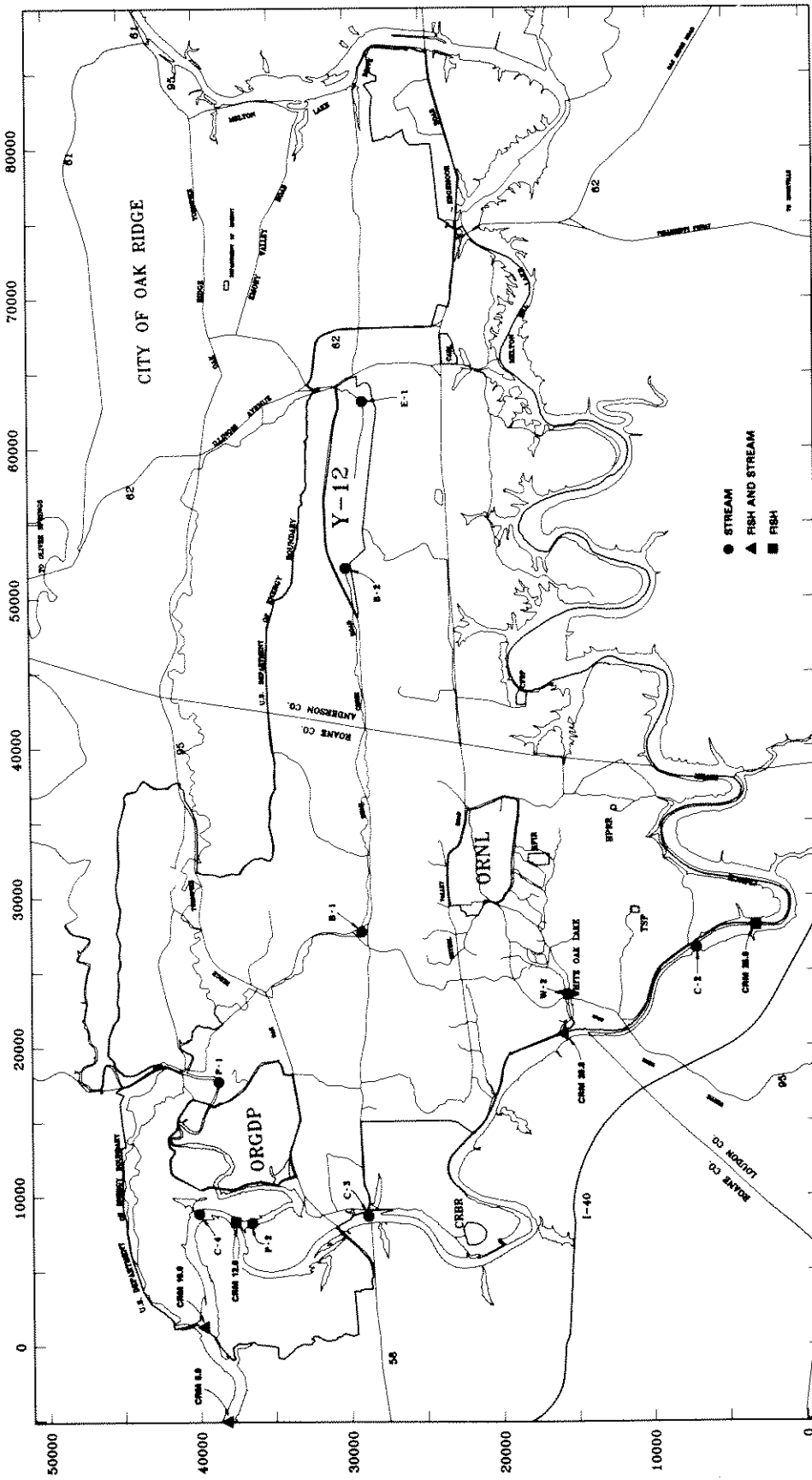


Fig. 14. Stream monitoring stations on the Oak Ridge Reservation.

Fission-product radionuclide concentrations were determined by specific radionuclide analysis and gamma spectrometry. Uranium analysis was by the fluorometric method or mass spectrometry. Transuranic alpha emitters were determined by chemical chromatography and alpha spectrometry.

Concentrations of radionuclides of primary concern in White Oak Creek and the Clinch River are given in Table 9. Radionuclide concentrations at White Oak Dam (W-2, Table 9) decreased from the values reported in 1983. The average concentration of ^{137}Cs showed a significant decline from $120 \text{ E-}9 \mu\text{Ci/mL}$ in 1983 to $29 \text{ E-}9 \mu\text{Ci/mL}$ in 1984. Both ^{90}Sr and ^{60}Co decreased slightly; however, the average ^3H value increased.

Table 9. 1984 concentrations of radionuclides in surface streams and tap water

Sampling location ^a	No. of measurements ^b	Value	^{90}Sr (E-9 $\mu\text{Ci/mL}$)	^{137}Cs (E-9 $\mu\text{Ci/mL}$)	^{60}Co (E-9 $\mu\text{Ci/mL}$)	^3H (E-6 $\mu\text{Ci/mL}$)	Effective dose equivalent ^c (millirem)
C-2	4	Max	0.54	0.54	< 0.54	7.0	< 0.34
		Min	0.27	< 0.22	< 0.22	< 1.8	
		Av	0.36	< 0.37	< 0.32	< 4.1	
C-3 ^d	4	Max	2.2	< 0.54	< 0.54	17	< 0.26
		Min	0.19	< 0.054	< 0.054	< 1.9	
		Av	1.1	< 0.24	< 0.31	< 7.2	
C-5	4	Max	0.46	1.5	2.1	< 1.8	< 0.19
		Min	0.22	< 0.054	< 0.081	< 1.8	
		Av	0.31	< 0.55	< 0.7	< 1.8	
ORNL tap water	4	Max	1.9	0.54	0.54	< 1.8	< 0.21
		Min	0.19	< 0.054	< 0.054	< 1.8	
		Av	0.7	< 0.23	< 0.3	< 1.8	
W-1	12	Max	89	270	38	360	16
		Min	14	7.6	1.2	25	
		Av	44	52	12	130	
W-2	52	Max	310	180	35	750	< 52
		Min	26	6.5	< 2.7	180	
		Av	170	29	< 10.8	480	

^aSee Fig. 14.

^bThree dosimeters are placed in a container at each location.

^cSeventy-year commitment based on consumption of 2.2 L of water per day. Calculations were based on summing the doses for all samples.

^dProcessed water.

Analysis of water samples collected at the confluence of White Oak Creek and the Clinch River (W-1, Fig. 14) showed that ^{90}Sr and ^3H concentrations were significantly less than those measured at White Oak Dam, ^{60}Co was the same, and ^{137}Cs was higher. Concentrations at this confluence point are dependent on the relative levels and flows of the creek and river in addition to the quantity of activity being discharged from White Oak Dam. Measurements were made at this location because it represents the closest point of access by the public to White Oak Creek. Concentrations determined at the Clinch River sampling stations downstream from the confluence of White Oak Creek and the Clinch River showed a marked decrease for all measured radionuclides, many of

which were below analytical detection limits. As points of reference, data are provided for samples collected at Melton Hill Dam above ORNL (C-2) and for samples of tap water collected at ORNL (Table 9).

Average uranium concentrations in East Fork Poplar Creek (E-1, Table 10 and Fig. 14), Bear Creek (B-1, Table 10 and Fig. 14), the Clinch River (C-3, C-4, and C-6, Table 10 and Fig. 14), and Poplar Creek (P-1 and P-2, Table 10 and Fig. 14) were about two times higher in 1984 than in 1983.

Table 10. 1984 concentrations of uranium in surface streams

Station ^a	No. of samples	Concentration (E-08 $\mu\text{Ci/mL}$)			95% CC ^b	Dose ^c (millirem)
		Max	Min	Av		
P-1	12	1.2	< 0.12	< 0.70	0.08	0.83
P-2	12	1.1	< 0.12	< 0.72	0.08	0.86
C-3	12	< 0.62	< 0.12	< 0.55	0.06	0.65
C-4	12	0.74	< 0.12	< 0.57	0.06	0.67
C-6	12	0.62	< 0.12	< 0.58	0.06	0.69
E-1	12	17	0.14	5.0	3.1	3.7
B-1	12	31	0.26	6.7	5.2	8.0

^aSee Fig. 14.

^b95% confidence coefficient about the average.

^cSeventy-year committed effective dose equivalent based on consumption of 2.2 L of water per day. Calculations were based on the average concentrations.

The committed effective dose equivalents for consumption of 2.2 L of water per day for one year from each of the surface water stations and ORNL tap are given in Tables 9 and 10. The section "Calculation of Potential Radiation Dose to the Public" contains a discussion of the significance of the doses.

Total curies discharged from White Oak Dam to the Clinch River were calculated based on weekly concentration and daily flow data. Trends in discharges of ⁹⁰Sr and ³H to the Clinch River are presented in Fig. 15. These are the principal contributors of radioactivity in terms of total curies to the discharge. Total curie amounts for the two radionuclides appeared to increase in 1984 compared with 1983—about 14% for ³H and 20% for ⁹⁰Sr. Most of the discharges are primarily the result of seepage from the SWSAs at ORNL and do not reflect current operational status. The annual variations in the discharges from White Oak Lake are generally a function of the variability in annual precipitation patterns. The 1984 discharge continues to reflect an increase in total curies discharged over White Oak Dam that began in 1980 after a significant decrease from 1979 levels. Some of the apparent increase in 1984 may result from improved accuracy in high-flow readings. New weirs and associated flow instrumentation were made operational in early 1984.

Quantities of radionuclides discharged to surface streams for the past five years are given in Table 11. The transuranic elements have shown a relatively constant level over the past five-year period, as have uranium, ²³²Th, and ¹³¹I (except for 1983). Cesium-137 and ⁶⁰Co have decreased since 1982, whereas ³H, ⁹⁰Sr, and ¹⁰⁶Ru appear to be increasing. Technetium-99 discharges have varied widely over the past five years, 1983 having the highest discharge and 1984 the lowest. The

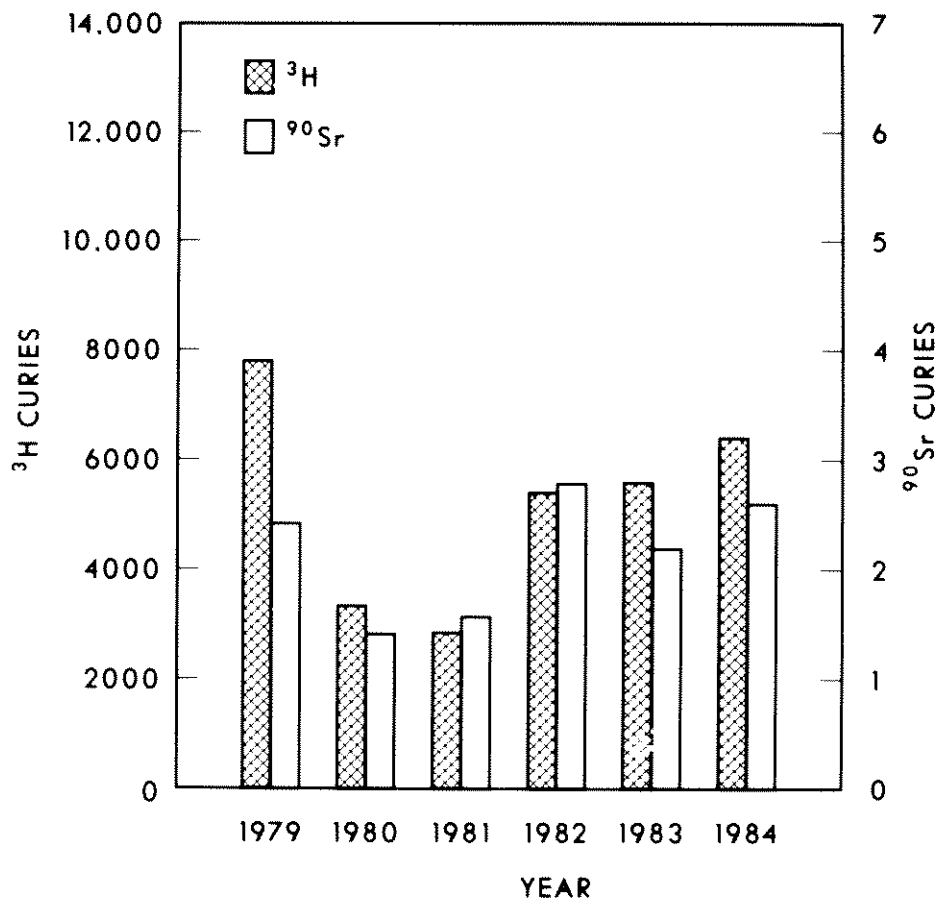


Fig. 15. Radioactive discharges over White Oak Dam.

^3H , ^{90}Sr , and ^{106}Ru quantities are all based on flow measurements at White Oak Dam. As mentioned previously, the capability to obtain more accurate measurements at high flows may have contributed to these results.

Rainwater. Trends in the gross beta activity in rainwater collected at perimeter and remote air monitoring stations over the past six years are shown in Fig. 16. Many of the measured activities for the remote and perimeter stations were at or near the limits of detection. Activities at the remote stations have been consistently higher than at the perimeter stations. Mean values in 1984 were higher than in 1983, but lower than in some previous years (1980 to 1981).

Nonradioactive

Water samples are collected for analysis of nonradioactive substances at the same locations discussed previously under radioactive water sampling. All samples are composited for monthly analyses; $\text{NO}_3(\text{N})$ values are determined from a monthly grab sample. EPA-approved methods are used for the determination of chemicals in water. Concentrations of chemicals in streams and creeks on or around the ORR are listed in Tables 12-22. Concentrations have been compared with Tennessee's instream allowable concentrations that are based on the long-term protection of domestic water supply, fish and aquatic life, and recreation classifications and recommendations made by

**Table 11. Discharges of radioactivity to surface streams
for 1980–1984**

Radionuclide	Quantity discharged (Ci/year)				
	1980	1981	1982	1983	1984
¹³⁷ Cs	0.60	0.23	1.5	1.2	0.56
⁶⁰ Co	1.4	0.66	0.96	0.29	0.17
³ H	3400	2900	5400	5600	6400
¹³¹ I	0.09	0.04	0.06	0.004	0.057
¹⁰⁶ Ru	< 0.01			0.18	0.28
⁹⁰ Sr	1.4	1.5	2.7	2.1	2.6
⁹⁹ Tc	5.1	3.5	1.7	17	0.29
Uranium ^a	0.60	0.87	0.67	0.42	0.32
²³² Th	0.0080	0.0080	0.0090	0.007	0.010
Transuranics ^b	0.040	0.043	0.034	0.048	0.028

^aUranium of varying enrichments—curie quantities calculated using the appropriate specific activity for material released.

^bValue based on gross transuranic alpha emitter analysis.

the TDHE to DOE Oak Ridge Operations.⁴ Concentrations of chemicals in the outlet for the ORGDP sanitary water plant (Table 16) are compared with Tennessee Water Quality Criteria for domestic water supply.

Maximum concentrations recommended by the state for some chemicals are so low that it is impossible to measure to criteria levels using even the most sensitive EPA-approved methods. Those chemicals whose detection limits exceeded Tennessee's criteria include mercury, cadmium, and lead; however, all laboratories are working toward reducing the detection limits for these metals. The average concentrations of the other chemicals may easily be compared with Tennessee criteria. Chromium, copper, cyanide, sulfates, nickel, and total dissolved solids (TDS) were all within the Tennessee criteria (Tables 12–22). Other average concentrations that exceeded the criteria include NO₃(N) at the confluence of White Oak Creek and the Clinch River (Table 13) and zinc and lead in East Fork Poplar Creek (Table 21). Average concentrations of fluoride were 100% of the Tennessee criteria at one location (Table 21).

In mid-1983, a program to collect weekly grab samples at station B-2 (Fig. 14) was initiated and continued during 1984. This station is located near the headwaters of Bear Creek and is influenced by discharges from the S-3 Ponds at Y-12. The disposal of plating shop and other liquid wastes at the S-3 Ponds was discontinued in March 1984 and neutralization activities in preparation for closure were initiated. Since that time, heavy metal concentrations at Station B-2 have

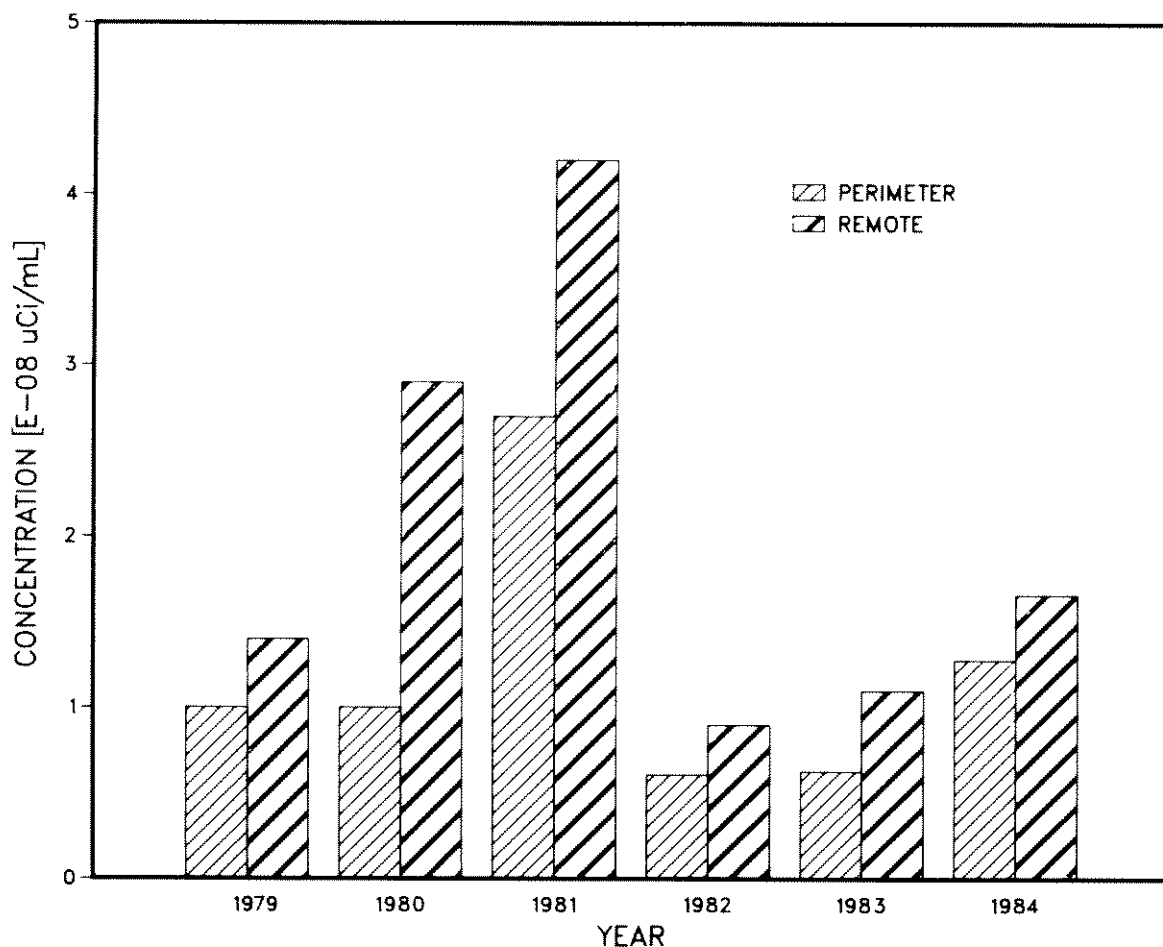


Fig. 16. Long-lived gross beta activity in rainwater.

Table 12. 1984 concentrations of chemicals in water collected at White Oak Dam (Location W-2, Fig. 14)

Chemical	No. of samples	Concentration (mg/L)				95% CC ^a	Criteria ^b	Percentage of Criteria
		Max	Min	Av				
Cr	12	0.025	< 0.01	< 0.011	0.0025	0.05	< 23	
Zn	12	0.036	< 0.02	< 0.024	0.0034	0.05	< 48	
NO ₃ (N)	12	7.2	0.4	4.1	1.2	10	41	
Hg	12	0.0002	< 0.00005	< 0.0001	0.00004	0.00005	< 200	

^a95% confidence coefficient about the average.

^bTennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

Table 13. 1984 concentrations of chemicals in water collected at confluence of White Oak Creek and Clinch River (Location W-1, Fig. 14)

Chemical	No. of samples	Concentration (mg/L)				95% CC ^a	Criteria ^b	Percentage of Criteria
		Max	Min	Av				
Cr	12	< 0.01	< 0.01	< 0.01	0	0.05	< 20	
Zn	12	0.08	< 0.02	< 0.049	0.011	0.05	< 98	
NO ₃ (N)	12	73	< 0.1	< 11	12	10	< 110	
Hg	12	0.001	< 0.00005	< 0.0002	0.0001	0.00005	< 400	

^a95% confidence coefficient about the average.

^bTennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

Table 14. 1984 concentrations of chemicals in water collected at Melton Hill Dam (Location C-2, Fig. 14)

Chemical	No. of samples	Concentration (mg/L)				95% CC ^a	Criteria ^b	Percentage of criteria
		Max	Min	Av				
Cr	12	< 0.01	< 0.01	< 0.01	0.00	0.05	< 20	
Zn	12	0.06	< 0.02	< 0.023	0.0067	0.05	< 47	
NO ₃ (N)	12	4.0	0.27	1.8	0.50	10	18	
Hg	12	< 0.0002 ^c	< 0.00005	< 0.0001	0.00005	0.00005	< 200	

^a95% confidence coefficient about the average.

^bTennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

^cDetection limit changed during 1984.

Table 15. 1984 concentrations of various parameters measured in water collected above Melton Hill Dam

Parameter ^a	Concentration (mg/L)	
	Third quarter	Fourth quarter
Ag	< 0.04	
Al	0.31	0.31
Alkalinity	94	105
²⁴¹ Am ^b		< 2.7
As	0.0005	0.001
Asbestos ^c	3.3	< 0.3
B	< 0.03	< 0.1
Ba	0.017	0.039
Be	< 0.0001	< 0.001
BOD	< 5	< 5
Br	< 5	< 5
Ca	30.2	33.0
Cd	0.0002	0.00005
Cl	2	4
²⁴⁴ Cm ^b		< 2.7
CN	< 0.0014	< 0.0014
Co	< 0.015	< 0.001
COD	5	1
Fecal coliform ^d	6	0
Cr	< 0.001	< 0.002
Cu	0.002	< 0.02
F	< 1	< 1
Fe	0.029	0.032
Hardness	109	106
Hg	< 0.00005	< 0.00005
Mg	8.0	11
Mn	0.012	0.019
Mo	0.016	0.020
Na	3.2	6.4
Ammonia (as N)	0.06	< 0.04
Ni	< 0.055	< 0.06
NO ₃	4.0	< 5.0
Oil and grease	< 2.0	< 2.0
Pb	< 0.002	< 0.0002
PCBs (total)		0.00014
PCB-1260	0.00006	
Phenols (total)	< 0.001	< 0.001
PO ₄	< 5.0	< 5.0
²³⁸ Pu ^b		< 2.7
²³⁹ , ²⁴⁰ Pu ^b	< 0.003	< 0.003
Sb	< 0.33	< 0.30
Se	< 0.005	< 0.003
Settleable solids ^e	< 0.1	< 0.1
Si	2.2	0.95
SO ₄	13	25
Sr	0.082	0.10

Table 15 (continued)

Parameter	Concentration (mg/L)	
	Third quarter	Fourth quarter
⁹⁹ Tc ^b		< 2.7
Total dissolved solids	229	170
Kjeldahl nitrogen	0.18	0.10
Total organic carbon	1.5	2.3
Total phosphorous	< 0.10	< 0.10
Total suspended solids	14	3.0
Total uranium ^f	0.00016	0.00031
V	< 0.022	< 0.030
Zn	< 0.02	< 0.02

^aSee Appendix B for abbreviations.

^bUnits are pCi/L.

^cUnits are millions of fibers per L.

^dUnits are colonies per 100 mL.

^eUnits are mL/L.

^fFor the third quarter, the percentages of uranium isotopes by weight were ²³⁴U, 0.008; ²³⁵U, 0.73; and ²³⁸U, 99.26. For the fourth quarter, the percentages of uranium isotopes by weight were ²³⁴U, 0.008; ²³⁵U, 0.71; and ²³⁸U, 99.28.

Table 16. 1984 chemical water quality data for the ORGDP sanitary water pumping station (Location C-3, Fig. 14)

Substance	No. of samples	Concentration (mg/L)				95% CC ^a	Criteria ^b	Percentage of criteria
		Max	Min	Av				
Cd	12	< 0.002	< 0.002	< 0.002	0.0	0.01	< 20	
Cr	12	< 0.01	< 0.01	< 0.01	0.0	0.05	< 20	
CN	12	< 0.002	< 0.002	< 0.002	0.0	0.2	< 1	
NO ₃ (N)	12	0.58	0.24	0.40	0.08	10	4	
Pb	12	0.038	< 0.004	< 0.009	0.01	0.05	< 18	
SO ₄ ²⁻	12	22	16	19	1.3	250	8	
TDS ^c	12	160	130	140	5	500	28	
Zn	12	0.09	< 0.02	< 0.03	0.01	5	< 1	
F ⁻	12	0.29	< 0.10	< 0.17	0.04	1.4-2.4 ^d	< 12	
Hg	12	< 0.001	< 0.001	< 0.001	0.0	0.0002	< 500	
Ni	12	0.04	< 0.01	< 0.01	0.01	0.1	< 10	

^a95% confidence coefficient about the average.

^bTennessee Water Quality Criteria standards for domestic water supplies.

^cTotal dissolved solids.

^dTemperature dependent. Below 12°C maximum fluoride concentration is 2.4 mg/L; above this, the maximum concentration is 1.4 mg/L.

Table 17. 1984 chemical water quality data for the ORGDP recirculating water pumping station (Location C-4, Fig. 14)

Substance	No. of samples	Concentration (mg/L)					Percentage of criteria
		Max	Min	Av	95% CC ^a	Criteria ^b	
Cd	12	< 0.002	< 0.002	< 0.002	0.0	0.000025	< 8000
Cr	12	< 0.01	< 0.01	< 0.01	0.0	0.05	< 20
CN	12	0.005	< 0.002	< 0.002	0.001	0.0035	< 57
NO ₃ (N)	12	0.58	0.27	0.43	0.07	10	4
Pb	12	0.006	< 0.004	< 0.006	0.003	0.0038	< 160
SO ₄ ²⁻	12	28	16	21	2	250	8
TDS ^c	12	170	110	150	10	500	30
Zn	12	0.14	< 0.02	< 0.04	0.02	0.05	< 80
F ⁻	12	0.32	< 0.10	< 0.18	0.04	1	< 18
Hg	12	< 0.001	< 0.001	< 0.001	0.0	0.00005	< 2000
Ni	12	0.15	< 0.01	< 0.02	0.03	0.1	< 20

^a95% confidence coefficient about the average.

^bTennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

^cTotal dissolved solids.

Table 18. 1984 chemical water quality data for the Clinch River downstream of ORGDP (Location C-6, Fig. 14)

Substance	No. of samples	Concentration (mg/L)					Percentage of criteria
		Max	Min	Av	95% CC ^a	Criteria ^b	
Cd	12	< 0.002	< 0.002	< 0.002	0.0	0.000025	< 8000
Cr	12	< 0.01	< 0.01	< 0.01	0.0	0.05	< 20
CN	12	< 0.002	< 0.002	< 0.002	0.0	0.0035	< 57
NO ₃ (N)	12	0.58	0.24	0.41	0.08	10	4
Pb	12	< 0.01	< 0.004	< 0.01	0.001	0.0038	< 270
SO ₄ ²⁻	12	22	16	19	1.4	250	8
TDS ^c	12	160	110	140	9.0	500	28
Zn	12	0.04	< 0.02	< 0.02	0.004	0.05	< 40
F ⁻	12	0.26	< 0.10	< 0.16	0.03	1.0	< 16
Hg	12	< 0.001	< 0.001	< 0.001	0.0	0.00005	< 2000
Ni	12	0.05	< 0.01	< 0.01	0.01	0.1	< 10

^a95% confidence coefficient about the average.

^bTennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

^cTotal dissolved solids.

**Table 19. 1984 chemical water quality data for Poplar Creek above Blair Bridge
(Location P-1, Fig. 14)**

Substance	No. of samples	Concentration (mg/L)					Percentage of criteria
		Max	Min	Av	95% CC ^a	Criteria ^b	
Cd	12	< 0.002	< 0.002	< 0.002	0.0	0.000025	< 8000
Cr	12	< 0.01	< 0.01	< 0.01	0.0	0.05	< 20
CN	12	< 0.002	< 0.002	< 0.002	0.0	0.0035	< 57
NO ₃ (N)	12	2.6	0.26	1.2	0.45	10	12
Pb	12	0.012	< 0.004	< 0.006	0.002	0.0038	< 270
SO ₄ ²⁻	12	45	17	33	6.4	250	13
TDS ^c	12	240	110	170	24	500	34
Zn	12	0.05	< 0.02	< 0.03	0.01	0.05	< 60
F ⁻	12	0.72	< 0.10	< 0.30	0.13	1	< 30
Hg	12	< 0.001	< 0.001	< 0.001	0.0	0.00005	< 500
Ni	12	0.04	< 0.01	< 0.02	0.01	0.1	< 20

^a95% confidence coefficient about the average.

^bTennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

^cTotal dissolved solids.

**Table 20. 1984 chemical water quality data for Poplar Creek near the Clinch River
(Location P-2, Fig. 14)**

Substance	No. of samples	Concentration (mg/L)					Percentage of criteria
		Max	Min	Av	95% CC ^a	Criteria ^b	
Cd	12	< 0.002	< 0.002	< 0.002	0.0	0.000025	< 8000
Cr	12	< 0.01	< 0.01	< 0.01	0.0	0.05	< 20
CN	12	0.003	< 0.002	< 0.002	0.0002	0.0035	< 57
NO ₃ (N)	12	0.90	0.19	0.49	0.15	10	5
Pb	12	0.016	< 0.004	< 0.006	0.002	0.0038	< 270
SO ₄ ²⁻	12	37	17	26	3.4	250	10
TDS ^c	12	170	98	130	18	500	26
Zn	12	0.04	< 0.02	< 0.02	0.004	0.05	< 40
F ⁻	12	0.31	0.10	0.18	0.05	1	18
Hg	12	< 0.001	< 0.001	< 0.001	0.0	0.00005	< 2000
Ni	12	0.03	< 0.01	< 0.01	0.004	0.1	< 10

^a95% confidence coefficient about the average.

^bTennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

^cTotal dissolved solids.

**Table 21. 1984 chemical water quality data for East Fork Poplar Creek
(Location E-1, Fig. 14)**

Substance	No. of samples	Concentration (mg/L)					Percentage of criteria
		Max	Min	Av	95% CC ^a	Criteria ^b	
Cd	12	0.003	< 0.002	< 0.002	0.0	0.000025	< 8000
Cl ⁻	12	42	6	15	8	250	6.0
Cr	12	0.02	< 0.01	< 0.01	0.03	0.05	< 20
Cu	12	0.048	0.008	0.016	0.01	0.02	80
F ⁻	12	1.1	0.6	1.0	0.1	1.0	100
Hg	12	0.0038	< 0.0005	< 0.0016	0.0009	0.00005	< 3200
NO ₃ (N)	12	6.0	2.4	3.8	1.0	10	38
Pb	12	0.03	< 0.01	< 0.01	0.005	0.0038	< 270
SO ₄ ²⁻	12	70	36	52	11	250	21
TDS ^c	12	260	180	220	24	500	44
Zn	12	0.20	0.03	0.07	0.04	0.05	140

^a95% confidence coefficient about the average.

^bTennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

^cTotal dissolved solids.

**Table 22. 1984 chemical water quality data for Bear Creek
(Location B-1, Fig. 14)**

Substance	No. of samples	Concentration (mg/L)					Percentage of criteria
		Max	Min	Av	95% CC ^a	Criteria ^b	
Cd	12	0.003	< 0.002	< 0.002	0.0002	0.000025	< 8000
Cl ⁻	12	21	5.0	8.0	4.0	250	3.2
Cr	12	< 0.01	< 0.01	< 0.01	0.0	0.05	< 20
Cu	12	0.013	< 0.004	< 0.007	0.003	0.02	< 35
F ⁻	12	0.6	0.1	0.2	0.1	1.0	20
Hg	12	0.0058	< 0.0005	< 0.0012	0.0014	0.00005	< 2400
NO ₃ (N)	12	15	3.2	7.3	3.1	10	73
Pb	12	< 0.01	< 0.01	< 0.01	0.0	0.00038	< 270
SO ₄ ²⁻	12	31	< 10	< 16	6	250	< 6
TDS ^c	12	350	180	220	53	500	44
Zn	12	0.18	< 0.02	< 0.04	0.04	0.05	< 80

^a95% confidence coefficient about the average.

^bTennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

^cTotal dissolved solids.

decreased significantly. TDS ranged from 120 to 6600 mg/L (2830 mg/L av), and NO₃ (N) varied from 1.5 to 900 mg/L (375 mg/L av).

A better guideline for those chemicals whose detection limit exceeds the Tennessee criteria was to compare stream water affected by the Oak Ridge facilities to waters above the facilities. Water samples were collected from above Melton Hill Dam and analyzed for many of EPA's priority pollutants. Results are given in Tables 14 and 15. Volatile organics, acid compounds, or pesticides were not detected in these samples. For this reason, they are not included in Tables 14 and 15. Cadmium was positively detected in the East Fork Poplar and Bear creeks (Tables 21 and 22). However, the detection limit of the method used for cadmium was higher at these locations than at Melton Hill Dam. Average lead concentrations at all ORGDP water sampling stations, at Poplar Creek stations, and in the East Fork Poplar Creek exceed those at Melton Hill Dam (Tables 15-22). Average mercury concentrations exceeded those above Melton Hill Dam at all stations except White Oak Dam. However, the only positive detectable concentrations of mercury occurred at White Oak Dam, the confluence of the Clinch River and White Oak Creek, Bear Creek, and East Fork Poplar Creek. The East Fork Poplar Creek had the highest average mercury concentrations. The average values for Pb, Cr, F⁻, Zn, and Hg reported for Bear Creek and/or East Fork Poplar Creek exceed the criteria limits shown in Tables 21 and 22.

NPDES permits were issued by the EPA for each of the Oak Ridge facilities in 1975. The permits established a number of discharge locations at each installation and listed specific concentration limits and/or monitoring requirements for a number of parameters at each discharge location. A new NPDES permit was issued to ORGDP in February 1984. Tables 23-25 list the discharge

Table 23. 1984 National Pollutant Discharge Elimination System (NPDES) compliance at ORNL

Discharge point	Effluent parameters	Effluent limits		Percentage of measurements in compliance
		Daily av (mg/L)	Daily max (mg/L)	
001 (White Oak Creek)	Dissolved oxygen	5 ^a		99
	Dissolved solids		2000	100
	Oil and grease	10	15	100
	Total chromium		0.05	100
	pH, units		6.0 - 9.0	100
002 (Melton Branch)	Total chromium		0.05	100
	Dissolved solids		2000	100
	Oil and grease	10	15	100
	pH, units		6.0 - 9.0	100
003 (Sewage treatment plant)	Ammonia (as N)		5	54
	BOD		20	90
	Residual chlorine		0.5 - 2.0	94

Table 23 (continued)

Discharge point	Effluent parameters	Effluent limits		Percentage of measurements in compliance
		Daily av (mg/L)	Daily max (mg/L)	
	Fecal coliform, No./100 mL	200 ^b	400 ^c	100
	pH, units		6.0 - 9.0	100
	Suspended solids		30	94
	Settleable solids, mL/L		0.5	96

^aMinimum.

^bMonthly average.

^cWeekly average.

locations at each installation, the parameters at each location for which limits have been established, the permit limits for each parameter, and the percentage of compliance achieved. NPDES violations at New Hope Pond in fluoride and zinc (Table 24) have been attributed primarily to process operations; pH violations are often result from the photosynthesis of vegetation in the pond. ORNL achieved compliance of only 54% for ammonia at the sewage treatment plant. An effort was made to achieve compliance by implementing (1) a line-item project (Improvements to Existing Sewage Treatment System), which requires replacement of the current plant with an extended aeration package plant, and (2) 1984 and 1985 General Plant Projects (GPP), which require rehabilitation of the sanitary sewer system to reduce the amount of water reaching the plant. The 1984 GPP has been completed, and the 1985 GPP and the line-item projects are well under way.

A new NPDES permit for ORNL has been drafted and is expected to be approved and issued in 1985. Release limits will be more restrictive, and a number of permit points will be added.

Table 24. 1984 National Pollutant Discharge Elimination System (NPDES) compliance at the Y-12 Plant

Discharge point	Effluent parameters	Effluent limits		Percentage of measurements in compliance
		Daily av (mg/L)	Daily max (mg/L)	
001 (Kerr Hollow Quarry)	Dissolved solids		2000	100
	Lithium		5	100
	pH, units		6.0 – 9.0	100
	Suspended solids		50	100
	Zirconium		3	100
002 (Rogers Quarry)	pH, units		6.0 – 9.0	98
	Suspended solids ^a	30	50	100
	Settleable solids, mL/L ^a		0.5	100
003 (New Hope Pond)	Ammonia (N)		1.6	100
	Chromium	0.05	0.08	100
	Dissolved oxygen	5 ^b		100
	Dissolved solids		2000	100
	Fluoride	1.5	2.0	92
	Lithium		5	100
	Oil and grease	10	15	100
	pH, units		6.0 – 9.0	96
	Phosphate (as MBAS)	5	8	100
	Suspended solids ^a		20	100
	Settleable solids, mL/L ^a		0.5	100
	Total nitrogen (as N)		20	100
	Zinc	0.1	0.2	90
004 (Bear Creek)	Oil and grease	10	15	100
	pH, units		6.0 – 8.5	100

^aLimit applicable only during normal operations. Not applicable during periods of increased discharge from surface run-off as a result of precipitation.

Table 25. 1984 National Pollutant Discharge Elimination System (NPDES)
compliance at ORGDP

Discharge point	Effluent parameters	Effluent limits				Percentage of measurements in compliance
		Monthly av (mg/L)	Daily max (mg/L)	Monthly av (kg/day)	Daily max (kg/day)	
001 (K-1700 discharge)	Aluminum		1.0		15.5	95
	Chromium	0.05	0.08	0.80	1.24	100
	Nitrate - N		20		311	100
	Suspended solids ^a	30	50	466	777	100
	Oil and grease	10 ^b	15	155	233	100
	pH, units		6.0 - 9.0			99
	Perchloroethylene	0.12	0.21	1.86	3.26	100
	Trichloroethane	0.11		1.71		100
	Methylene chloride	0.035		0.54		99
	Trichloroethylene	0.41	0.61	6.37	9.48	100
	Lead	0.008	0.93	0.12	14.4	100
	Zinc	0.12	1.52	1.86	23.6	100
	Total halomethanes	1.23	2.05	19.1	31.8	100
	Beryllium	0.001	0.002	0.016	0.032	100
	Cadmium	0.004	0.01	0.06	0.16	100
	Mercury	0.0013	0.011	0.021	0.170	100
	Selenium	0.12	0.31	1.86	4.82	100
	Silver	0.014	0.027	0.22	0.42	99
005 (K-1203 Sanitary Treatment Facility) ^c	Ammonia nitrogen	5	7	12.4	17.3	100
	BOD	15	20	37.1	49.5	99
	Chlorine residual		0.24			99
	Dissolved oxygen	5 ^b				100
	Fecal coliform, No./100 mL	200	400			96
	pH, units		6.0 - 9.0			100
	Suspended solids	30	45	74	111	99
	Settleable solids, mL/L		0.5			99
	Beryllium	0.001	0.002	0.002	0.005	100
	Cadmium	0.004	0.01	0.01	0.025	100
	Mercury	0.0013	0.011	0.003	0.027	100
	Selenium	0.12	0.31	0.30	0.77	100
	Silver	0.014	0.027	0.035	0.067	100
	Lead	0.008	0.93	0.02	2.30	100
	Zinc	0.12	1.52	0.30	3.76	100
	Perchloroethylene	0.12	0.21	0.30	0.52	100
	Trichloroethane	0.11		0.27		100
	Methylene chloride	0.035		0.087		99
	Trichloroethylene	0.41	0.61	1.01	1.51	100
	Total halomethanes	1.23	2.05	3.04	5.07	100
006 (K-1007-B Holding Pond)	COD	20	25	121	152	94
	Chromium (total)		0.05		0.30	100
	Dissolved oxygen	5 ^b				100
	Fluoride	1.0	1.5	6.1	9.1	100
	Oil and grease	10	15	61	91	100
	pH, units		6.0 - 9.0			100
	Suspended solids ^a	30	50	182	304	100

Table 25 (continued)

Discharge point	Effluent parameters	Effluent limits				Percentage of measurements in compliance
		Monthly av (mg/L)	Daily max (mg/L)	Monthly av (kg/day)	Daily max (kg/day)	
007						
K-901A Holding Pond)	Chromium (total)		0.05		0.68	94
	Fluoride	1.0	1.5	4.2	6.25	100
	Oil and grease	10	15	42	62.5	100
	pH, units		6.0 - 10			100
	Suspended solids ^a	30	50	125	208	100
009						
(Sanitary Water Plant)	Suspended solids ^a	30	50	34	51	100
	Aluminum	5.0	10.0	5.70	11.0	100
	Sulphate		1400		1591	100
	pH, units		6.0 - 9.0			100

^aLimit applicable only during normal operations. Not applicable during periods of increased discharge due to surface run-off resulting from precipitation.

^bDaily minimum.

^cBecause of the small flow rates at the K-710 sanitary treatment facility, (discharge point 008), a rapid sand filter was installed May 1, 1978, eliminating the surface discharge and the need for monitoring.

Biological Monitoring

Milk

Raw milk is monitored for ¹³¹I and ⁹⁰Sr by the collection and analysis of samples from nine locations within a radius of 80 km of Oak Ridge. Samples are collected approximately weekly from five stations located near the Oak Ridge area. Four other stations are more remote (Fig. 3) with respect to the Oak Ridge facilities and are sampled at the rate of one station about every two weeks. Locations of the sampling stations near Oak Ridge are shown in Fig. 17. Samples are analyzed by ion exchange and gamma spectrometry, and the results are compared with intake guidelines specified by the Federal Radiation Council (FRC).⁵

All ¹³¹I concentrations in milk from both the immediate and remote stations were below the analytical detection limit of $0.8 \text{ E}-9 \mu\text{Ci/mL}$. According to the FRC, concentrations in this range require adequate surveillance to confirm calculated intakes (see Table 26 for explanation of FRC range categories and surveillance requirements). Concentrations of ⁹⁰Sr in milk samples are shown in Table 26. The average ⁹⁰Sr concentration for the stations in the immediate Oak Ridge area was $<1.6 \pm 0.08 \text{ E}-9 \mu\text{Ci/mL}$ (Range I, FRC Guide), and the average for each individual station was within the Range I category. Remote stations averaged $<1.2 \pm 0.20 \text{ E}-9 \mu\text{Ci/mL}$, and all stations were within the Range I limits.

Fish

Five to six species of fish are collected at several CRM stream locations each year and analyzed for mercury, PCBs, and radionuclide content. Radionuclide concentrations are determined on a

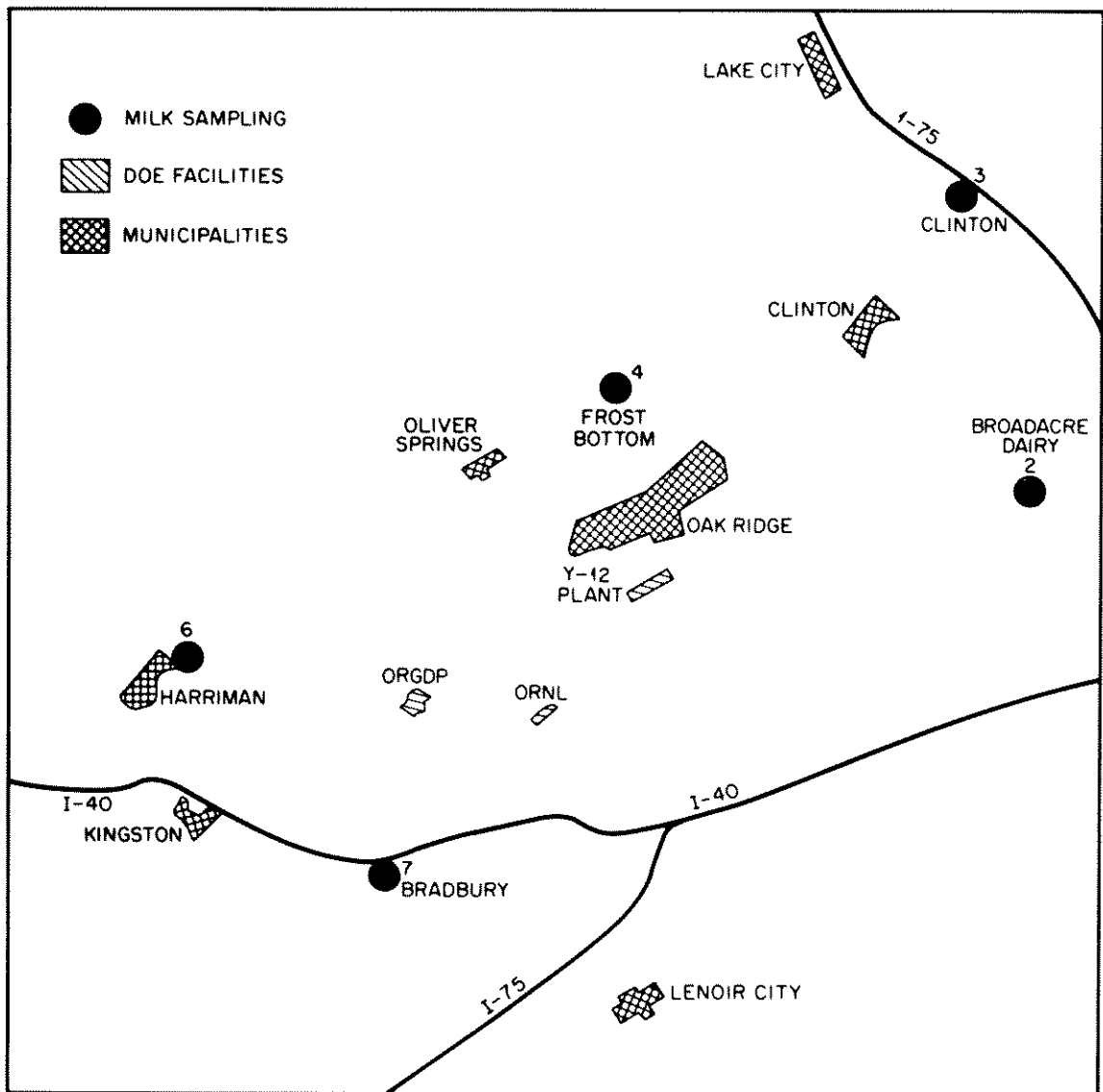


Fig. 17. Immediate environs milk sampling stations.

composite sample from 8 to 12 fish, whereas mercury and PCB analyses are run on samples from individual fish. Scales, head, and entrails are removed from each fish before samples are obtained. A fresh flesh sample is taken for mercury and PCB determinations. The flesh samples are composited, ashed, and analyzed by gamma spectrometry and radiochemical techniques for the radionuclides that contribute most to the potential radiation dose to humans.

TVA was authorized by DOE to conduct a study as part of the Oak Ridge Task Force during 1984 on contaminant concentrations in fish and other aquatic animals. Samples were collected during May and June 1984 from selected sites in Watts Bar and Melton Hill reservoirs, East Fork Poplar Creek, Bear Creek, Poplar Creek, lower White Oak Creek, and White Oak Lake. The results of this study have been recently reported.⁶

Table 26. 1984 concentrations of ⁹⁰Sr in milk^a

Station	No. of samples	Concentration E-9 μ Ci/mL				Comparison with standard ^c
		Max	Min	Av	95% CC ^b	
<i>Immediate environs^d</i>						
2	43	2.7	< 0.8	< 1.3	0.13	Range I
3	41	2.4	< 0.8	< 1.3	0.14	Range I
4	43	3.8	< 0.8	< 2.0	0.19	Range I
6	39	2.7	< 0.8	< 1.6	0.13	Range I
7	44	3.2	< 0.8	< 1.6	0.16	Range I
Av				< 1.6	0.08	Range I
<i>Remote environs^e</i>						
51	3	1.9	1.4	1.6	0.31	Range I
52	4	1.9	1.4	1.6	0.26	Range I
53	6	1.1	< 0.8	< 0.86	0.09	Range I
56	4	1.1	< 0.8	< 0.88	0.14	Range I
Av				< 1.2	0.20	Range I

^aRaw milk samples, except for station 2, which is a dairy.

^b95% confidence coefficient about the average.

^cApplicable FRC standard, assuming 1 L/d intake: Range I, 0 to 2 E-8 μ Ci/mL, adequate surveillance required to confirm calculated intakes; Range II, 2 E-8 to 2 E-7 μ Ci/mL, active surveillance required; and Range III, 2 E-7 to 2 E-6 μ Ci/mL, positive control action required. Note: Upper limit of Range II can be considered the concentration guide.

^dSee Fig. 17.

^eSee Fig. 3.

Data on the concentration of radionuclides in Clinch River fish are given in Tables 27 and 28. TVA published a limited amount of data on radionuclides in fish.⁶ The concentrations reported for ⁹⁰Sr and ¹³⁷Cs at CRM 11.0 were much lower than those reported in Table 28 for CRM 12.0. The differences may be attributed to the variability among the composite samples and the counting techniques. The calculations for effective dose equivalent-70-year commitment (see Table 28) for all the radionuclides shown in Tables 27 and 28 are based on the consumption of 17 kg of fish flesh per year.⁷ The highest dose estimate (1.1 millirem) is from the consumption of bass collected at CRM 20.8, the confluence of White Oak Creek and the Clinch River. For comparison with applicable guides and natural background exposures see the section "Calculation of Potential Radiation Dose to the Public."

In general, the dose estimates for all species are highest in the vicinity of CRM 20.8 and 12.0. Values for dose estimates for CRM 25.0, above Melton Hill Dam, may be construed as background or baseline values because these waters are upstream of the DOE Oak Ridge facilities. Dose estimates for species collected below CRM 10.0 are generally within the range of the estimates for CRM 25.0.

Table 27. 1984 radionuclide concentrations in Clinch River fish—alpha emitters

Location	Species ^a	Concentration (pCi/kg wet wt)				
		²³⁸ Pu	²³⁹ Pu	²³⁴ U	²³⁵ U	²³⁸ U
CRM 2.0	Bass	< 0.001	0.001	0.24	0.024	0.038
	Bluegill	< 0.019	< 0.015	0.95	0.19	0.73
	Carp	< 0.014	< 0.019	0.63	0.11	0.38
	Crappie	< 0.027	< 0.020	0.81	0.033	0.51
	Shad	0.037	< 0.026	9.0	1.1	5.8
CRM 5.0	Bass	< 0.014	< 0.0004	0.50	0.092	0.18
	Bluegill	0.14	< 0.019	2.4	0.047	0.62
	Carp	< 0.028	< 0.028	1.4	0.14	0.82
	Catfish	< 0.017	< 0.017	2.0	0.47	0.80
	Crappie	< 0.016	0.007	1.6	0.031	0.41
	Shad	< 0.026	0.11	11	0.64	7.0
CRM 10.0	Bass	0.021	0.048	1.5	0.094	0.48
	Bluegill	< 0.014	0.29	1.7	0.12	0.42
	Carp	0.003	0.038	1.3	0.060	0.64
	Shad	< 0.020	< 0.013	9.4	0.37	7.4
CRM 12.0 ^b	Bass	0.014	0.011	0.94	0.12	0.31
	Bluegill	0.056	0.062	7.6	0.91	3.7
	Carp	0.026	0.057	2.8	0.21	1.6
	Catfish	< 0.026	< 0.026	3.9	0.60	2.2
	Crappie	0.018	0.068	1.3	0.17	0.52
	Shad	0.23	1.5	53	2.5	30
CRM 20.8 ^b	Bass	< 0.029	0.045	4.4	0.60	1.4
	Bluegill	0.052	< 0.036	1.6	0.19	0.68
	Carp	0.018	0.078	0.71	0.041	0.38
	Catfish	0.41	0.13	3.8	0.36	3.5
	Crappie	0.18	0.087	1.5	0.029	0.67
	Shad	< 0.027	0.12	4.5	0.89	3.0
CRM 25.0	Bass	< 0.012	0.030	1.4	0.089	0.36
	Bluegill	< 0.035	0.19	2.7	0.19	1.1
	Carp	0.043	< 0.022	0.66	0.017	0.44
	Crappie	< 0.018	0.007	3.2	0.36	0.75
	Shad	0.11	< 0.017	2.2	0.10	0.91

^aComposite of 8–12 fish in each species, except for catfish (1–10 individuals).

^bAverage of quarterly samples.

Because ⁹⁰Sr concentrates in bone (both in fish and human bones) and because it is one of the primary nuclides discharged through the water pathway, a study was conducted to assess the effects of ingesting carp patties, which consist of ground flesh and bone. The carp patties were assumed to contain all bones (including rib and back), but not the head, skin, and fins. Although the practice is not widespread, individuals in the past have been known to consume such fish patties, and currently some commercial processing of fish uses the bones.⁸ Table 29 contains estimates of dose commitments from ingestion of fish patties (flesh and bone) produced from Clinch River carp. Assessment

Table 28. 1984 radionuclide concentrations of beta and gamma emitters in Clinch River fish and dose commitments from ingestion of fish

Location	Species ^a	Concentration (pCi/kg wet wt)			Dose (millirem) ^b
		¹³⁷ Cs	⁶⁰ Co	⁹⁰ Sr	
CRM 2.0	Bass	43	< 1.5	1.2	0.037
	Bluegill	50	6.5	9.9	0.069
	Carp	41	< 1.6	3.3	0.044
	Crappie	120	< 6.7	4.0	0.11
	Shad	79	< 5.3	9.5	0.13
CRM 5.0	Bass	81	< 4.2	2.1	0.071
	Bluegill	62	< 4.3	23	0.12
	Carp	48	< 4.2	7.6	0.064
	Catfish	77	< 3.4	2.0	0.074
	Crappie	44	< 5.6	6.3	0.056
	Shad	89	< 16	11	0.15
CRM 10.0	Bass	91	< 2.4	1.5	0.083
	Bluegill	70	12	13	0.11
	Carp	53	< 3.8	13	0.078
	Shad	74	13	27	0.17
CRM 12.0 ^c	Bass	140	2.7	4.8	0.13
	Bluegill	1100	10	69	1.0
	Carp	49	3.6	8.8	0.075
	Catfish	62	< 2.3	10	0.090
	Crappie	71	< 4.2	5.8	0.079
	Shad	130	11	57	0.57
CRM 20.8 ^c	Bass	1300	14	33	1.1
	Bluegill	770	20	57	0.72
	Carp	530	16	42	0.51
	Catfish	88	24	22	0.18
	Crappie	42	20	27	0.12
	Shad	490	19	96	0.62
	CRM 25.0	Bass	30	< 1.8	6.0
Bluegill	11	< 7.7	9.3	0.058	
Carp	6.6	< 4.4	3.1	0.021	
Crappie	< 3.2	< 4.6	4.6	0.027	
Shad	5.0	< 4.2	7.9	0.039	

^aComposite of 8–12 fish in each species, except for catfish (1–10 individuals).

^bEffective dose equivalent—70-year commitment for all radionuclides in both Tables 27 and 28, based on the consumption of 17 kg of fish per year.

^cAverage of quarterly samples.

Table 29. 1984 dose commitments from ingestion of Clinch River carp patties

Location ^a	No. of samples ^b	Endosteal cells (millirem/kg) ^c				Effective dose equivalent (millirem/kg) ^c			
		Max	Min	Av	95% CC ^d	Max	Min	Av	95% CC ^d
CRM 2.0	1	0.12	0.12	0.12		0.012	0.012	0.012	
CRM 5.0	1	0.24	0.24	0.24		0.022	0.022	0.022	
CRM 10.0	1	0.24	0.24	0.24		0.022	0.022	0.022	
CRM 12.0	4	0.49	0.14	0.36	0.16	0.032	0.015	0.023	0.008
CRM 20.8	4	15	0.29	4.3	7.4	1.4	0.037	0.40	0.66
CRM 25.0	1	0.063	0.063	0.063		0.006	0.006	0.006	

^aSee Fig. 14.

^bComposite of eight to twelve fish per sample.

^cSeventy-year dose commitment.

^d95% confidence coefficient about the average.

of dose commitments from ingestion of fish patties (flesh and bone) is presented in the section "Calculation of Potential Radiation Dose to the Public."

The program for monitoring mercury in fish collected from various locations in the Clinch River was revised in 1984. Previously mercury was measured in a composite sample of several individuals. Samples were collected in 1984 from individual fish to determine the variability of this parameter within fish commonly caught from the river. Table 30 gives a summary of mercury concentrations found in these species. All average values were below the FDA action level (1000 ng/g),⁹ the highest values were from the vicinity of CRM 12.0, the approximate point where Poplar Creek enters the Clinch River (Fig. 18). Average concentrations decreased downstream with increasing distance from CRM 12.0. Values for each species were generally less than those reported in 1983 from the same locations (Table 31), except for bass, carp, and shad from CRM 12.0. Average concentrations of mercury in fish measured by TVA at CRMs 2.0, 6.0, and 11.0 are similar to those reported in Table 30 for CRMs 2.0, 5.0, 10.0, and 12.0.⁶ Mercury concentrations in fish measured by TVA were highest in tissue from East Fork Poplar Creek mile 13.8. Average concentrations of total mercury in largemouth bass and redbreast sunfish from this location exceeded the FDA action level, and those in carp were at the action level. Tissue samples from Bear Creek did not indicate elevated mercury concentrations.

During 1984 analyses were made to determine the PCB concentration in individual fish of several species. Summary concentration values are shown in Table 32. The highest average concentrations of PCBs in Clinch River fish were found in carp, except for those at CRM 10.0 (Fig. 19, Table 32). The average concentrations were about the same in all species at this location, although the highest was in shad. The FDA tolerance level of 2 $\mu\text{g/g}$ for fish and shellfish¹⁰ was exceeded at CRM 5.0 for two of the species, bluegill and carp (Fig. 19). A bend in the river occurs at CRM 5.0, where sediments tend to accumulate. High levels of PCBs in fish may result from sediment deposition in this area. Concentrations of PCBs were measured by TVA in fish flesh from 146 individuals representing 9 species.⁶ Sixteen of these individuals (13 channel catfish and 3 carp) had levels at or above the FDA tolerance. The highest average concentrations were in catfish collected

Table 30. 1984 mercury concentrations in Clinch River fish

Location	Species	No. of fish sampled	Concentration (ng/g wet wt)			95% CC ^a	Percentage of A.L. ^b
			Min	Max	Av		
CRM 2.0	Bass	5	84	300	140	83	14
	Bluegill	5	62	180	97	43	9.7
	Carp	5	24	410	120	150	12
	Crappie	5	21	65	40	16	4.0
	Shad	5	12	24	18	4.1	1.8
CRM 5.0	Bass	5	110	170	140	22	14
	Bluegill	5	84	160	120	30	12
	Carp	12	35	460	200	90	20
	Catfish	1	260	260	260		26
	Crappie	5	20	93	38	28	3.8
	Shad	5	13	25	20	5	2.0
CRM 10.0	Bass	5	58	350	180	96	18
	Bluegill	5	100	360	190	90	19
	Carp	6	66	720	260	210	26
	Crappie	5	81	190	130	48	13
	Shad	5	17	35	25	7.6	2.5
CRM 12.0	Bass	37	60	910	310	57	31
	Bluegill	48	54	750	350	50	35
	Carp	27	21	1,300	410	120	41
	Catfish	1	200	200	200		20
	Crappie	38	15	800	240	67	24
	Shad	28	13	170	65	14	6.5
CRM 20.8	Bass	31	33	270	87	17	8.7
	Bluegill	27	11	260	76	20	7.6
	Carp	28	13	230	86	20	8.6
	Catfish	1	44	44	44		4.4
	Crappie	2	23	27	25	4.0	2.5
	Shad	34	6.0	89	20	5.6	2.0
CRM 25.0	Bass	5	17	33	22	5.8	2.2
	Bluegill	5	14	140	43	49	4.3
	Carp	5	76	190	120	45	12
	Crappie	2	10	38	24	28	2.4
	Shad	5	6	10	8.6	1.5	0.9

^a95% confidence coefficient about the average.

^bPercentage of Food and Drug Administration action level of mercury in fish (1000 ng/g) for the average concentration.

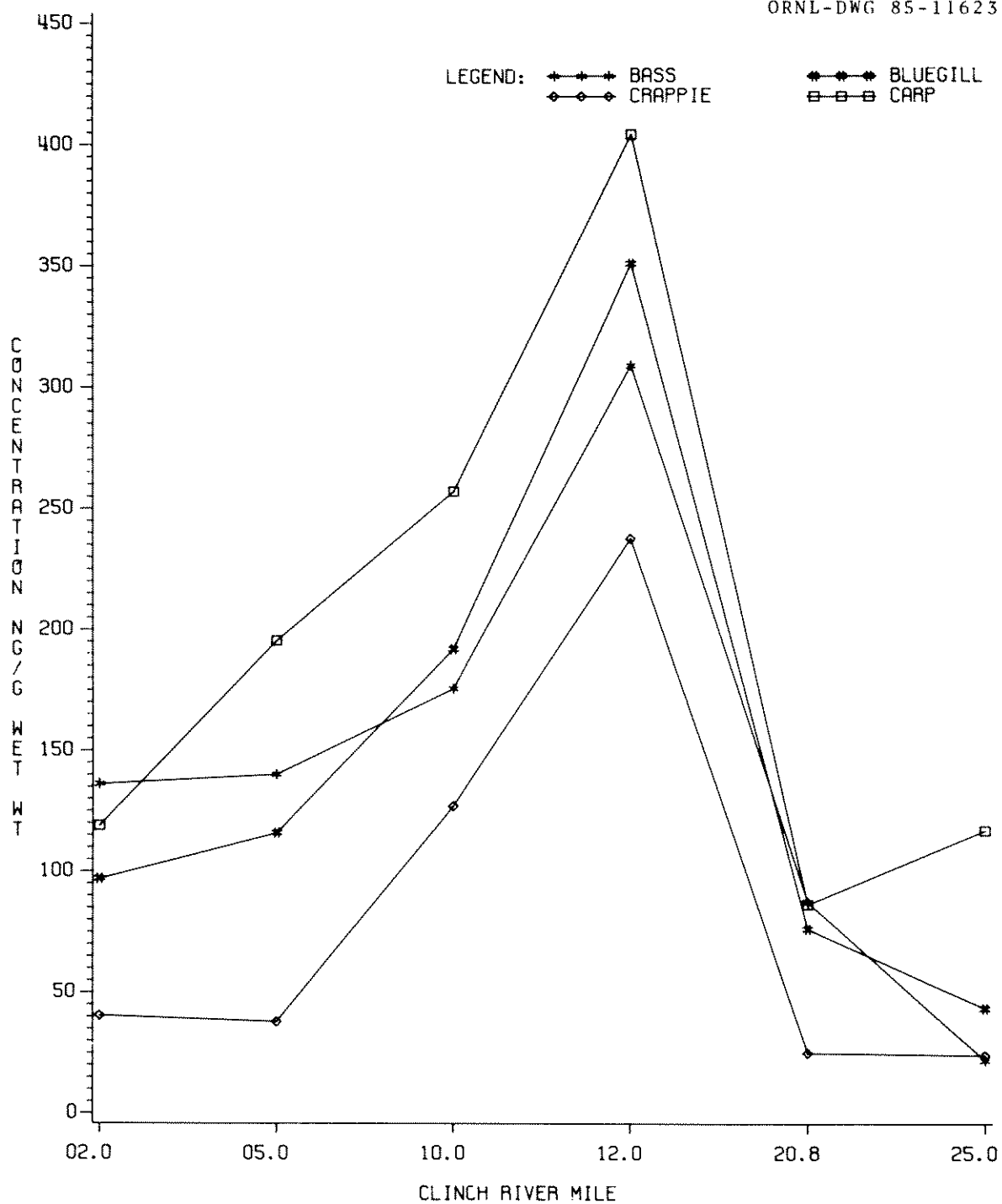


Fig. 18. Mercury in Clinch River fish.

Table 31. Mercury in Clinch River fish, 1978 through 1984

Location	Species ^a	Concentration (ng/g net wt)						
		1978 ^b	1979 ^b	1980	1981	1982	1983	1984 ^c
CRM 5.0	Bass	215	195	157	133	120	120	140
	Bluegill	265	173	220	86	170	240	120
	Carp	357	430	199	289	280	340	200
	Crappie		152	65	401	59		38
	Shad	40	41	25	73	30	30	20
CRM 10.0	Bass				237	200	340	180
	Bluegill				257	150	170	190
	Carp				487	210	280	260
	Crappie				131	99	160	130
	Shad				44	29	50	25
CRM 12.0	Bass	110	370	430	43	220	190	310
	Bluegill	123	380	470	18	560	350	350
	Carp	740	1530	102	575	530	340	410
	Crappie	53	320	122	102	180	270	240
	Shad	70	100	18	23	190	20	65
CRM 20.8 ^d	Bass	233	113	99	144	99	135	87
	Bluegill	78	232	219	117	160	110	76
	Carp	278	197	193	108	240	220	86
	Crappie	77	201	45	253 ^e	43		25
	Shad	32	30	24	44	19	35	20
CRM 25.0	Bass		103	11	16	13	100	22
	Bluegill		56	59	57	34	30	43
	Carp		120	109	124	97	90	120
	Crappie			21	30			24
	Shad		14	7	12	7	10	8.6

^aFor years 1978 through 1983, ten fish from each species were composited. During 1984, concentrations in individual fish were measured and the average is reported here.

^bCorrected data—data in the 1978 and 1979 Environmental Monitoring Reports were too low because of an error in converting data to the proper weight basis.

^cAverage of individual fish.

^dAverage of quarterly samples.

^eAverage of three quarterly samples. Crappie were not collected in the second quarter.

Table 32. 1984 PCB concentrations in Clinch River fish

Location	Species	No. of fish sampled	Concentration (ng/g wet wt)			95% CC ^a	Percentage of A.L. ^b
			Min	Max	Av		
CRM 2.0	Bass	5	< 0.10	0.39	< 0.21	0.10	< 10
	Bluegill	5	< 0.10	0.49	< 0.27	0.15	< 14
	Carp	4	0.18	4.2	1.4	1.9	70
	Crappie	5	< 0.10	0.26	< 0.16	0.06	< 8.0
	Shad	5	< 0.10	0.54	< 0.23	0.16	< 12
CRM 5.0	Bass	5	< 0.10	0.47	< 0.25	0.13	< 12
	Bluegill	5	0.11	9.1	2.4	3.4	120
	Carp	5	0.84	4.9	3.0	1.5	150
	Catfish	1	1.1	1.1	1.1		55
	Crappie	5	< 0.10	0.29	< 0.17	0.09	< 8.5
	Shad	5	0.13	0.57	0.31	0.15	16
CRM 10.0	Bass	5	0.19	0.30	0.23	0.04	12
	Bluegill	5	0.05	0.43	0.24	0.14	12
	Carp	4	0.15	0.33	0.21	0.08	10
	Crappie	5	0.08	0.12	0.10	0.02	5.0
	Shad	5	0.04	0.72	0.30	0.23	15
CRM 12.0	Bass	38	0.09	1.2	0.29	0.07	14
	Bluegill	46	0.06	8.2	0.58	0.35	29
	Carp	43	0.06	12	1.5	0.66	75
	Catfish	1	0.08	0.08	0.08		4.0
	Crappie	31	0.04	1.7	0.26	0.11	13
	Shad	41	0.13	2.4	1.0	0.22	50
CRM 20.8	Bass	36	0.04	3.2	0.31	0.18	16
	Bluegill	36	0.01	1.2	0.18	0.08	9.0
	Carp	46	0.03	3.7	0.70	0.25	35
	Catfish	1	0.32	0.32	0.32		16
	Crappie	2	0.02	0.02	0.02	0.00	1.0
	Shad	41	0.02	1.4	0.36	0.10	18
CRM 25.0	Bass	4	< 0.10	0.44	< 0.24	0.17	< 12
	Bluegill	5	< 0.10	< 0.10	< 0.10	0.00	< 5.0
	Carp	5	0.17	0.69	0.39	0.19	20
	Crappie	2	< 0.10	< 0.10	< 0.10	0.00	< 5.0
	Shad	5	< 0.10	0.29	< 0.14	0.08	< 7.0

^a95% confidence coefficient about the average.

^bPercentage of Food and Drug Administration tolerance for PCBs in fish (2 µg/g wet wt) for the average concentration.

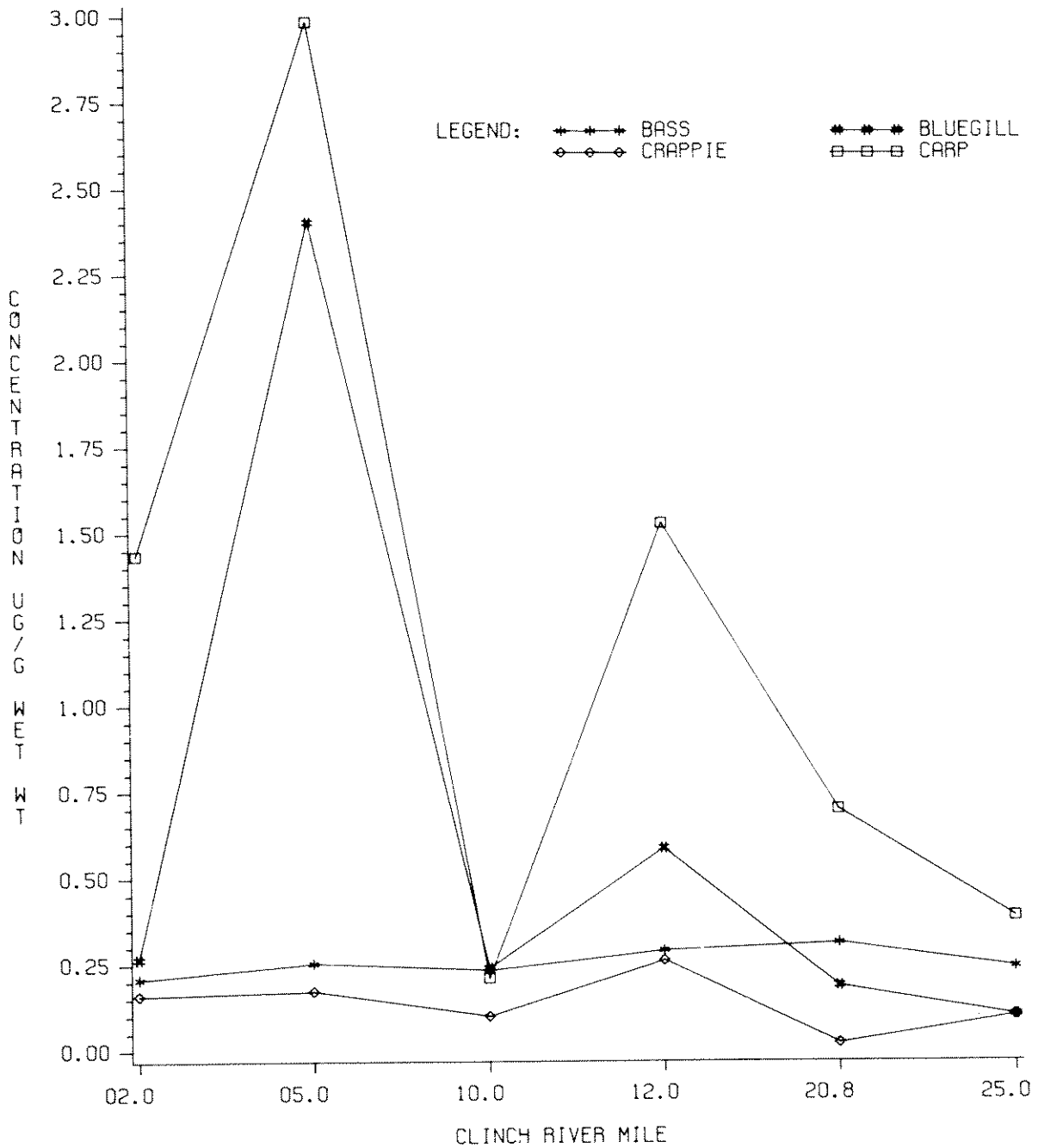


Fig. 19. PCBs in Clinch River fish.

from White Oak Creek mile 0.2; the next highest, from East Fork Poplar Creek mile 13.8. These data are difficult to compare with those in Table 32 because only three catfish were collected during 1984 by the Oak Ridge facilities. All other values were below the tolerance level.

Deer

Deer are frequently killed by automobiles on or near the ORR (see "Special Studies" section, "Oak Ridge Reservation Deer Population"). Samples from 76 deer were analyzed in 1984, 7 of

which were not killed on the Reservation. Summary data of ORR and off-site radionuclide and mercury concentrations in liver, muscle, and thyroid samples are presented in Table 33. No significant differences between ORR and off-site concentrations of radionuclides or mercury were found.

Table 33. Summary of 1984 levels of radionuclides and mercury in deer samples

Analysis	Sample type	Location	No. of samples	Concentration (pCi/g wet wt)			95% CC ^a
				Max	Min	Av	
⁶⁰ Co	Liver	Reservation	8	0.38	0.019	0.085	0.085
¹³⁷ Cs	Liver	Reservation	68	2.5	< 0.002	< 0.10	0.08
		Off-site	7	0.68	< 0.011	< 0.17	0.18
¹³⁷ Cs	Muscle	Reservation	69	5.1	< 0.004	< 0.24	0.17
		Off-site	7	0.38	< 0.011	< 0.14	0.11
¹³⁷ Cs	Thyroid	Reservation	7	0.76	0.035	0.32	0.22
¹³¹ I	Thyroid	Reservation	62	20	< 0.057	< 1.8	0.86
		Off-site	3	0.54	< 0.19	< 0.31	0.23
⁴⁰ K	Liver	Reservation	24	5.8	1.7	2.8	0.41
		Off-site	4	2.7	2.2	2.4	0.21
⁴⁰ K	Muscle	Reservation	25	3.3	1.9	2.9	0.11
		Off-site	4	3.6	2.8	3.1	0.34
⁹⁰ Sr	Muscle	Reservation	28	0.10	< 0.001	< 0.015	0.008
		Off-site	6	0.01	< 0.002	< 0.006	0.004
Hg ^b	Muscle	Reservation	29	14 ^b	1.2 ^b	3.0 ^b	0.87
		Off-site	6	9.7 ^b	1.1 ^b	3.7 ^b	2.6

^a95% confidence coefficient about the average.

^bHg: ng/g wet weight.

Insects

Insects represent a means by which radioactive materials may be transported through the food chain. Collection devices, consisting of ultraviolet lights to attract the insects and several traps, were placed adjacent to White Oak Lake at White Oak Dam and at a control site near Powell, Tennessee, to collect insects for ¹³⁷Cs analysis. Collections were made for a 12-week period, June through September 1984. Traps were emptied several times a week, and the insects were placed in plastic bags, labeled with date and location, and frozen for later analyses. Insect samples were composited monthly and placed in counting containers for gamma spectrometric analysis.

Results are presented in Table 34. Concentrations of ¹³⁷Cs in the insects collected from White Oak Dam are significantly higher than those in the controls. Although the insects were not identified by species, the bulk of the radioactivity was probably from immature-stage insects that live in aquatic environments and emerge as adult terrestrial insects.

Table 34. Cesium-137 in insects collected during 1984 at a control location and at White Oak Dam

Location	No. of samples	Concentration (pCi/g wet wt)			95% CC ^a
		Max	Min	Av	
Control ^b	12	0.5	< 0.027	< 0.14	0.08
White Oak Dam	12	47	1.1	13	8.0

^a95% confidence coefficient about the average.

^bTop of Copper Ridge near Powell, Tennessee.

Honey

There are several commercial beekeepers on the DOE ORR. To assess the uptake of radioactivity in honey, experimental hives were established at six sites in or around ORNL during 1984. These sites included (1) control hives in Oak Ridge, near the intersection of Florida and Tennessee avenues; (2) hives north of Melton Branch just below the High Flux Isotope Reactor facility; (3) hives adjacent to the pond at the old shale hydrofracture facility; (4) hives at the old gas-cooled reactor site at ORNL; (5) hives on the northern side of White Oak Lake; and (6) hives southwest of the south parking area at ORNL. To achieve statistically valid monitoring, the sampling program used during 1983 was modified so that (1) samples were collected during the spring, early summer, and late summer and (2) three hives from each site were sampled. This required adding one hive each at the White Oak Lake, shale fracture, and ORNL sites. By so designing the sampling program, estimates of variability at each site may be calculated. To establish three functional hives at each site, a number of wild swarms were captured and placed in the experimental hives.

The scope of the sampling program has been broadened so that sources of contamination and accumulation pathways through the food chain—from source to bees to honey to humans—may be identified. Locations where the foragers from the various hives collect food and water are pinpointed, and materials are analyzed for contaminants. Flowers, pollen, water, bees, and honey have been collected and analyzed for ¹³⁷Cs, ⁶⁰Co, and ³H.

Samples of whole honey, water extracted from whole honey, and surface water from areas adjacent to or near the hives were collected and analyzed for ³H (Table 35). The ³H concentration was lowest in whole-honey samples collected from the control hives and highest in those samples collected in the hives nearest Melton Branch. The ³H concentration in water samples collected from Melton Branch was lower than in water sources near the control hives, suggesting that the bees at that location were watering from a more highly contaminated source than the Branch itself.

Table 36 shows the concentration of ¹³⁷Cs in water, forage flowers, pollen, bees, and honey collected from the various hive sites. The shale fracture site had the highest concentrations of ¹³⁷Cs in all media, generally an order of magnitude greater than at any other site. The White Oak Lake and ORNL sites also appear to have substantially greater concentrations than the control site.

The occurrence of ⁶⁰Co in the samples was somewhat sporadic (Table 37). The bees collected from the Melton Branch site had the highest concentration, as did the honey from this site.

The 70-year committed effective dose equivalent from consuming 1 kg of honey produced from the experimental hives was calculated based on the average radionuclide concentrations at each site (Table 38).

Table 35. 1984 concentrations of tritium in water, honey water, and whole honey near ORNL^a

Location	Sample type	No. of samples	Tritium concentration (pCi/L)		
			Max	Min	Av
Control residential, East Oak Ridge	Water	2	1,900	1,800	1,800
	Honey water	3	< 1,600	< 1,600	< 1,600
	Honey ^b	3	1,900	1,100	1,600
Melton branch below HFIR	Water	2	2,200	1,100	1,600
	Honey water	2	66,000	51,000	59,000
	Honey ^b	3	180,000	110,000	140,000
Shale fracture site	Water	1			66,000
	Honey water	2	110,000	66,000	86,000
	Honey ^b	2	140,000	99,000	120,000
Near old gas-cooled reactor site	Water	2	2,000	1,100	1,500
	Honey water	1			5,400
	Honey ^b	1			5,100
White Oak Lake northside	Water	2	460,000	440,000	450,000
	Honey water	1			24,000
	Honey ^b	2	25,000	21,000	23,000
ORNL: SW of south parking lot	Water	2	87,000	6,500	46,000
	Honey water	2	15,000	10,000	13,000
	Honey ^b	3	24,000	14,000	17,000

^aHoney water extracted from whole honey; honey from bee hives at or near ORNL. All water samples taken from stream near hive.

^bpCi/kg.

Table 36. 1984 concentrations of ¹³⁷Cs in natural samples in or around beehives near ORNL

Location	Sample type	No. of samples	¹³⁷ Cs concentration (pCi/kg)		
			Max	Min	Av
Control residential, East Oak Ridge	Water ^a	2	2	1	1
	Flowers	2	27	20	24
	Pollen	3	65	19	34
	Bees	6	23	3	11
	Honey	6	21	2	6
Melton Branch below HFIR	Water ^a	2	13	7	10
	Flowers	2	90	54	72
	Pollen	5	1,500	110	750
	Bees	6	220	20	85
	Honey	5	15	4	9
Shale fracture site	Water ^a	1			200,000
	Flowers	2	9,200	840	5,000
	Pollen	5	6,800	4,300	5,400
	Bees	4	61,000	1,400	24,000
	Honey	4	5,900	1,100	2,700

Table 36. (continued)

Location	Sample type	No. of samples	¹³⁷ Cs concentration (pCi/kg)		
			Max	Min	Av
Near old gas-cooled reactor site	Water ^a	2	4	1	2
	Flowers	2	40	19	29
	Pollen	2	66	43	55
	Bees	2	15	7	11
	Honey	2	11	6	9
White Oak Lake northside	Water ^a	2	46	25	35
	Flowers	2	69	68	68
	Pollen	4	4,200	320	1,600
	Bees	3	140	29	69
	Honey	3	97	31	55
ORNL: SW of south parking lot	Water ^a	2	29	3	16
	Flowers	2	1,500	68	790
	Pollen	4	3,000	160	1,600
	Bees	4	620	170	430
	Honey	5	200	41	93

^apCi/L.Table 37. 1984 concentrations of ⁶⁰Co in natural samples in or around beehives near ORNL

Location	Sample type	No. of samples	⁶⁰ Co concentration (pCi/kg)		
			Max	Min	Av
Control residential, East Oak Ridge	All		Not detected		
Melton Branch below HFIR	Flowers	1			1,700
	Bees	6	33,000	1,300	7,900
	Honey	4	100	14	44
Shale fracture site	Water ^a	1			730
	Bees	4	430	120	230
	Honey	4	22	4	13
Near old gas-cooled reactor site	All		Not detected		
White Oak Lake northside	Water ^a	1			23,000
	Bees	3	110	61	91
	Honey	1			19
ORNL: SW of south parking lot	Water ^a	1			16
	Bees	4	120	69	93
	Honey	1			11

^apCi/L.

Table 38. Seventy-year committed effective dose equivalent to an adult from ingestion of honey produced near ORNL and other locations for 1984

Location	Dose ^a (millirem/kg)
Control: residential, East Oak Ridge	0.00040
Melton Branch below HFIR	0.014
Shale fracture site	0.15
Near old gas- cooled reactor site	0.00084
White Oak Lake: northside	0.0049
ORNL: SW of south parking lot	0.0059

^a70-year dose commitment.

Vegetation

Samples of grass were collected semiannually from the perimeter and annually from the remote air sampling stations (Figs. 2 and 3). At each station, the grass from five 0.2-m² plots was collected. One sample was taken from a plot beside the station, and the other four were taken from plots 15 m from the station at right angles to each other. The grass from each station was then dried, composited, and analyzed by gamma spectrometry and radiochemical techniques for a variety of radionuclides. These results are presented in Table 39.

Since 1981 the average concentrations of ¹³⁷Cs, ⁹⁰Sr, and uranium in grass have generally decreased both at the perimeter and remote sampling stations (Figs. 20–24). Concentrations of these radionuclides in grass are probably the result of worldwide fallout from the weapons testing during 1981. Uranium concentrations appear to be enriched at both the perimeter and remote sites but are probably not attributable to plant operations. All of the remote stations (rather than just those in the predominant wind direction) appear to indicate enriched uranium concentrations.

Samples of pine needles and grass were collected from 14 areas around ORGDP and from 7 areas around the Y-12 Plant (Fig. 2). These samples were analyzed for uranium and fluoride. Fluorometric analysis is used for the determination of uranium, and colorimetric analysis is used for the determination of fluorides. Data on the uranium and fluoride contents in vegetation are presented in Tables 40 and 41. The fluoride concentration in grass at all sampling points was below the 30- μ g/g level considered to produce no adverse effects when ingested by cattle.¹¹ Around ORGDP, the highest uranium concentration in grass was at station VS-19 near the contaminated

Table 39. 1984 radioactivity in grass samples from perimeter and remote monitoring stations

Station ^a	Concentration (pCi/g dry wt)						
	⁹⁰ Sr	¹³⁷ Cs	²³⁹ Pu	²³⁸ Pu	²³⁸ U	²³⁵ U	²³⁴ U
<i>Perimeter^b</i>							
HP-32	0.17	0.037	0.0019	0.0002	0.043	0.0057	0.097
HP-33	0.14	< 0.020	0.0007	< 0.0003	0.006	0.0036	0.042
HP-34	0.07	< 0.034	0.026	0.0076	0.018	0.0043	0.036
HP-35	0.04	0.034	0.0003	< 0.0003	0.011	0.0063	0.042
HP-36	0.11	< 0.023	< 0.0003	< 0.0003	0.012	0.0047	0.036
HP-37	0.15	0.041	0.0020	0.0006	0.012	0.0017	0.027
HP-38	0.13	< 0.019	0.0046	0.0005	0.007	0.0036	0.036
HP-39	0.14	< 0.042	0.0015	0.0002	0.013	0.0033	0.069
HP-40	0.26	< 0.023	0.0015	< 0.0003	0.068	0.032	0.59
HP-41	0.17	0.038	< 0.0008	0.0026	0.012	0.0077	0.079
Avg.	0.14	< 0.031	< 0.0041	< 0.0013	0.019	0.0074	0.11
<i>Remote^c</i>							
HP-51	0.18	< 0.010	0.0023	< 0.0003	0.0081	0.0010	0.022
HP-52	0.35	< 0.030	0.0012	0.0013	0.0024	0.0001	0.0070
HP-53	0.24	0.016	0.0012	< 0.0003	0.010	0.0012	0.017
HP-55	0.24	< 0.017	0.0007	< 0.0003	0.0040	0.0007	0.0097
HP-56	0.46	0.026	< 0.0008	< 0.0005	0.0035	< 0.0003	0.0059
HP-57	0.11	< 0.013	< 0.0008	< 0.0008	0.0020	0.0015	0.011
HP-58	0.15	< 0.020	< 0.0019	< 0.0016	0.011	< 0.0002	0.030
Avg.	0.25	< 0.019	< 0.0013	< 0.0007	0.006	< 0.0007	0.015

^aSee Figs. 2 and 3.

^bAverage of two samples except for HP-32 (one sample). Limits of detection vary with sample size and other factors.

^cOne sample. Limits of detection vary with sample size and other factors.

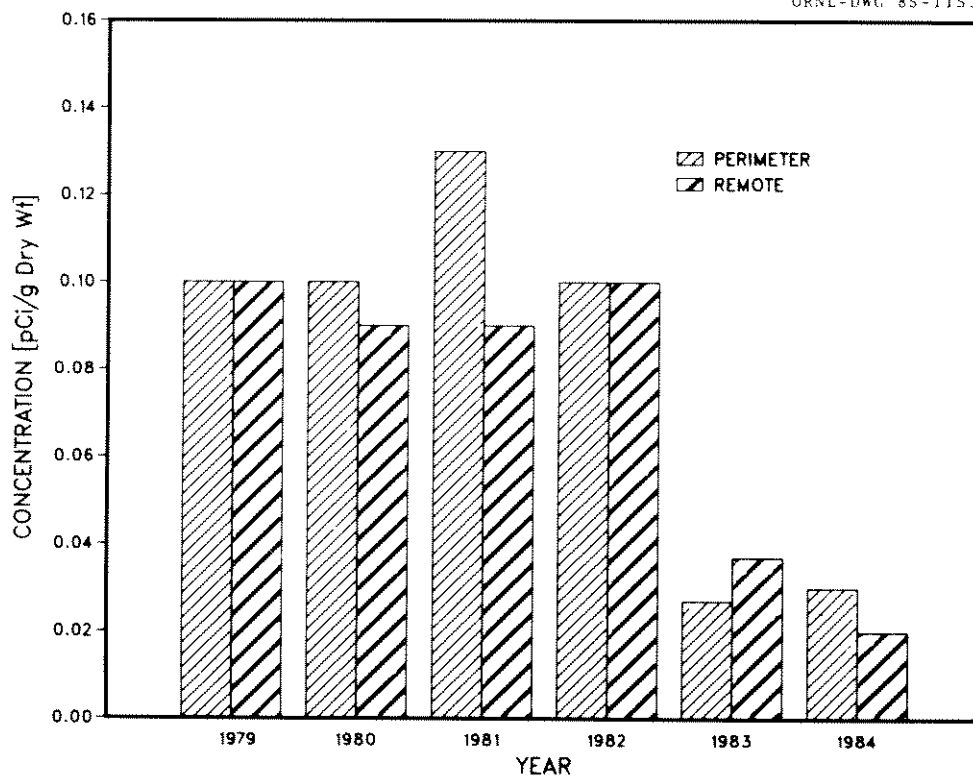


Fig. 20. Cesium-137 in grass samples.

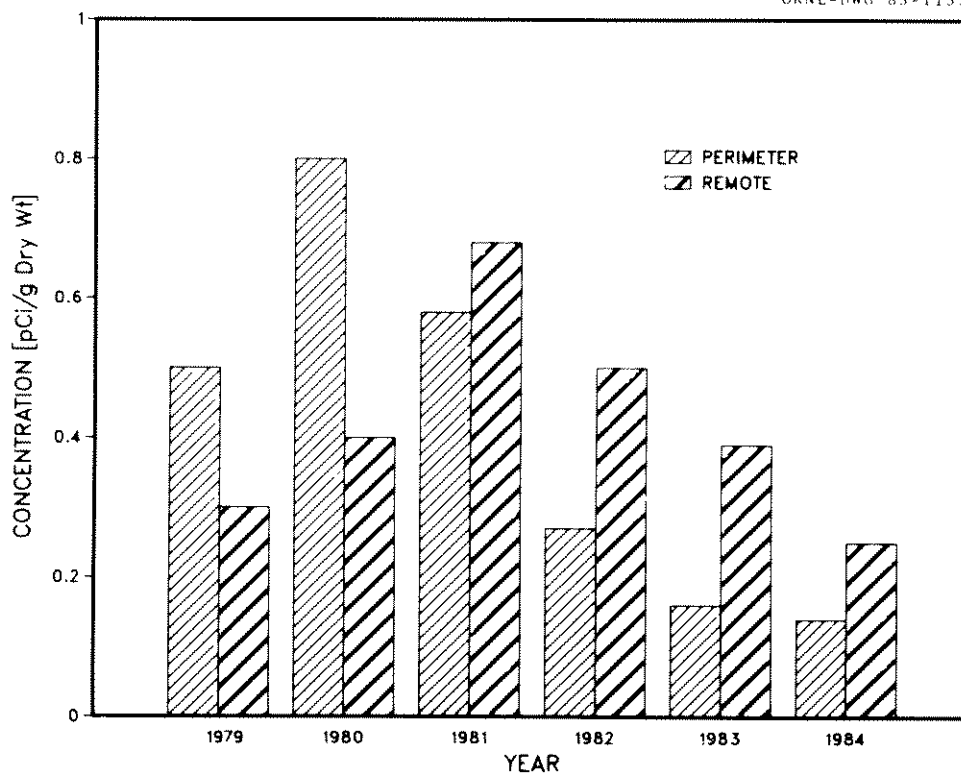


Fig. 21. Strontium-90 in grass samples.

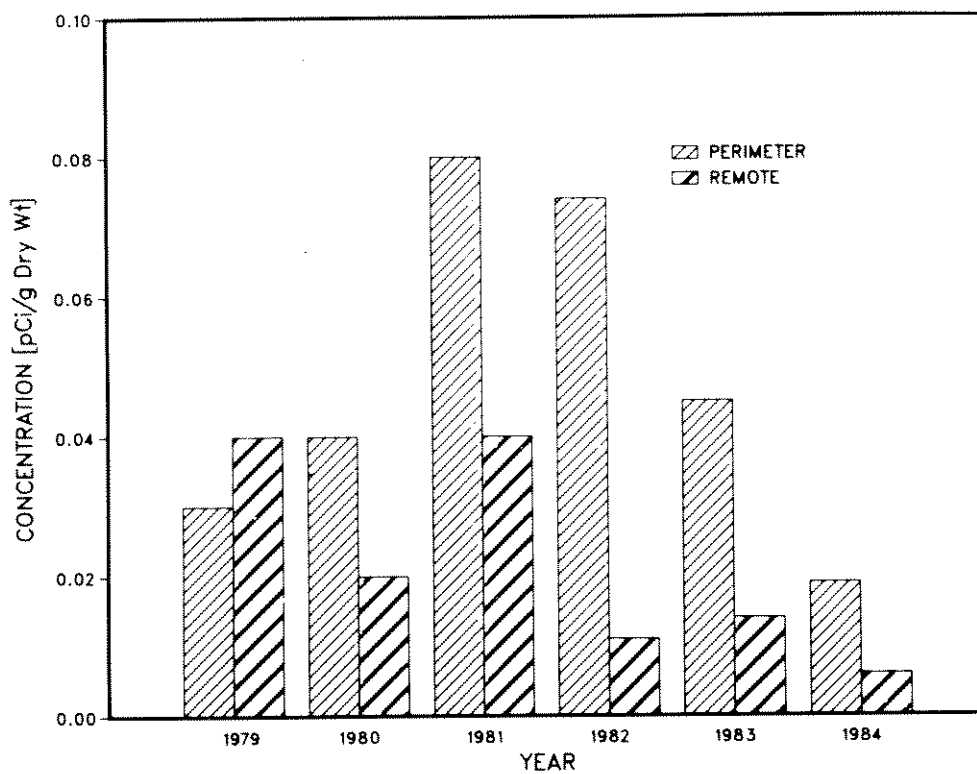


Fig. 22. Uranium-238 in grass samples.

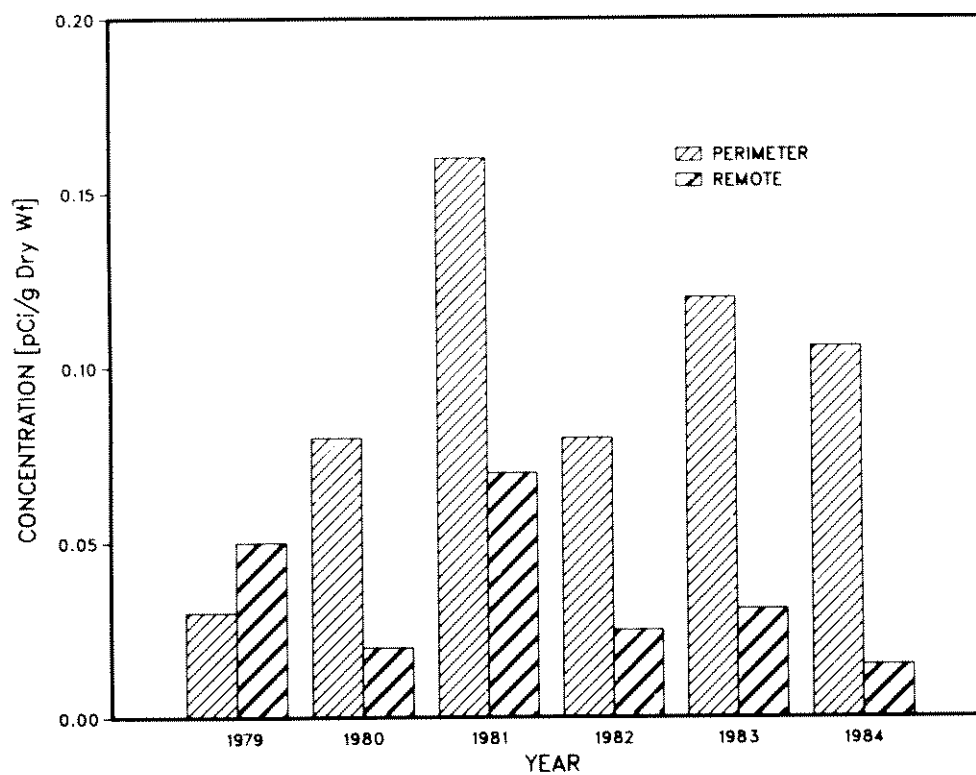


Fig. 23. Uranium-234 in grass samples.

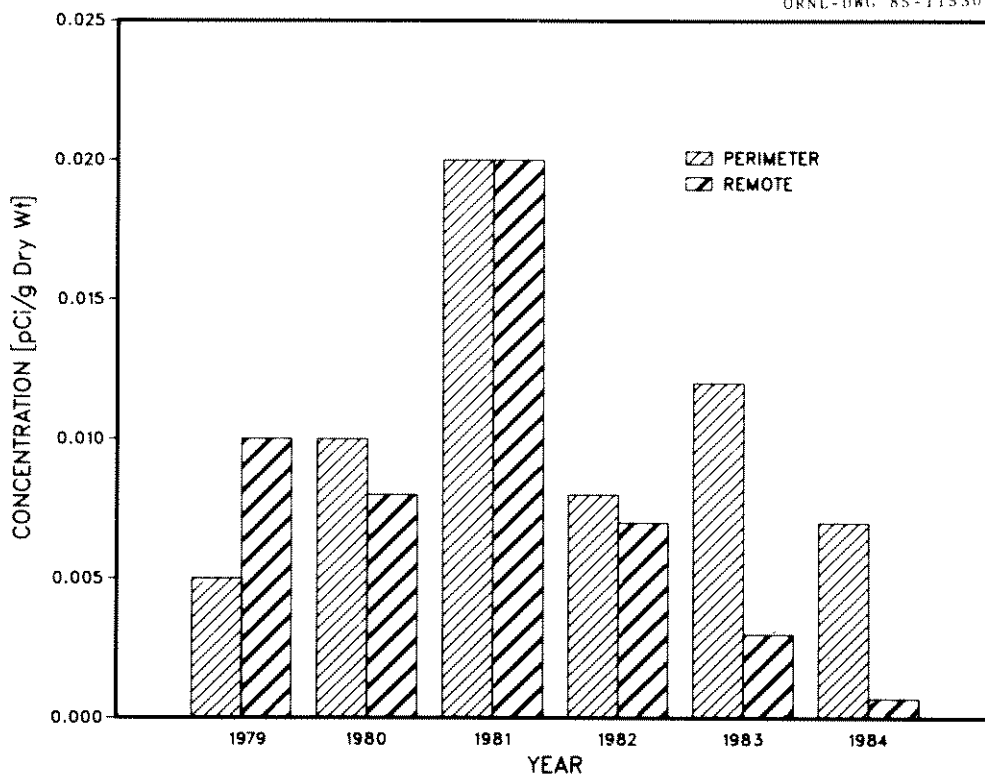


Fig. 24. Uranium-235 in grass samples.

scrap yard (Table 40). Uranium concentrations in grass and pine needles at stations around Y-12 were highest at stations in the downwind direction from Y-12 (Table 41).

The average background concentration of total uranium in grass, based on the average of the values from remote monitoring stations, was about $0.02 \mu\text{g/g}$ dry wt. There are no background concentrations for uranium in pine needles. Because station V-7 (Fig. 2) is not in the prevailing wind direction from the Y-12 Plant and is sufficiently removed from the Y-12 Plant, concentrations measured at this station might be used for comparison with concentrations from other stations. In general, concentrations were higher in grass than in pine needles among all stations. Uranium and fluoride concentrations were slightly higher in vegetation during 1984 than in 1983.

Soil and Sediment

Soil

Soil samples were collected from the same plots where the grass samples were collected. Two 8-cm-diam by 5-cm-depth cores were taken from each of the five plots, and a composite of the ten cores for each station was analyzed for the presence of radionuclides. Results are given in Table 42.

The trend toward decreasing concentrations of ^{137}Cs and ^{90}Sr in the grass at the perimeter and remote stations is apparent in soil samples collected from the same sites (Figs. 25 and 26). The soil concentrations of ^{234}U and ^{238}U , however, have remained somewhat constant, whereas ^{235}U , having shown an overall increase through 1983, has declined in samples collected for 1984 (Figs. 27-29).

Table 40. 1984 vegetation sampling data—ORGDP^a

Station ^b	F ⁻ concentration ($\mu\text{g/g}$ dry wt)		U (total) concentration ^c ($\mu\text{g/g}$ dry wt)	
	Grass	Pine needles	Grass	Pine needles
VS-1	8.9		0.23	
VS-5	5.5	4.0	0.09	0.11
VS-8	6.5	4.0	0.12	0.15
VS-9	6.9	6.0 ^d	0.17	0.09 ^d
VS-10	17 ^d	10	0.12 ^d	0.13
VS-11	8.5	4.5	0.11	0.15
VS-13	12 ^d	3.3 ^d	3.6 ^d	0.13 ^d
VS-15	18		0.10	
VS-16	7.4	5.7	0.15	0.11
VS-17	9.0 ^d	5.0 ^d	0.12 ^d	0.05 ^d
VS-18	8.9		0.17	
VS-19	5.0		5.2	
VS-20	4.0		1.3	
VS-21	4.0		0.08	

^aA 30- $\mu\text{g/g}$ dry weight of fluoride in gram is considered to produce no adverse effect when ingested by cattle. Background concentrations of uranium in grass are about 0.02 $\mu\text{g/g}$ dry weight.

^bSee Fig. 2.

^cConcentration based on two sample collections.

^dConcentration based on one sample collection.

Table 41. 1984 vegetation sampling data—Y-12 Plant^a

Station ^b	F ⁻ concentration ^c ($\mu\text{g/g}$ dry wt)		U (total) concentration ^c ($\mu\text{g/g}$ dry wt)	
	Grass	Pine needles	Grass	Pine needles
V-1	4.0	2.0	0.060	0.023
V-2	3.0	3.0	0.051	0.053
V-3	4.0	4.0	0.041	0.085
V-4	3.0	3.0	0.075	0.072
V-5	3.0	2.0	0.076	0.048
V-6	4.0	3.0	0.026	0.053
V-7	4.0	3.0	0.037	0.027

^aA 30- $\mu\text{g/g}$ dry weight of fluoride in gram is considered to produce no adverse effect when ingested by cattle. Background concentrations of uranium in grass are about 0.02 $\mu\text{g/g}$ dry weight.

^bSee Fig. 2.

^cConcentration based on a single sample collection.

Table 42. Radioactivity in soil samples from perimeter and remote monitoring stations for 1984

Station ^a	Concentration (pCi/g dry wt)						
	⁹⁰ Sr	¹³⁷ Cs	²³⁹ Pu	²³⁸ Pu	²³⁸ U	²³⁵ U	²³⁴ U
<i>Perimeter^b</i>							
HP-32	0.15	0.73	< 0.003	< 0.003	0.49	0.12	0.86
HP-33	0.20	1.3	0.016	0.001	0.27	0.04	0.38
HP-34	0.12	0.62	0.005	0.001	0.17	0.05	0.28
HP-35	0.04	0.36	0.008	0.002	0.30	0.04	0.43
HP-36	0.14	0.90	0.008	< 0.001	0.25	0.04	0.34
HP-37	0.17	0.77	0.010	0.001	0.21	0.05	0.31
HP-38	0.21	0.90	0.013	0.001	0.20	0.03	0.26
HP-39	0.29	0.84	0.011	0.001	0.39	0.05	0.57
HP-40	0.14	0.41	0.006	< 0.002	0.77	0.18	2.4
HP-41	0.30	0.14	0.005	< 0.001	0.31	0.06	0.46
Av	0.18	0.70	< 0.009	< 0.001	0.33	0.06	0.62
<i>Remote^c</i>							
HP-51	0.21	1.0	0.013	< 0.003	0.20	0.059	0.27
HP-52	0.081	1.1	0.010	0.002	0.35	0.076	0.49
HP-53	0.16	1.1	< 0.0003	< 0.0003	0.54	0.032	0.65
HP-55	0.32	1.5	0.015	< 0.001	0.38	0.092	0.46
HP-56	0.10	0.89	< 0.003	< 0.003	0.19	0.007	0.20
HP-57	0.24	1.6	0.030	< 0.0005	0.38	0.078	0.41
HP-58	0.26	0.92	0.0024	< 0.003	0.32	0.062	0.32
Av	0.20	1.2	< 0.011	< 0.002	0.34	0.058	0.40

^aSee Figs. 2 and 3.

^bAverage of two samples, except for HP-32 (single sample).

^cSingle sample.

Uranium concentrations in soil appear to be enriched at the perimeter stations but not at the remote stations (Table 42). The results shown in Table 42 indicate that samples from stations HP-32 and HP-40 had higher levels of uranium than at other perimeter or remote stations. Stations HP-32 and HP-40 are close to and in the predominant downwind direction from Y-12, and the data indicate that Y-12 contributed to the uranium in the samples at these points. In all other results, natural radioactivity and worldwide fallout from past weapons tests predominated.

For radionuclides measured in soil and grass, concentrations were higher in the soil than in grass (Tables 39–43), except for ⁹⁰Sr. The high water solubility of ⁹⁰Sr and its consequent uptake by vegetation may be responsible for this result. For other radionuclides, the higher soil concentrations may result from long residence time in soil and the tendency of radionuclides to bind to particulates.

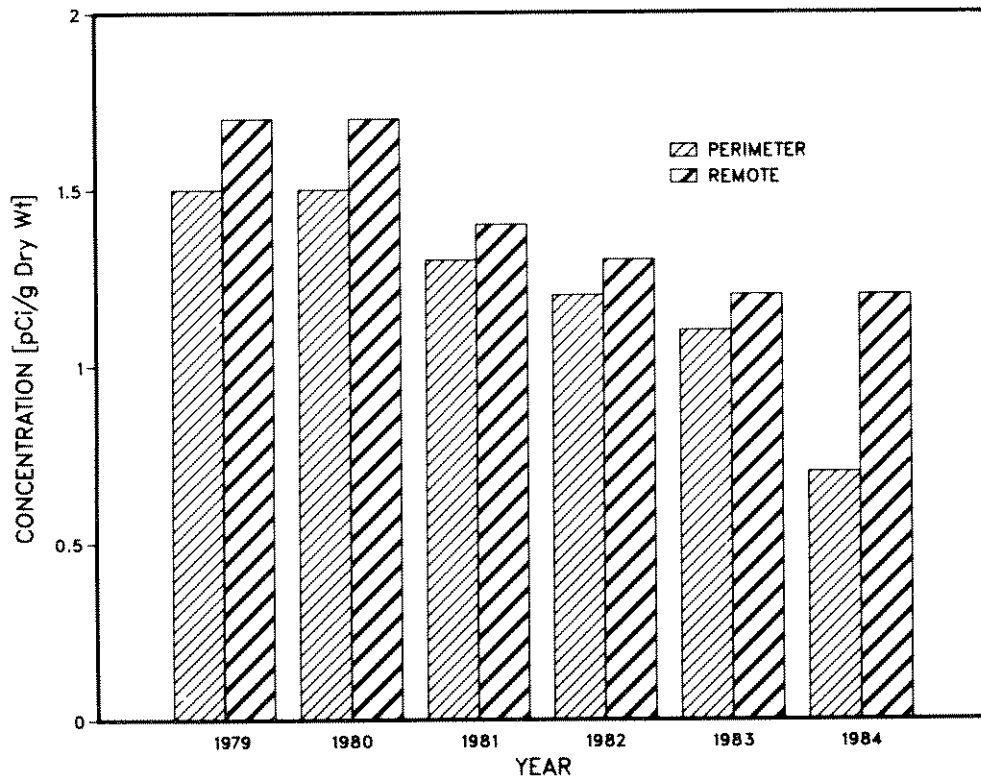


Fig. 25. Cesium-137 in soil samples.

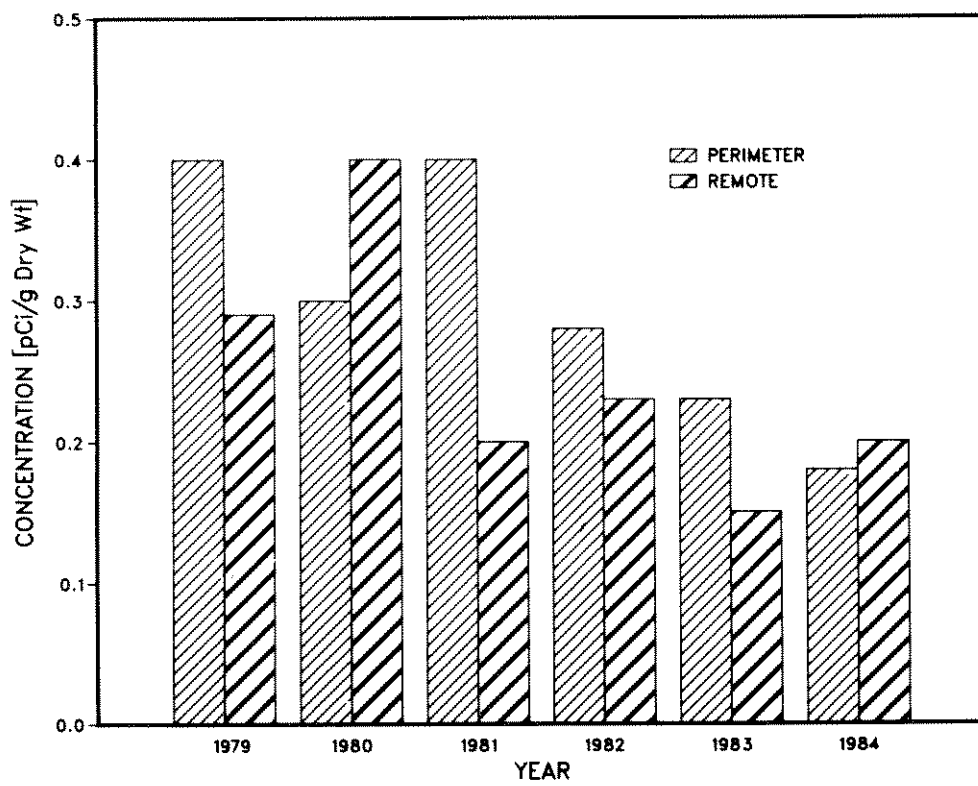


Fig. 26. Strontium-90 in soil samples.

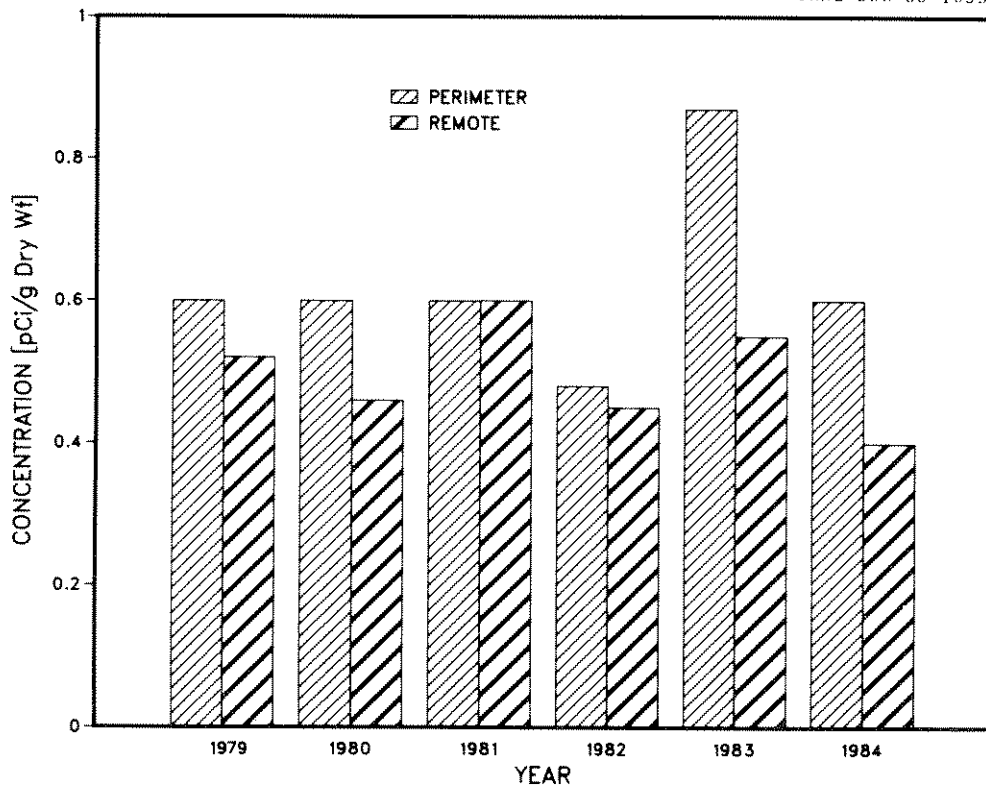


Fig. 27. Uranium-234 in soil samples.

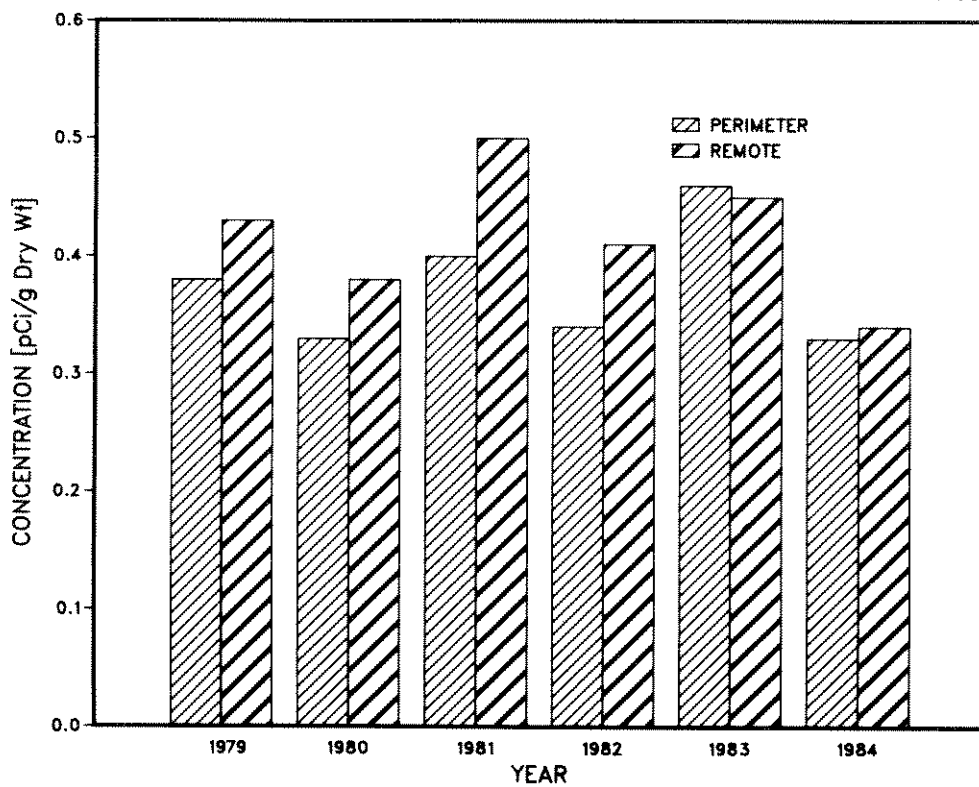


Fig. 28. Uranium-238 in soil samples.

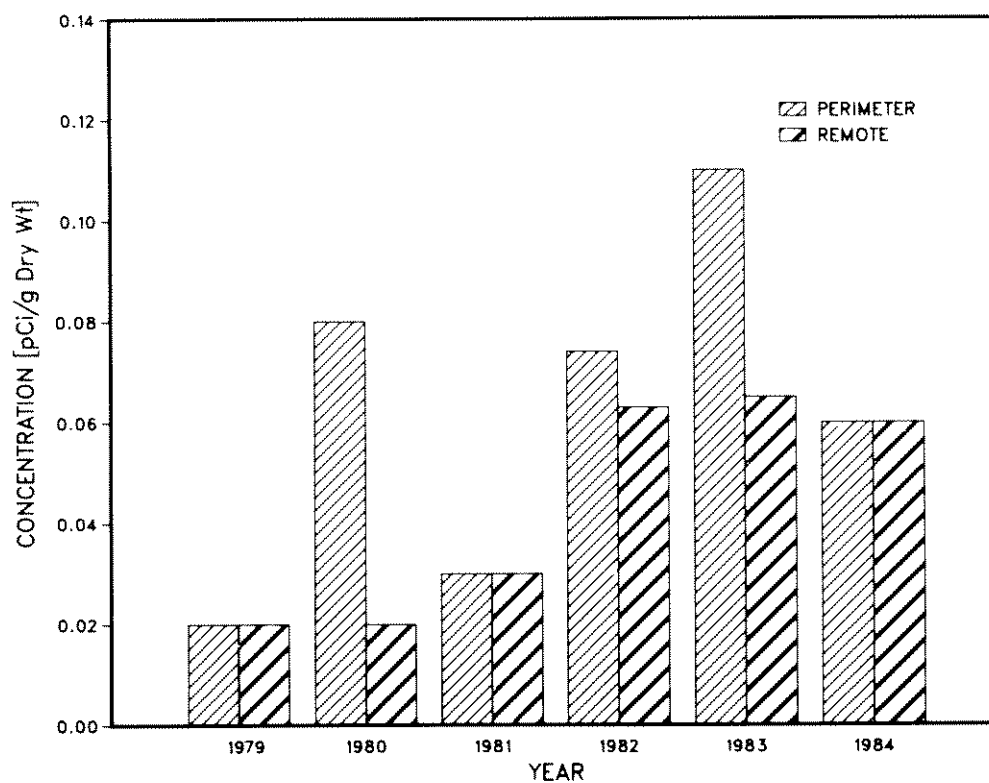


Fig. 29. Uranium-235 in soil samples.

Table 43. 1984 soil sampling data around ORGDP
(Upper 1 cm of soil column)

Station ^a	F ⁻ concentration ^b ($\mu\text{g/g}$ dry wt)	U (total) concentration ^b ($\mu\text{g/g}$ dry wt)
VS-1	420	2.7
VS-5	130	15
VS-8	180	4.9
VS-9	360	4.7
VS-10	410	3.6
VS-11	440	4.6
VS-13	390	2.9
VS-15	200	25
VS-16	310	2.2
VS-17	480	2.6
VS-18	280	7.0
VS-19	850	400
VS-20	630	24
VS-21	230	6.0

^aSee Fig. 2.

^bConcentration based on semiannual collections in February and September.

Soil samples were collected semiannually around ORGDP to determine concentrations of uranium and fluoride present at the 14 locations where samples of pine needles and grass are collected (Fig. 2). About 450 g (1 lb) of soil is collected from each location at a maximum depth of 1 cm. Fluorometric analysis is used to determine uranium levels, and colorimetric analysis is used to determine fluoride levels. Data on the fluoride and uranium content of the soil around ORGDP are listed in Table 43.

The fluoride concentrations in soil around ORGDP have increased since 1983 at about one-half of the stations. Uranium concentrations have increased at 5 of the 14 stations. Average background uranium concentrations in soil, as measured at the remote stations, was about 1.1 $\mu\text{g/g}$ dry wt. Concentrations of uranium at some stations around ORGDP indicate that plant processes may be contributing to soil concentrations. High uranium concentrations at VS-19 (Fig. 2) are believed to result from the cleanup of the contaminated scrap yard and not from atmospheric releases from ORGDP.

Sediment

A sediment sampling program was initiated at ORGDP in 1975 to determine the concentrations of various metallic ions in the sediment of Poplar Creek. The current sampling program consists of eight sampling locations (Fig. 30). Six of these are affected by ORGDP effluents (and possibly Y-12 effluents). Two of these sampling locations are on the Clinch River (CS1 and CS20) and are used for reference information. CS1 is above the confluence of Poplar Creek and the Clinch River, whereas CS20 is below the confluence. PS19, near the confluence of East Fork Poplar Creek and Poplar Creek, is not influenced by operations at ORGDP. Samples were collected semiannually and analyzed by atomic absorption.

The concentrations of metals in the stream sediment samples (Table 44) generally exceeded background levels of metals in remote streams. An examination of the liquid effluent sources indicated that only very small quantities of any of these metals are currently being released. This suggests that current concentrations found in sediment samples are residual metals from earlier Oak Ridge plant operations. Data from stations CS1 and CS20 were almost the same. Average metal concentrations at these two stations were the lowest, except for manganese. The highest concentrations of manganese were found at these two stations, suggesting a source other than ORGDP. For most of the metals, the highest concentrations occurred at stations in the creek close to ORGDP: PS17, PS10, and PS21. Metal concentrations in sediments at these stations were similar to those for 1983.

Table 45 presents data from a single sample collection of Clinch River sediments at locations where fish were collected. The highest values for ^{60}Co , ^{137}Cs , and ^{90}Sr (Fig. 14) were at the confluence of White Oak Creek and the Clinch River (CRM 20.8, Station W-1) and are related to the discharges over White Oak Dam (Table 9). The other radionuclides were highest at CRM 12.0 where Poplar Creek joins the Clinch River. Downstream stations generally showed decreasing concentrations with distance from where the radioactivity enters the river system. Trends in radionuclide concentrations appear to be similar in fish and sediments from the Clinch River (Tables 27, 28, and 45). No direct comparisons are possible because of the low number of sediment samples and because data from fish represent a composite of several fish samples.

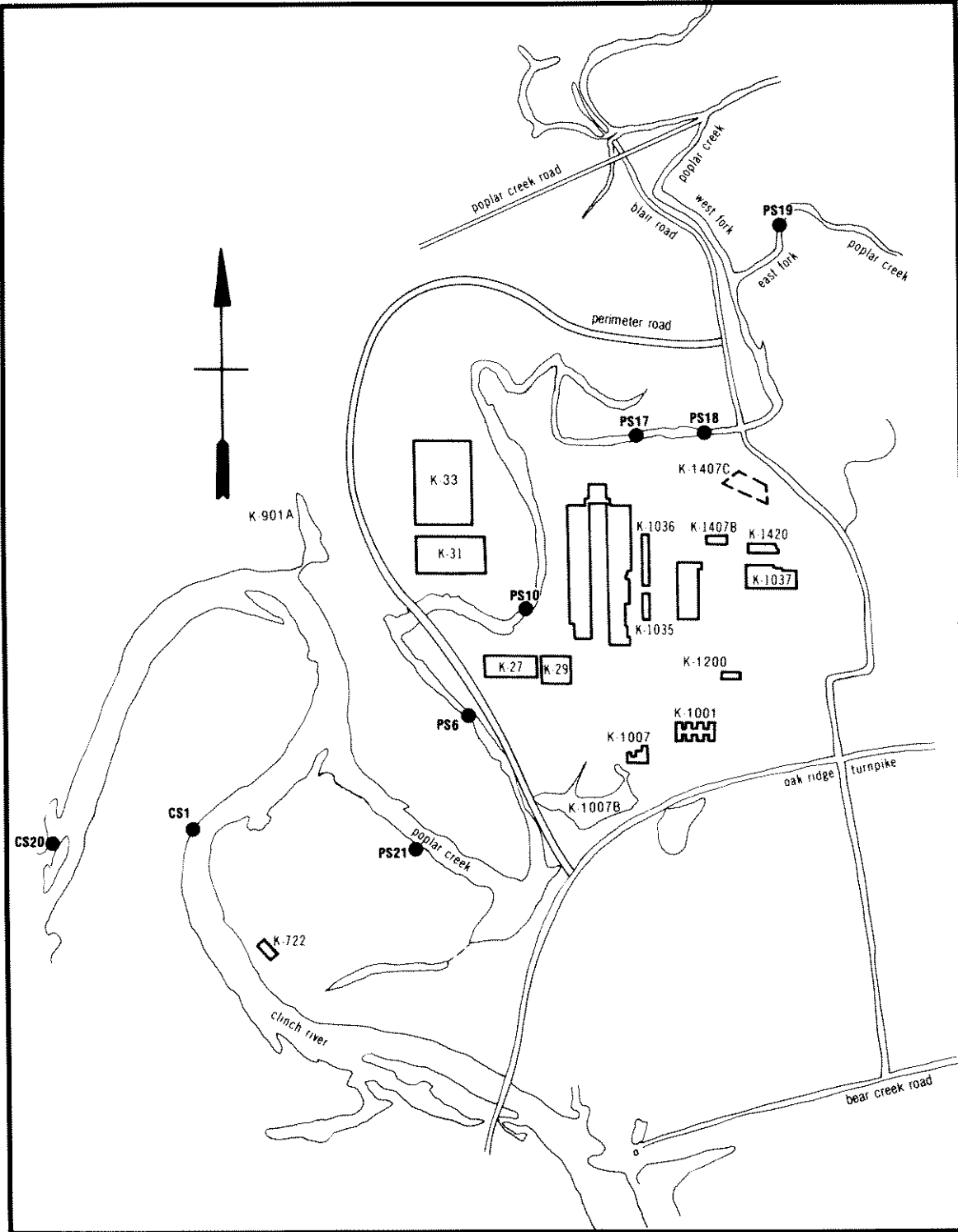


Fig. 30. Surface water and sediment sampling locations at ORGDP.

Table 44. 1984 concentrations of various elements in stream sediment samples near ORGDP

Station ^a	Concentration ^b ($\mu\text{g/g}$ dry wt)									
	U	Hg	Pb	Ni	Cu	Zn	Cr	Mn	Al	Th
PS6	5	8	50	81	48	140	65	670	44,000	< 20
PS10	23	47	39	120	50	130	140	530	34,000	< 20
PS17	43	4	39	170	59	130	55	640	34,000	< 20
PS18	6	7	34	49	25	90	29	530	29,000	< 20
PS19	10	20	49	44	57	110	64	530	30,000	< 20
PS21	11	43	41	120	61	130	97	620	44,000	< 20
CS1	1	3	29	24	12	45	33	790	21,000	< 20
CS20	1	< 1	29	22	13	42	30	650	19,000	< 20

^aSee Fig. 30.^bConcentration based on semi-annual sample collections in July and December.**Table 45. Radioactivity in sediment samples from the Clinch River
(December 1983)**

Location	Concentration (pCi/g dry wt)						
	⁶⁰ Co	¹³⁷ Cs	⁴⁰ K	²³⁸ Pu	²³⁹ Pu	⁹⁰ Sr	²³⁴ U
CRM 5.0	0.14	1.1	3.8	0.0003	0.011	0.049	0.13
CRM 10.0	0.16	2.1	10	0.0024	0.021	0.14	0.14
CRM 12.0	0.12	0.73	13	0.0038	0.035	0.18	3.0
CRM 20.8	0.49	5.7	12	0.0022	0.022	0.70	0.15
CRM 24.0	< 0.022	0.020	3.8	0.0005	< 0.0005	0.068	0.20
Av	< 0.19	1.9	8.5	0.0018	< 0.018	0.23	0.72

Groundwater

ORNL

The groundwater system in Melton Valley basically has a very shallow active zone. The system is characterized by highest permeability for groundwater flow near the surface and declining permeability with depth. Although quantitative studies of near-surface groundwater flow during storm events are still in progress, it appears that most subsurface flow occurs in a near-surface region that extends to a depth of less than about 5 m. The general hydrologic picture is that of rather closely coupled surface water and groundwater systems in which circulation is rather shallow and much of

the movement occurs in the near-surface zone during the wetter part of the year (late November through April). The more traditional concept of a subsurface contamination plume as a primary pathway for contaminant migration is not appropriate in this instance. The hydraulic conductivity of the less-weathered material is about 2 cm/d, whereas the near-surface zone is characterized by 20- to 40-cm/d (or higher) hydraulic conductivities. Furthermore, the distribution coefficients for most radionuclides in the Conasauga Group (shales) are rather high, suggesting that any deep migration would occur at a very slow rate. The primary pathway for contaminant migration, where it occurs, is thought to be via the bathtub effect (i.e., a trench collects enough water to cause an overflow at the downstream end). Thus, subsequent movement is over the surface and vertically downward along the flow path. A variation of that process is movement of shallow subsurface flow in fill material along and just above the interface with native materials underlying the fill. Thus, the nature of the groundwater system suggests that long-range subsurface flow is not likely for most areas because of the low permeability of formations.

Based on the preceding, it is believed that no significant potential exists for groundwater contamination of the 16 public groundwater supplies within a 32.3-km radius of ORNL from operations at ORNL. The hydrologic structure is such that any groundwater flow that occurs is likely to be in an east or west direction (along strike) rather than across formations. Thus, the likely direction for any deep groundwater flow would be to the west, toward the Clinch River from ORNL storage areas, and then into the Clinch, which would be the discharge point for groundwater flow in the area. Finally, the most significant factor to consider is the rate of movement of groundwater and radionuclides in the Conasauga Group formations underlying ORNL disposal areas. Using the measured hydraulic conductivity of 2 cm/d (or less) and an average gradient of 0.01 m per month, with an effective porosity of 0.10, the expected water velocity would be 0.2 cm/d or about 0.73 m per year. At that rate, about 1370 years would be required for water to travel 1 km underground. Considering the fact that most radionuclides have retardation factors on the order of 100 or greater (retardation factor refers to the ratio of water velocity to radionuclide velocity), calculations have shown that movement of groundwater contaminants with even minimal sorption in the Conasauga Group formations would require in excess of 10,000 to 100,000 years for a travel distance of 1 km. Furthermore, decay, adsorption, dilution, and dispersion of contaminants would reduce original concentrations by many orders of magnitude over the first 1 km of travel. Because no public groundwater supplies exist within 1 km of any of the disposal areas, no reasonable probability exists that groundwater contaminants will move from ORNL storage sites to public groundwater supplies in detectable concentrations.

Groundwater was sampled from wells in SWSAs 4, 5, 6, and the pits and trenches area at ORNL (Figs. 31–34). Wells were selected for quarterly sampling from a group of about 100 monitoring wells, based on studies conducted by the Environmental Sciences Division at ORNL and on surface water flow patterns. Because of the permeability of the formation in the SWSAs, it is believed that well water represents primarily surface water runoff and, secondarily, shallow surface flow. Reference wells in the SWSA are hydraulically upgradient from the waste storage area. They should be considered only as reference wells and not as background wells because they are located in the SWSA and do receive surface runoff. In 1984 samples were analyzed for one or more of the following: gamma emitters, gross alpha activity, ^3H , and ^{90}Sr . Data on the concentrations of selected radionuclides measured in the sample and reference wells are presented in Table 46. Concentrations of ^{137}Cs were highest in SWSA 4. SWSA 5 had the highest concentrations of ^3H and ^{90}Sr . The pits and trenches area had the highest concentrations of ^{60}Co and gross alpha activity.

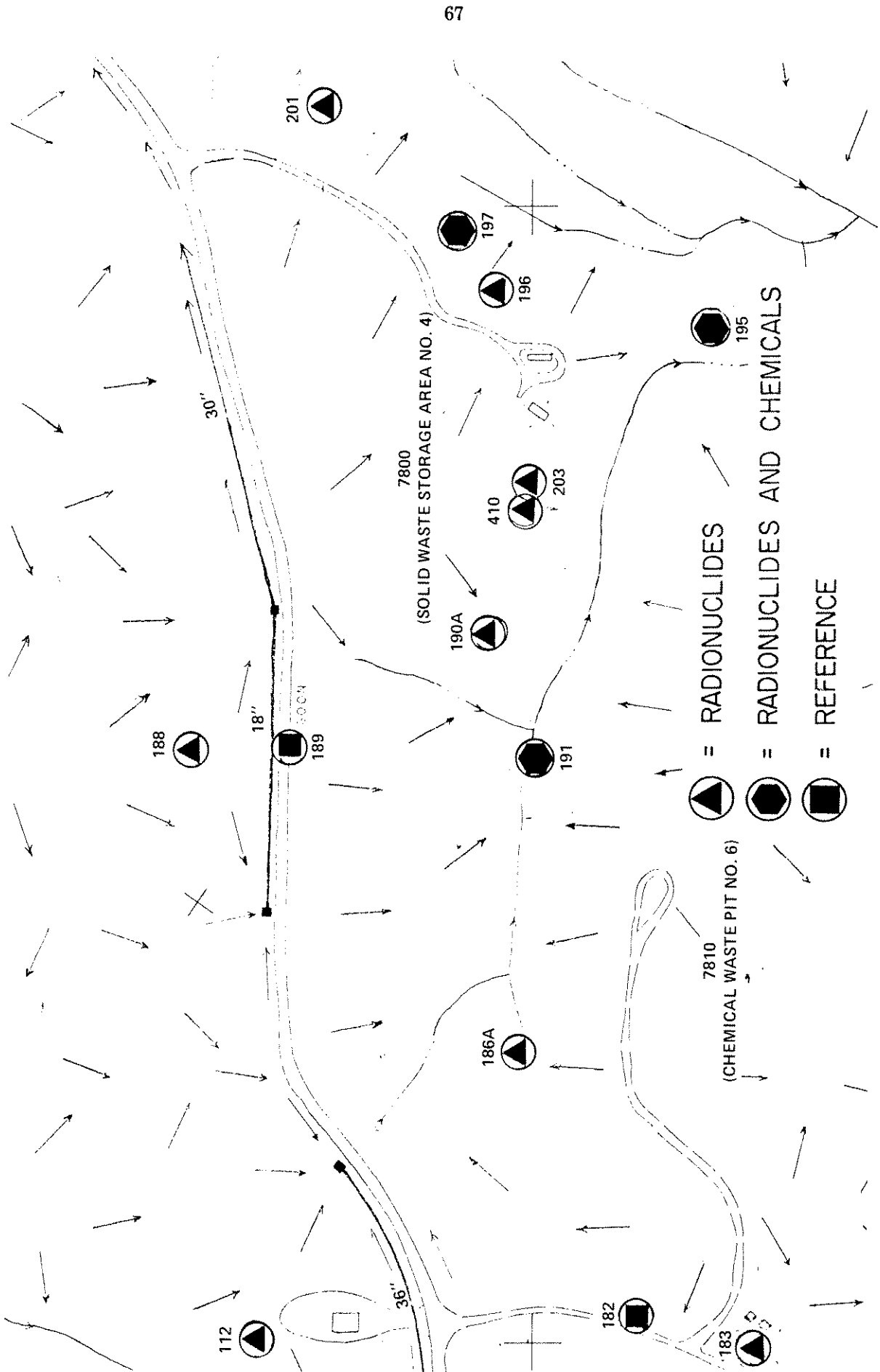


Fig. 31. ORNL groundwater monitoring well locations—SWSA 4.

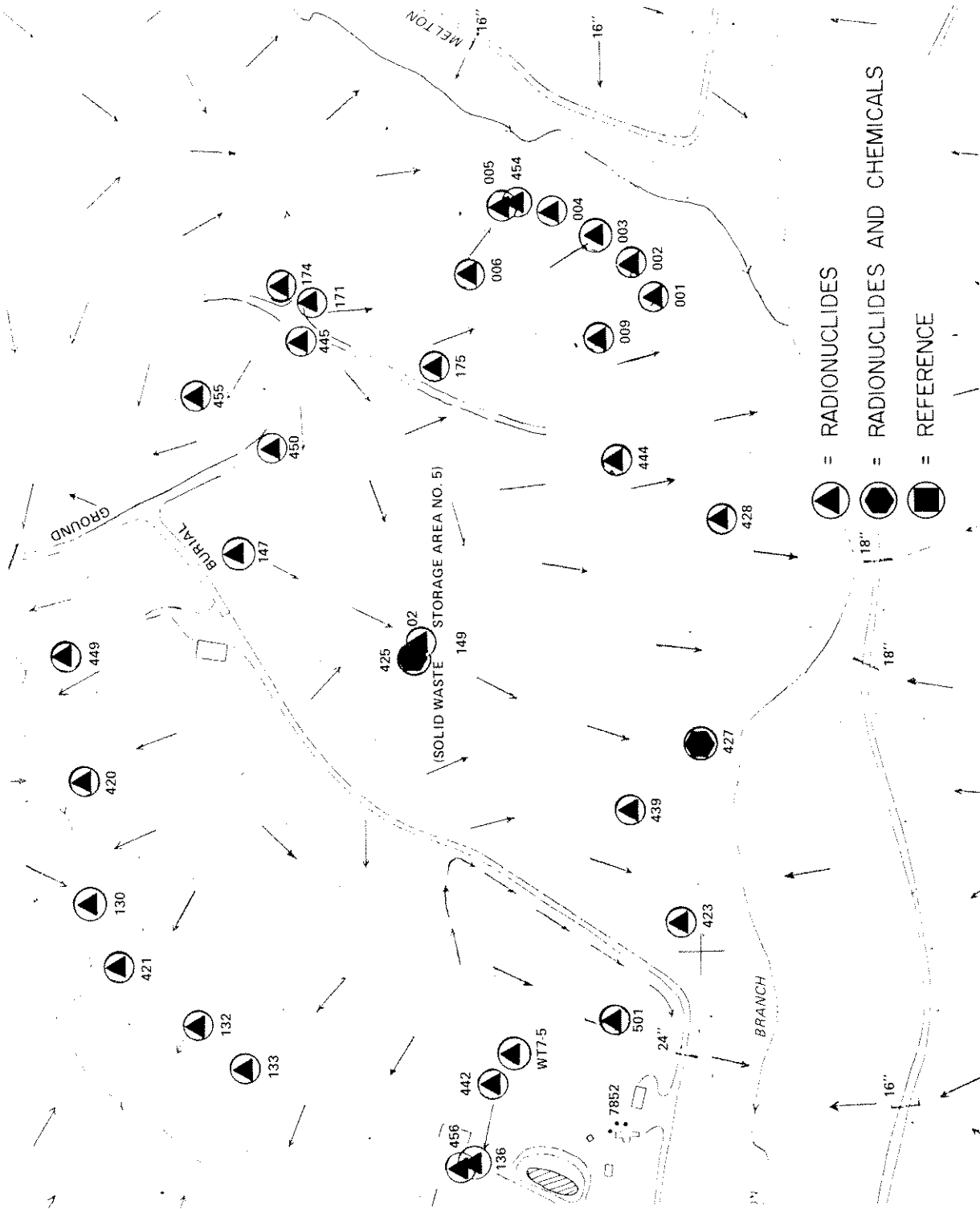


Fig. 32. ORNL groundwater monitoring well locations—SWSA 5.

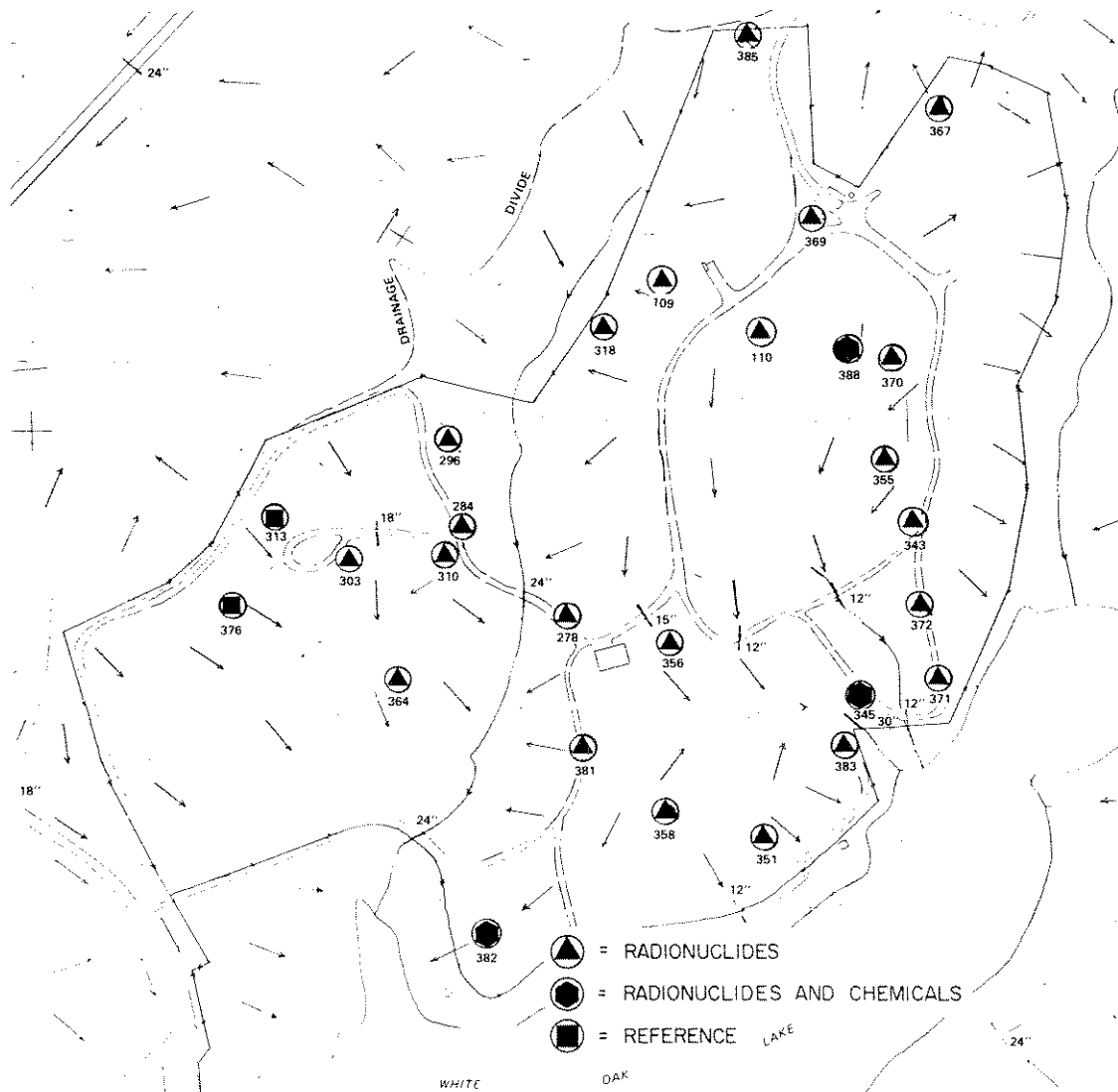


Fig. 33. ORNL groundwater monitoring well locations—SWSA 6

The wells having the highest concentrations of radionuclides were those along drainage areas, in low-lying areas, or in the path of surface water movement. Except for the low average measurements of gross alpha in SWSA 6, average concentrations of radionuclides from the monitoring wells in all SWSAs and the pits and trenches area were higher than from the reference wells. Radionuclide concentrations exceeded EPA drinking water standards for most wells sampled.

During each quarterly sampling period, parameters in well water that are measured in the field include specific conductance, depth, dissolved oxygen, pH, temperature, and turbidity. Table 47 gives the summary statistics for these parameters for each SWSA, the pits and trenches area, and the reference wells. These parameters were similar among the sampling wells and the reference wells, except for specific conductance and turbidity measured in wells in the pits and trenches area. Conductivity was about five times higher in wells receiving surface drainage from chemical waste pits 4 and 7 than from reference wells. Turbidity was highest in a well located near trench 6 in a low-lying area.

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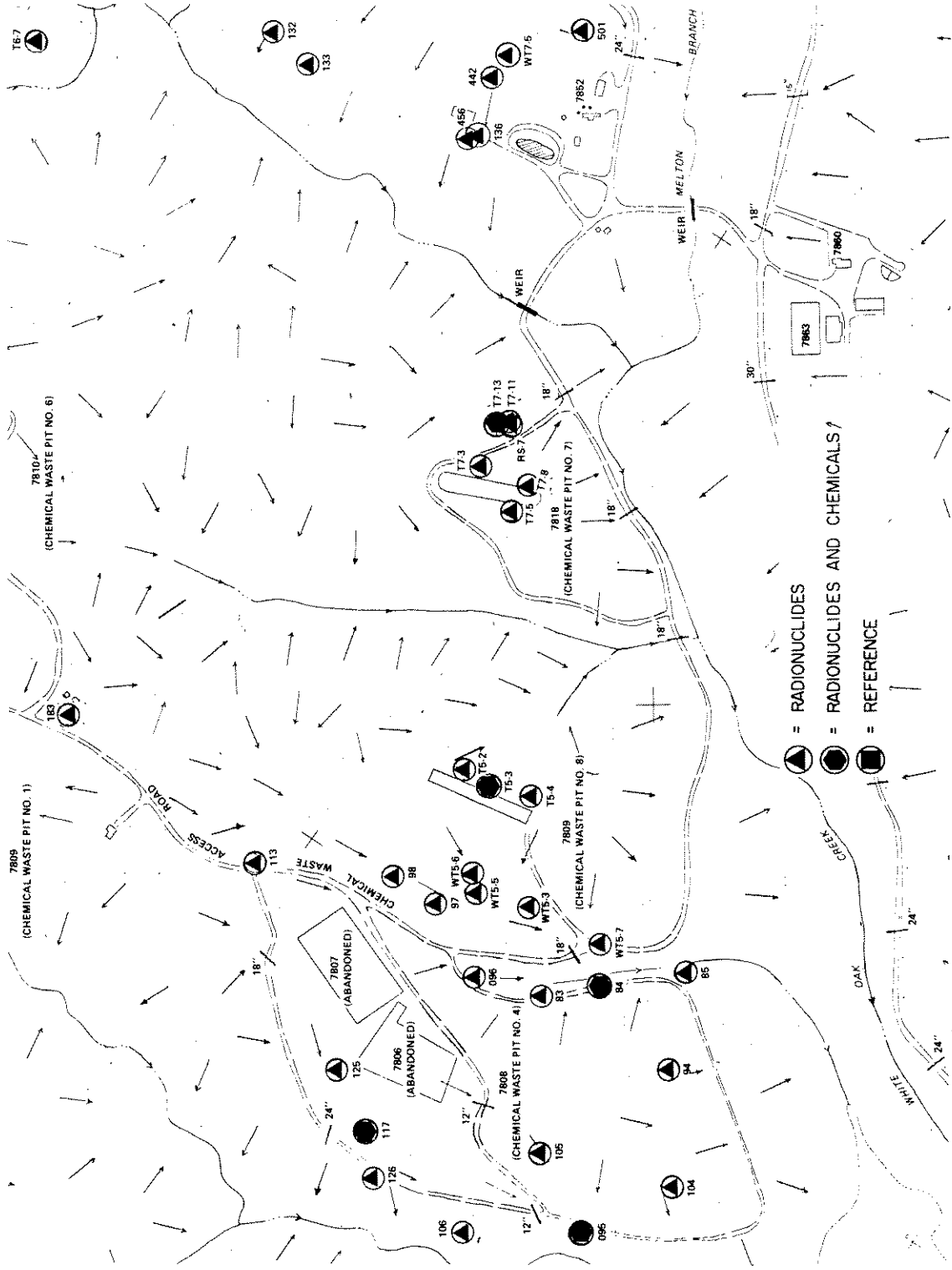


Fig. 34. ORNL groundwater monitoring well locations—pits and trenches area

**Table 46. 1984 groundwater monitoring
of radionuclides—ORNL**

Analysis	No. of samples	Concentration (E-8 $\mu\text{Ci/mL}$)		
		Max	Min	Av
<i>Solid Waste Storage Area 4</i>				
^{60}Co	17	6.2	< 0.22	< 1.5
^{137}Cs	26	270	0.76	32
Gross alpha	10	68	0.27	15
^3H	24	170,000	590	28,000
^{90}Sr	27	4,100	12	1,100
<i>Solid Waste Storage Area 5</i>				
^{60}Co	33	6.5	< 0.19	< 1.1
^{137}Cs	54	51	< 0.19	< 6.1
Gross alpha	24	25	0.27	4.6
^3H	49	34,000,000	1,800	4,700,000
^{90}Sr	50	220,000	0.49	5,500
<i>Solid Waste Storage Area 6</i>				
^{60}Co	4	1.4	< 0.16	< 0.70
^{137}Cs	9	23	< 0.54	< 10.0
Gross alpha	3	2.7	0.81	2.1
^3H	11	3,900	< 81	< 1,300
^{90}Sr	12	470	1.9	140
<i>Pits and Trenches</i>				
^{60}Co	36	2,600	0.41	410
^{137}Cs	36	130	0.57	16
Gross alpha	15	410	0.27	62
^3H	34	25,000	570	10,000
^{90}Sr	35	230	0.43	29
<i>Reference Wells</i>				
^{60}Co	3	1.4	< 0.08	< 0.58
^{137}Cs	7	12	< 1.0	< 5.0
Gross alpha	2	2.7	2.2	2.4
^3H	10	360	< 81	< 220
^{90}Sr	10	35	1.0	13

Table 47. 1984 results of in situ groundwater monitoring—ORNL

Parameter	No. of samples	Units ^a		
		Max	Min	Av
<i>Solid Waste Storage Area 4</i>				
Specific conductance	24	0.97	0.091	0.47
Depth	24	4.9	0.052	2.0
Dissolved oxygen	24	9.6	1.2	4.2
pH	24	10	5.3	
Temperature	24	20	2.1	13
Turbidity	24	130	0.14	52
<i>Solid Waste Storage Area 5</i>				
Specific conductance	47	0.71	0.030	0.37
Depth	47	6.7	0.30	2.9
Dissolved oxygen	47	7.9	1.2	3.8
pH	47	11	4.8	
Temperature	47	21	9.0	16
Turbidity	47	160	0.80	47
<i>Solid Waste Storage Area 6</i>				
Specific conductance	16	0.47	0.050	0.25
Depth	16	6.7	0.91	3.0
Dissolved oxygen	16	6.8	0.090	3.3
pH	16	9.6	6.1	
Temperature	16	21	9.8	16
Turbidity	16	130	7.1	47
<i>Pits and Trenches</i>				
Specific conductance	39	2.7	0.013	0.58
Depth	39	7.7	0.91	2.6
Dissolved oxygen	39	10	1.3	3.8
pH	39	11	6.0	
Temperature	39	23	5.0	14
Turbidity	39	200	0.22	25
<i>Reference Wells</i>				
Specific conductance	12	0.51	0.11	0.29
Depth	12	7.2	2.0	4.1
Dissolved oxygen	12	7.6	1.1	3.8
pH	12	8.9	5.5	
Temperature	12	22	11	16
Turbidity	12	88	0.16	21

^aUnits of measurement are: μ mhos/cm for specific conductance, meters for depth, mg/L for dissolved oxygen, units for pH, °C for temperature, and NTU for turbidity.

Of the approximately 100 wells monitored at ORNL for radioactivity, 13 were selected for extensive chemical analyses. Most monitoring involved quarterly sampling of two to four wells in each SWSA. Tables 48–52 present data for the SWSAs, pits and trenches area, and reference wells. Samples were analyzed for volatile organics, and findings above the detection limit are included in these tables. The results from monitoring of chemicals may be used for trend analysis but should not be construed to be accurate estimates. Many of the wells were not constructed for water quality monitoring and may themselves contain materials that may contaminate the samples.

Table 48. 1984 groundwater monitoring of chemicals—ORNL Solid Waste Storage Area 4

Chemical	No. of samples	Concentration (mg/L)		
		Max	Min	Av
Ag	4	0.070	< 0.018	< 0.046
Al	4	0.29	0.067	0.16
Alkalinity	4	310	280	300
As	4	0.0050	0.0010	0.0039
Asbestos ^a	3	1.0	< 0.30	< 0.53
B	4	0.14	0.070	0.11
Ba	4	0.28	0.045	0.15
Be	4	0.0026	< 0.0010	< 0.0018
BOD	3	8.0	3.0	5.3
Br	4	5.0	< 1.0	< 3.0
Ca	4	97	< 52	< 80
Cd	4	0.013	< 0.0090	< 0.010
Cl	4	40	< 17	< 29
CN	4	0.0020	< 0.0009	< 0.0016
Co	4	0.023	0.013	0.018
COD	4	32	7.0	14
Cr	4	0.025	0.020	0.022
Cu	4	0.032	< 0.017	< 0.022
F	4	1.0	< 1.0	< 1.0
Fe	4	7.2	0.028	4.7
Fecal coliform ^b	3	600	3.0	200
Ga	4	0.50	< 0.07	< 0.23
Hardness	4	350	150	290
Hf	4	0.50	< 0.040	< 0.20
Hg	4	0.0002	< 0.00005	< 0.0001
K	3	36	2.8	16
Li	4	1.20	0.88	1.1
Mg	4	19	18	19
Mn	4	13	3.40	8.50
Mo	4	0.027	< 0.010	< 0.018
Na	3	21	12	17
NH ₃	1	0.41	0.41	0.41
NH ₃ (as N)	3	0.72	0.32	0.57
Ni	4	0.11	0.026	0.063
NO ₃	4	5.0	< 1.0	< 3.8

Table 48 (continued)

Chemical	No. of samples	Concentration (mg/L)		
		Max	Min	Av
Oil and grease	4	16	< 2.0	< 7.6
P	4	0.33	< 0.10	< 0.25
Pb	4	0.26	0.036	0.16
PCB	3	0.028	0.00004	0.0095
Phenols	4	0.001	< 0.001	< 0.001
PO ₄	4	5.0	< 1.0	< 3.8
Sb	4	0.33	0.13	0.24
Se	4	0.43	< 0.027	< 0.29
Si	4	3.7	1.7	3.0
SO ₄	4	33	24	28
Sr	4	0.25	0.19	0.23
Ti	4	0.065	< 0.015	< 0.039
TDS ^c	4	440	370	400
Total Kjeldahl nitrogen	4	1.4	0.41	0.82
Total organic carbon	4	4.6	3.0	3.8
V	4	0.080	< 0.015	< 0.038
Zn	4	0.93	0.025	0.30
Zr	4	0.060	0.018	0.043
Volatile organics ^d				
Benzene	4	1.5	< 0.0050	< 0.38
Chloroform	4	0.039	< 0.0021	< 0.017
Methylene chloride	4	0.083	< 0.0020	< 0.031
Toluene	4	12	< 0.0050	< 6.2
1,2-trans-dichloroethylene	4	0.37	< 0.050	< 0.16

^a10⁶ fibers per liter.

^bColonies per 100 mL.

^cTotal dissolved solids.

^dThose above detection limits.

Results of these analyses indicated that groundwater from several wells was contaminated with a variety of pollutants. The most contaminated appear to be well 195 in SWSA 4, wells 425 and 427 in SWSA 5, wells 84 and 95 in the pits and trenches area, and well 382 in SWSA 6 (Figs. 31–34). Well 182 (Fig. 31) was contaminated with volatile organics; wells 182 and 376 (Figs. 31 and 33) had the highest BOD concentrations; and well 313 (Fig. 33) had detectable levels of asbestos. Phenols, PCB-1260, and some volatile organics were found in SWSA 6 in water from well 362, placed to monitor a biological waste disposal area. Contaminants in groundwater that exceeded the State of Tennessee Stream Standards for the long-term protection of drinking water, fish and aquatic life, and recreation classifications included iron, manganese, nickel, selenium, TDS, zinc, antimony, cyanide, fluoride, lead, mercury, phenols, and silver. For comparison, at Melton Hill Dam these chemicals were either not detected in water or were at concentrations lower than the State of Tennessee Stream Standard.

Table 49. 1984 groundwater monitoring of chemicals—ORNL Solid Waste Storage Area 5

Chemical	No. of samples	Concentration (mg/L)		
		Max	Min	Av
Ag	5	0.070	< 0.018	< 0.034
Al	5	1.7	0.096	0.46
Alkalinity	5	290	24	190
As	5	0.0050	0.0006	0.003
Asbestos ^a	3	1.0	< 0.30	< 0.53
B	5	0.21	< 0.076	< 0.12
Ba	5	0.24	0.069	0.13
Be	5	0.0024	< 0.0010	< 0.0016
BOD	3	8.0	< 5.0	< 6.0
Br	5	5.0	< 2.0	< 3.0
Ca	5	73	6.2	46
Cd	5	0.013	< 0.0090	< 0.0099
Cl	5	30	1.0	13
CN	5	0.0040	< 0.0005	< 0.0017
Co	5	0.021	< 0.013	< 0.016
COD	5	32	< 5.0	< 13
Cr	5	0.023	0.012	0.018
Cu	5	0.032	< 0.017	< 0.024
F	5	1.0	< 1.0	< 1.0
Fe	5	15	< 0.028	< 6.2
Fecal coliform ^b	2	0	0	0
Ga	5	0.50	< 0.070	< 0.19
Hardness	5	340	41	190
Hf	5	0.20	< 0.04	< 0.077
Hg	5	0.0002	< 0.00005	< 0.00014
K	4	35	1.2	14
Li	5	0.20	0.056	0.12
Mg	5	12	4.5	8.5
Mn	5	5.5	0.13	2.1
Mo	5	0.030	< 0.010	< 0.022
Na	4	26	1.6	8.4
NH ₃	2	0.20	< 0.20	< 0.20
NH ₃ (as N)	3	0.40	0.04	0.26
Ni	5	0.11	0.021	0.071
NO ₃	5	5.0	< 4.0	< 4.8
Oil and grease	5	4.0	< 2.0	< 2.4
P	5	0.33	< 0.1	< 0.26
Pb	5	0.26	0.083	0.19
PCB	5	0.071	0.00011	0.015
Phenols	5	0.0080	< 0.0010	< 0.0024
PO ₄	5	5.0	< 4.0	< 4.8
Sb	5	0.33	0.20	0.25
Se	5	1.4	< 0.30	< 0.60
Si	5	4.9	0.68	2.6
SO ₄	5	14	5.0	9.2

Table 49 (continued)

Chemical	No. of samples	Concentration (mg/L)		
		Max	Min	Av
Sr	5	0.13	0.038	0.085
Ti	5	0.11	< 0.015	< 0.054
TDS ^c	5	370	81	230
Total Kjeldahl nitrogen	5	0.54	< 0.20	< 0.38
Total organic carbon	5	3.8	< 2.0	< 2.9
V	5	0.052	< 0.015	< 0.027
Zn	5	5.8	1.2	3.0
Zr	5	0.060	< 0.018	< 0.039
Volatile organics ^d				
Benzene	5	1.5	< 0.0050	< 0.31
Methylene chloride	5	0.059	< 0.0020	< 0.021
Toluene	5	12	< 0.0050	< 5.0

^a10⁶ fibers per liter.

^bColonies per 100 mL.

^cTotal dissolved solids.

^dThose above detection limits.

Table 50. 1984 groundwater monitoring of chemicals—ORNL Solid Waste Storage Area 6

Chemical	No. of samples	Concentration (mg/L)		
		Max	Min	Av
Ag	11	0.070	< 0.018	< 0.039
Al	11	0.81	0.053	0.33
Alkalinity	11	280	27	150
As	11	0.0050	0.0008	0.0034
Asbestos ^a	8	1.0	0.30	0.56
B	11	0.10	< 0.030	< 0.070
Ba	11	0.33	0.018	0.16
Be	11	0.0021	< 0.0010	< 0.0015
BOD	8	27	2.3	7.3
Br	8	5.0	< 2.0	< 3.6
Ca	11	98	0.085	42
Cd	11	0.013	< 0.0090	< 0.01
Cl	11	11	1.0	7.5
CN	11	0.0020	< 0.0014	< 0.0017
Co	11	0.12	< 0.010	< 0.026
COD	11	63	< 5.0	< 17
Cr	11	0.023	< 0.0080	< 0.015
Cu	11	0.032	< 0.017	< 0.022
F	11	1.0	< 1.0	< 1.0
Fe	11	42	0.028	8.1

Table 50 (continued)

Chemical	No. of samples	Concentration (mg/L)		
		Max	Min	Av
Fecal coliform ^b	8	56	0	19
Ga	11	0.50	< 0.032	< 0.20
Hardness	11	270	25	160
Hf	11	0.22	< 0.016	< 0.060
Hg	11	0.0002	< 0.00005	< 0.00013
K	9	14	0.80	7.3
Li	11	0.20	0.025	0.11
Mg	11	12	2.1	7.6
Mn	11	12	0.015	1.8
Mo	11	0.027	< 0.010	< 0.019
Na	9	7.2	2.8	5.0
NH ₃	3	0.20	< 0.20	< 0.20
NH ₃ (as N)	8	0.50	< 0.03	< 0.26
Ni	11	0.14	< 0.0049	< 0.073
NO ₃	11	5.0	< 4.0	< 4.8
Oil and grease	11	5.0	< 2.0	< 2.4
P	11	0.49	< 0.10	< 0.28
Pb	11	0.26	0.015	0.16
PCB	11	0.035	0.00009	0.0068
Phenols	11	0.050	< 0.0010	< 0.0070
PO ₄	11	5.0	< 4.0	< 4.8
Sb	11	0.33	< 0.076	< 0.22
Se	11	0.69	< 0.027	< 0.36
Si	11	4.3	1.6	3.3
SO ₄	11	17	4.0	8.5
Sr	11	0.16	0.023	0.090
Ti	11	0.080	< 0.015	< 0.040
TDS ^c	11	310	37	190
Total Kjeldahl nitrogen	11	1.1	0.19	0.43
Total organic carbon	11	10	0.50	3.4
V	11	0.030	< 0.010	< 0.021
Zn	11	1.1	< 0.010	< 0.023
Zr	11	0.060	< 0.010	< 0.034
Volatile organics ^d				
Chloroform	11	0.075	< 0.0021	< 0.019
Methylene chloride	11	0.041	< 0.0020	< 0.016
Toluene	11	12	< 0.0050	< 5.7
1,2-trans-dichloroethylene	11	0.057	0.035	0.049
1,1,1-trichloroethylene	11	0.050	< 0.016	< 0.031

^a10⁶ fibers per liter.^bColonies per 100 mL.^cTotal dissolved solids.^dThose above detection limits.

Table 51. 1984 groundwater monitoring of chemicals—ORNL pits and trenches area

Chemical	No. of samples	Concentration (mg/L)		
		Max	Min	Av
Ag	12	0.070	< 0.018	< 0.035
Al	12	3.2	0.052	0.38
Alkalinity	12	520	200	370
As	12	0.012	0.0009	0.0041
Asbestos ^a	8	1.0	< 0.30	< 0.56
B	12	0.32	< 0.030	< 0.13
Ba	12	0.23	0.027	0.11
Be	12	0.0018	< 0.0010	< 0.0014
BOD	8	5.0	< 1.0	< 4.0
Br	12	5.0	< 1.0	< 2.7
Ca	12	76	7.3	40
Cd	12	0.013	< 0.0090	< 0.010
Cl	12	42	1.0	17
CN	12	0.099	< 0.0014	< 0.012
Co	12	0.11	< 0.010	< 0.036
COD	12	16	< 5.0	< 9.0
Cr	12	0.028	0.010	0.018
Cu	12	0.032	< 0.017	< 0.023
F	12	4.0	< 0.50	< 1.5
Fe	12	44	< 0.02	< 4.9
Fecal coliform ^b	8	8.0	0	3.4
Ga	12	0.50	< 0.032	< 0.17
Hardness	12	250	16	130
Hf	12	0.060	< 0.016	< 0.038
Hg	12	0.0002	< 0.00005	< 0.00014
K	9	36	1.2	18
Li	12	0.23	0.064	0.14
Mg	12	18	1.3	7.1
Mn	12	2.1	0.045	0.58
Mo	12	0.027	< 0.010	< 0.021
Na	12	440	21	200
NH ₃	4	0.25	< 0.20	< 0.21
NH ₃ (as N)	8	0.29	< 0.03	< 0.13
Ni	12	0.11	< 0.0049	< 0.073
NO ₂	1	30	30	30
NO ₃	12	310	< 1.0	< 37
Oil and grease	12	18	< 2.0	< 7.2
P	12	1.1	< 0.10	< 0.32
Pb	12	0.26	< 0.0092	< 0.16
PCB	12	0.043	0.00001	0.008
Phenols	12	0.0010	< 0.0010	< 0.0010
PO ₄	12	5.0	< 1.0	< 3.5
Sb	12	0.33	< 0.076	< 0.22
Se	13	0.75	< 0.027	< 0.37
Si	12	7.3	1.5	4.6

Table 51 (continued)

Chemical	No. of samples	Concentration (mg/L)		
		Max	Min	Av
SO ₄	12	200	40	98
Sr	11	0.53	0.021	0.17
Ti	12	0.067	< 0.015	< 0.039
TDS ^c	12	1100	290	680
Total Kjeldahl nitrogen	12	1.1	< 0.10	< 0.37
Total organic carbon	12	9.7	< 0.50	< 3.6
V	12	0.030	< 0.01	< 0.018
Zn	12	0.31	0.017	0.083
Zr	12	0.060	0.013	0.034
Volatile organics ^d				
Benzene	12	1.5	< 0.0050	< 0.26
Toluene	12	12	< 0.005	< 5.2

^a10⁶ fibers per liter.

^bColonies per 100 mL.

^cTotal dissolved solids.

^dThose above detection limits.

Table 52. 1984 groundwater monitoring—ORNL reference wells

Chemical	No. of samples	Concentration (mg/L)		
		Max	Min	Av
Ag	8	0.070	< 0.018	< 0.036
Al	8	0.33	< 0.058	< 0.17
Alkalinity	8	300	99	170
As	8	0.0050	0.0006	0.0029
Asbestos ^a	6	3.0	< 0.30	< 0.98
B	8	0.10	< 0.030	< 0.057
Ba	8	0.25	0.062	0.12
Be	8	0.0020	< 0.0010	< 0.0015
BOD	6	5.0	1.0	3.7
Br	7	5.0	< 1.0	< 3.1
Ca	8	78	34	53
Cd	8	0.013	< 0.0090	< 0.010
Cl	8	3.0	1.0	1.5
CN	8	0.002	< 0.0014	< 0.0015
Co	8	0.034	< 0.010	< 0.017
COD	8	9.4	2.0	5.6
Cr	8	0.023	0.0092	0.015
Cu	8	0.032	< 0.0170	< 0.0220

Table 52 (continued)

Chemical	No. of samples	Concentration (mg/L)		
		Max	Min	Av
F	8	1.0	< 1.0	< 1.0
Fe	8	35	< 0.028	< 4.6
Fecal coliform ^b	6	28	0	7.2
Ga	8	0.50	< 0.032	< 0.17
Hardness	8	300	95	170
Hf	8	0.060	0.0170	0.038
Hg	8	0.0002	< 0.00005	< 0.00013
K	5	14	3.6	9.4
Li	8	0.20	0.034	0.10
Mg	8	22	2.3	10
Mn	8	0.39	< 0.0010	< 0.15
Mo	8	0.027	< 0.010	< 0.019
Na	5	4.6	2.1	3.7
NH ₃	2	0.20	< 0.20	< 0.20
NH ₃ (as N)	6	0.20	< 0.030	< 0.12
Ni	8	0.11	0.028	0.068
NO ₃	8	5.0	< 1.0	< 4.1
Oil and grease	8	16	< 2.0	< 3.9
P	8	0.33	< 0.10	< 0.22
Pb	8	0.26	0.052	0.16
PCB	8	0.053	0.00002	0.015
Phenols	8	0.001	< 0.001	< 0.001
PO ₄	8	5.0	< 1.0	< 4.1
Sb	8	0.33	< 0.076	< 0.23
Se	8	0.56	< 0.027	< 0.34
Si	8	9.0	1.2	5.2
SO ₄	8	39	< 4.0	< 12
Sr	8	0.15	0.053	0.090
Ti	8	0.057	< 0.015	< 0.036
TDS ^c	8	380	110	210
Total Kjeldahl nitrogen	8	0.31	< 0.10	< 0.21
Total organic carbon	8	2.7	< 0.50	< 1.8
V	8	0.030	< 0.010	< 0.020
Zn	8	5.0	0.010	0.89
Zr	8	0.060	< 0.011	< 0.036
Volatile organics ^d				
Benzene	8	1.5	< 0.0050	< 0.20
Methylene chloride	8	0.024	< 0.0020	< 0.0092
Toluene	8	12	< 0.0050	< 6.2
1,2-trans-dichloroethylene	8	0.050	0.047	0.050

^a10⁶ fibers per liter.

^bColonies per 100 mL.

^cTotal dissolved solids.

^dThose above detection limits.

Contaminants that did not exceed the criteria in any of the wells during any period include arsenic, barium, boron, chloride, chromium, and sulfates. Of the 25 volatile organics sought, only 6 were detected, which included benzene, chloroform, methylene chloride, toluene, 1,2 *trans*-dichloroethylene, and 1,1,1-trichloroethane. These organics were not detected in background water samples collected above Melton Hill Dam.

Y-12

The Y-12 Plant routinely monitors 29 wells (Fig. 35), which are situated around the various disposal facilities. Samples of groundwater are collected quarterly from all wells and analyzed for a variety of parameters. The wells vary in depth from 18 to 181 ft, and, in general, each well has been drilled down through the saturated zone and extends partially into weathered bedrock.

The analytical parameters chosen for each disposal facility well cluster have been selected to ensure compliance with the applicable state and federal regulations and to adequately monitor the materials being disposed. Although some parameters are included strictly for precautionary reasons, others are used as indicators of groundwater quality. Data acquired from the Y-12 Plant groundwater monitoring program are presented in Tables 53-57.

ORGDP

Groundwater monitoring at ORGDP for CY 1984 consisted of sample collection around the classified burial ground and the K-1407-C holding pond (Fig. 36). Samples were collected during April and October from both "shallow" wells and "deep" wells situated to provide monitoring for the unsaturated and saturated zones, respectively. Inorganic parameters are determined by atomic absorption spectroscopy, and organic constituents are identified by gas chromatography.

Groundwater data for ORGDP are presented in Tables 58-61. The data from both the deep and shallow wells are inconsistent with data collected in 1983. The data are not sufficiently consistent to determine trends or to identify the direction of contaminant migration, if any, from the monitored areas. Currently, a groundwater protection program is being implemented at ORGDP. A contract will be awarded to an outside engineering firm to evaluate the need for a specific groundwater quality monitoring program. A geohydrologic characterization of the appropriate plant areas will be prepared. This characterization will include a water table map and information on groundwater flow patterns that will contribute to the decisions about the location and depth of monitoring wells. After a specific plan is developed, concurrence from the EPA and TDHE will be obtained before more work is begun.

As a part of this program, new wells will be installed around the classified burial ground, the K-1407-C holding pond, and other areas at ORGDP where applicable. Data consistency and trend analysis should be enhanced in the future as a result of data obtained from these new wells.

Calculation of Potential Radiation Dose to the Public

The calculation of potential radiation dose to the public requires the use of models of various degrees of complexity that represent the movement of radioactive materials through the environment from the source to humans. These models have to take into account the nature and physical and chemical characteristics of the radioactive materials, as well as their methods of release. The models then have to reflect the characteristics of the environment and of humans that influence the consequent exposure of individuals and groups.¹²

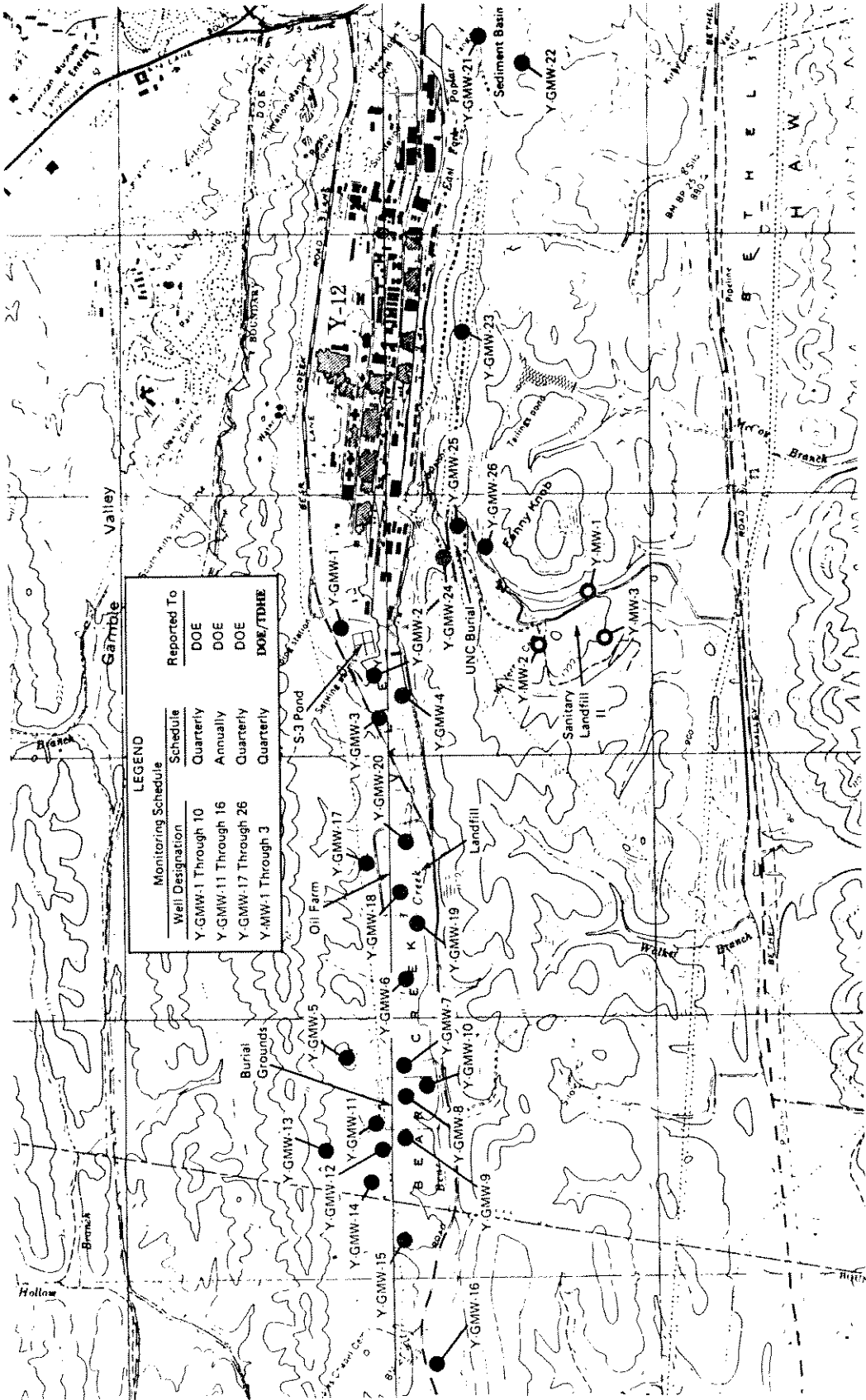


Fig. 35. Groundwater monitoring well locations at the Y-12 Plant.

Table 53. Groundwater monitoring—Y-12 Chestnut Ridge sediment basin^a

Parameter	Concentration (mg/L)		
	Max	Min	Av
Hg	0.0035	< 0.0005	< 0.0012
Se	< 0.002	< 0.002	< 0.002
CN	< 0.002	< 0.002	< 0.002
TKN ^b	0.8	< 0.2	< 0.28
NO ₃ (N)	1.6	0.2	0.6
Total N	1.6	0.4	0.8
PCB	< 0.0005	< 0.0005	< 0.0005
pH, units	8.1	5.2	
TOC ^c	6	< 2	< 4
Specific conductance, μ mhos/cm	290	19	147
Chloroform	< 0.01	< 0.01	< 0.01
Methyl bromide	< 0.01	< 0.01	< 0.01
Methyl chloride	< 0.01	< 0.01	< 0.01
Methylene chloride	0.04	< 0.01	< 0.02
Tetrachloroethylene	< 0.01	< 0.01	< 0.01
Toluene	0.03	< 0.01	< 0.02
Xylene	< 0.01	< 0.01	< 0.01
Chloroethane	< 0.01	< 0.01	< 0.01
Dichloroethane	< 0.01	< 0.01	< 0.01
Trichloroethane	< 0.01	< 0.01	< 0.01
Uranium	0.032	< 0.001	< 0.006
Th	0.08	< 0.02	< 0.03
Ag	< 0.01	< 0.01	< 0.01
Al	55	0.12	12
As	0.12	< 0.06	< 0.07
B	< 0.02	< 0.02	< 0.02
Ba	< 0.2	< 0.2	< 0.2
Be	0.0032	< 0.0005	< 0.001
Ca	29	0.6	14
Cd	< 0.002	< 0.002	< 0.002
Ce	0.18	< 0.03	< 0.07
Co	0.043	< 0.002	< 0.014
Cr	0.05	< 0.01	< 0.02
Cu	0.096	< 0.004	< 0.025
Fe	61	0.19	14
Ga	< 0.04	< 0.04	< 0.04
K	4.2	0.2	1.67
La	0.09	< 0.01	< 0.03
Li	0.04	< 0.01	< 0.02
Mg	15	0.3	7.9
Mn	1.5	< 0.01	< 0.52
Mo	< 0.1	< 0.1	< 0.1
Na	1.3	0.5	0.85
Nb	< 0.02	< 0.02	< 0.02
Ni	0.12	< 0.01	< 0.04
P	0.72	< 0.03	< 0.19

Table 53 (continued)

Parameter	Concentration (mg/L)		
	Max.	Min.	Avg.
Pb	0.18	< 0.01	< 0.05
Sc	0.018	< 0.001	< 0.005
Sr	0.018	0.004	0.012
Ti	0.16	0.002	0.037
V	0.12	< 0.003	< 0.031
Y	0.17	< 0.001	< 0.043
Zn	0.51	< 0.02	< 0.13
Zr	0.033	< 0.001	< 0.009

^aSee Fig. 36.

^bTotal Kjeldahl nitrogen.

^cTotal organic carbon.

Table 54. 1984 groundwater monitoring—Y-12 United Nuclear Disposal Site^a

Parameter	Concentration (mg/L)		
	Max	Min	Av
Hg	< 0.0005	< 0.0005	< 0.0005
Se	< 0.002	< 0.002	< 0.002
TKN ^b	0.4	< 0.2	< 0.28
NO ₃ (N)	7.5	< 0.1	< 1.1
Total N	7.8	< 0.3	< 1.4
PCB	< 0.0005	< 0.0005	< 0.0005
pH, units	10.1	7.4	
TOC ^c	40	< 2	< 12
Specific conductance, μ mhos/cm	470	110	280
Chloroform	< 0.01	< 0.01	< 0.01
Methyl bromide	< 0.01	< 0.01	< 0.01
Methyl chloride	< 0.01	< 0.01	< 0.01
Methylene chloride	0.02	< 0.01	< 0.01
Tetrachloroethylene	< 0.01	< 0.01	< 0.01
Toluene	0.03	< 0.01	< 0.01
Xylene	< 0.01	< 0.01	< 0.01
Chloroethane	< 0.01	< 0.01	< 0.01
Dichloroethane	< 0.01	< 0.01	< 0.01
Trichloroethane	< 0.01	< 0.01	< 0.01
Uranium	0.008	< 0.001	< 0.003
Th	< 0.02	< 0.02	< 0.02
Ag	< 0.01	< 0.01	< 0.01
Al	5.5	0.12	1.27
As	< 0.06	< 0.06	< 0.06

Table 54 (continued)

Parameter	Concentration (mg/L)		
	Max	Min	Av
B	< 0.02	< 0.02	< 0.02
Ba	< 0.2	< 0.2	< 0.2
Be	0.0006	< 0.0005	< 0.0005
Ca	49	7.3	30
Cd	< 0.002	< 0.002	< 0.002
Ce	< 0.03	< 0.03	< 0.03
Co	0.004	< 0.002	< 0.002
Cr	< 0.01	< 0.01	< 0.01
Cu	0.008	< 0.004	< 0.004
Fe	6.3	0.33	1.5
Ga	< 0.04	< 0.04	< 0.04
K	11.0	0.7	4.9
La	< 0.01	< 0.01	< 0.01
Li	< 0.01	< 0.01	< 0.01
Mg	24	0.7	13
Mn	0.17	0.02	0.06
Mo	< 0.1	< 0.1	< 0.1
Na	3.8	0.6	2.1
Nb	< 0.02	< 0.02	< 0.02
Ni	< 0.01	< 0.01	< 0.01
P	0.10	< 0.03	< 0.04
Pb	0.04	< 0.01	< 0.02
Sc	0.002	< 0.001	< 0.001
Sr	0.074	0.020	0.047
Ti	0.036	< 0.001	< 0.012
V	0.020	< 0.003	< 0.008
Y	0.006	< 0.001	< 0.002
Zn	0.06	< 0.02	< 0.03
Zr	0.008	< 0.001	< 0.002

^aSee Fig. 36.^bTotal Kjeldahl nitrogen.^cTotal organic carbon.

Table 55. 1984 groundwater monitoring—Y-12 Bear Creek burial grounds^a

Parameter	Concentration (mg/L)		
	Max	Min	Av
Hg	0.0094	< 0.0005	< 0.0014
Se	< 0.002	< 0.002	< 0.002
CN	0.003	< 0.002	< 0.002
TKN ^b	3.3	< 0.2	< 0.45
NO ₃ (N)	41	< 0.1	< 3.65
Total N	41	< 0.3	< 4.50
PCB	0.0018	< 0.0005	< 0.0006
pH, units	12	3.4	
TOC ^c	640	< 2	< 23
Specific conductance, μ mhos/cm	1200	80	510
Chloroform	0.06	< 0.01	< 0.01
Methyl bromide	< 0.01	< 0.01	< 0.01
Methyl chloride	0.02	< 0.01	< 0.01
Methylene chloride	0.07	< 0.01	< 0.04
Tetrachloroethylene	18	< 0.01	< 0.96
Toluene	< 0.01	< 0.01	< 0.01
Xylene	< 0.01	< 0.01	< 0.01
Chloroethane	< 0.01	< 0.01	< 0.01
Dichloroethane	2.0	< 0.01	< 0.10
Trichloroethane	0.51	< 0.01	< 0.04
Uranium	0.13	< 0.001	< 0.006
Th	0.049	< 0.02	< 0.02
Ag	< 0.01	< 0.01	< 0.01
Al	4.6	0.17	2.9
As	< 0.06	< 0.06	< 0.06
B	0.67	< 0.02	< 0.08
Ba	1.4	< 0.2	< 0.28
Be	< 0.0005	< 0.0005	< 0.0005
Ca	230	13	66
Cd	< 0.002	< 0.002	< 0.002
Ce	< 0.03	< 0.03	< 0.03
Co	0.13	< 0.002	< 0.006
Cr	< 0.01	< 0.01	< 0.01
Cu	0.033	< 0.004	< 0.18
Fe	14	0.34	2.61
Ga	< 0.04	< 0.04	< 0.04
K	19	0.7	3.9
La	< 0.01	< 0.01	< 0.01
Li	0.13	< 0.01	< 0.02
Mg	25	0.2	7.9
Mn	4.6	< 0.01	< 0.35
Mo	< 0.01	< 0.01	< 0.01
Na	22	0.5	6.6
Nb	< 0.02	< 0.02	< 0.02
Ni	0.37	< 0.01	< 0.03
P	0.36	< 0.03	< 0.07

Table 55 (continued)

Parameter	Concentration (mg/L)		
	Max	Min	Av
Pb	0.03	< 0.01	< 0.01
Sc	< 0.001	< 0.001	< 0.001
Sr	2.9	0.015	1.4
Ti	0.029	< 0.001	< 0.006
V	0.005	< 0.003	< 0.003
Y	0.034	< 0.001	< 0.002
Zn	1.9	< 0.02	< 0.06
Zr	0.005	< 0.001	< 0.001

^aSee Fig. 36.^bTotal Kjeldahl nitrogen.^cTotal organic carbon.Table 56. 1984 groundwater monitoring—Y-12 Centralized Sanitary Landfill II^a

Parameter	Concentration (mg/L)		
	Max	Min	Av
Hg	0.0030	< 0.0005	< 0.0013
Se	< 0.002	< 0.002	< 0.002
Cl	11	< 2	< 6.0
F	1.8	< 0.1	< 0.25
MBAS ^b	0.06	< 0.05	< 0.05
TKN ^c	0.02	< 0.02	< 0.02
NO ₃ (N)	31	< 0.1	< 6.8
Total N	31	< 0.3	< 7.0
Phenol	0.002	< 0.001	< 0.001
SO ₄	< 10	< 10	< 10
PCB	0.0005	< 0.0005	< 0.0005
pH, units	7.9	4.6	
TOC ^d	5.0	< 2	< 3.17
Coliform, colonies/100 ml	7.0	< 1	< 2.8
Color, apparent units	25	< 5	< 7.3
Specific conductance, μ mhos/cm	380	230	310
Chloroform	0.01	< 0.01	< 0.01
Methyl bromide	< 0.01	< 0.01	< 0.01
Methyl chloride	< 0.01	< 0.01	< 0.01
Methylene chloride	0.07	< 0.01	< 0.02
Tetrachloroethylene	< 0.01	< 0.01	< 0.01
Toluene	< 0.01	< 0.01	< 0.01
Xylene	< 0.01	< 0.01	< 0.01

Table 56 (continued)

Parameter	Concentration (mg/L)		
	Max	Min	Av
Chloroethane	< 0.01	< 0.01	< 0.01
Dichloroethane	< 0.01	< 0.01	< 0.01
Trichloroethane	< 0.01	< 0.01	< 0.01
Uranium	0.006	< 0.001	< 0.003
Th	0.024	< 0.02	< 0.02
Ag	< 0.01	< 0.01	< 0.01
Al	0.59	0.13	0.28
As	< 0.06	< 0.06	< 0.06
B	< 0.02	< 0.02	< 0.02
Ba	< 0.2	< 0.2	< 0.2
Be	< 0.0005	< 0.0005	< 0.0005
Ca	53	25	36
Cd	< 0.002	< 0.002	< 0.002
Ce	< 0.03	< 0.03	< 0.03
Co	< 0.002	< 0.002	< 0.002
Cr	< 0.01	< 0.01	< 0.01
Cu	0.008	< 0.004	< 0.004
Fe	0.61	0.19	0.30
Ga	< 0.04	< 0.04	< 0.04
K	1.3	0.5	0.92
La	< 0.01	< 0.01	< 0.01
Li	< 0.01	< 0.01	< 0.01
Mg	16	4.2	9.9
Mn	0.06	< 0.01	< 0.02
Mo	< 0.01	< 0.01	< 0.01
Na	3.7	0.5	1.4
Nb	< 0.02	< 0.02	< 0.02
Ni	0.02	< 0.01	< 0.01
P	0.11	< 0.03	< 0.05
Pb	0.05	< 0.01	< 0.02
Sc	< 0.001	< 0.001	< 0.001
Sr	0.056	0.016	0.032
Ti	0.006	< 0.001	< 0.003
V	< 0.003	< 0.003	< 0.003
Y	0.001	< 0.001	< 0.001
Zn	0.05	< 0.02	< 0.03
Zr	0.002	< 0.001	< 0.001

^aSee Fig. 36.^bMethylene blue absorbing substances.^cTotal Kjeldahl nitrogen.^dTotal organic carbon.

Table 57. 1984 groundwater monitoring—Y-12 S-3 ponds^a

Parameter	Concentration (mg/L)		
	Max	Min	Av
Ag	< 0.01	< 0.01	< 0.01
Al	42	0.82	9.1
As	< 0.06	< 0.06	< 0.06
B	0.11	< 0.02	< 0.04
Ba	5.0	< 0.2	< 1.9
Be	0.027	< 0.0005	< 0.006
Ca	1300	26	390
Cd	0.069	< 0.002	< 0.02
Ce	0.42	< 0.03	< 0.11
Co	0.16	< 0.002	< 0.04
Cr	0.08	< 0.01	< 0.01
Cu	0.018	< 0.004	< 0.007
Fe	3.1	0.39	1.5
Ga	< 0.04	< 0.04	< 0.04
Hg	0.0052	< 0.0005	< 0.0016
K	18	1.0	7.2
La	0.33	< 0.01	< 0.07
Li	0.05	< 0.01	< 0.02
Mg	180	3.7	71
Mn	15	0.07	3.7
Mo	< 0.1	< 0.1	< 0.1
Na	110	3.6	38
Nb	0.08	< 0.02	< 0.03
Ni	0.60	< 0.01	< 0.15
P	0.70	< 0.03	< 0.09
Pb	0.02	< 0.01	< 0.01
Sc	< 0.001	< 0.001	< 0.001
Sr	4.9	0.096	1.7
Ti	0.015	< 0.001	< 0.005
V	0.007	< 0.003	< 0.003
Y	0.48	< 0.001	< 0.10
Zn	0.17	< 0.02	< 0.06
Zr	0.006	< 0.001	< 0.002
Se	< 0.002	< 0.002	< 0.002
CN	0.017	< 0.002	< 0.004
TKN	6.2	< 0.2	< 0.99
NO ₃ (N)	1200	< 0.1	< 480
Total N	1200	< 0.3	< 480
PCB	< 0.0005	< 0.0005	< 0.0005
pH, units	7.2	4.5	
TOC ^a	13	< 2	< 6.8
Specific conductance, μ mhos/cm	8500	220	3400
Chloroform	< 0.01	< 0.01	< 0.01
Methyl bromide	< 0.01	< 0.01	< 0.01
Methyl chloride	< 0.01	< 0.01	< 0.01

Table 57 (continued)

Parameter	Concentration (mg/L)		
	Max	Min	Av
Methylene chloride	0.06	< 0.01	< 0.03
Tetrachloroethylene	0.02	< 0.01	< 0.01
Toluene	< 0.01	< 0.01	< 0.01
Xylene	< 0.01	< 0.01	< 0.01
Chloroethane	< 0.01	< 0.01	< 0.01
Dichloroethane	< 0.01	< 0.01	< 0.01
Trichloroethane	< 0.01	< 0.01	< 0.01
Uranium	0.44	< 0.001	< 0.16
Th	0.30	< 0.02	< 0.08

^aSee Fig. 36.

^bTotal organic carbon.

Potential pathways of human exposure from radioactive effluents released by the operations of the DOE Oak Ridge facilities that are considered in the dose estimates are presented in Fig. 37. Only the principal pathways for exposure are included. The doses received by a tissue or organ from the various pathways are weighted and then summed to estimate the total risk. This assumes that (1) a linear relationship (without threshold) exists between dose and the probability of an effect and (2) the severity of each type of effect is independent of dose. These assumptions are based on the recommendations of the International Commission on Radiological Protection (ICRP).¹²

Table 62 presents the estimated doses from each of the predominant pathways to an adult individual at locations of maximum exposure. Doses resulting from gaseous effluents were calculated for each of the three plants and summed. This table presents both the committed effective dose equivalent and the dose equivalent to a critical organ. Definitions of units and terms can be found in Appendix B.

The ICRP had formerly recommended that when one or more than one organ of the body is exposed, the irradiation of one particular organ or tissue is likely to be of greatest importance because of (1) the dose it received, (2) its sensitivity to radiation, or (3) the importance to health of any damage that results. This tissue or organ was referred to as the critical organ. The ICRP now recommends a procedure that takes into account the total risk attributable to the exposure of all tissues irradiated. This dose is now referred to as the effective dose equivalent. Table 62 presents both dose summations to facilitate comparison with previous years and those regulations that still specify a dose limit to a critical organ.

Exposures to radionuclides that originate in the effluents released from the DOE facilities in Oak Ridge were converted to estimates of radiation dose to individuals using models and data presented in publications of the ICRP,¹²⁻¹⁵ other recognized literature on radiation protection,¹⁶⁻¹⁸ and computer programs incorporating some of these models and data.^{19,20} Radioactive material taken into the body by inhalation or ingestion will continuously irradiate the body until it is

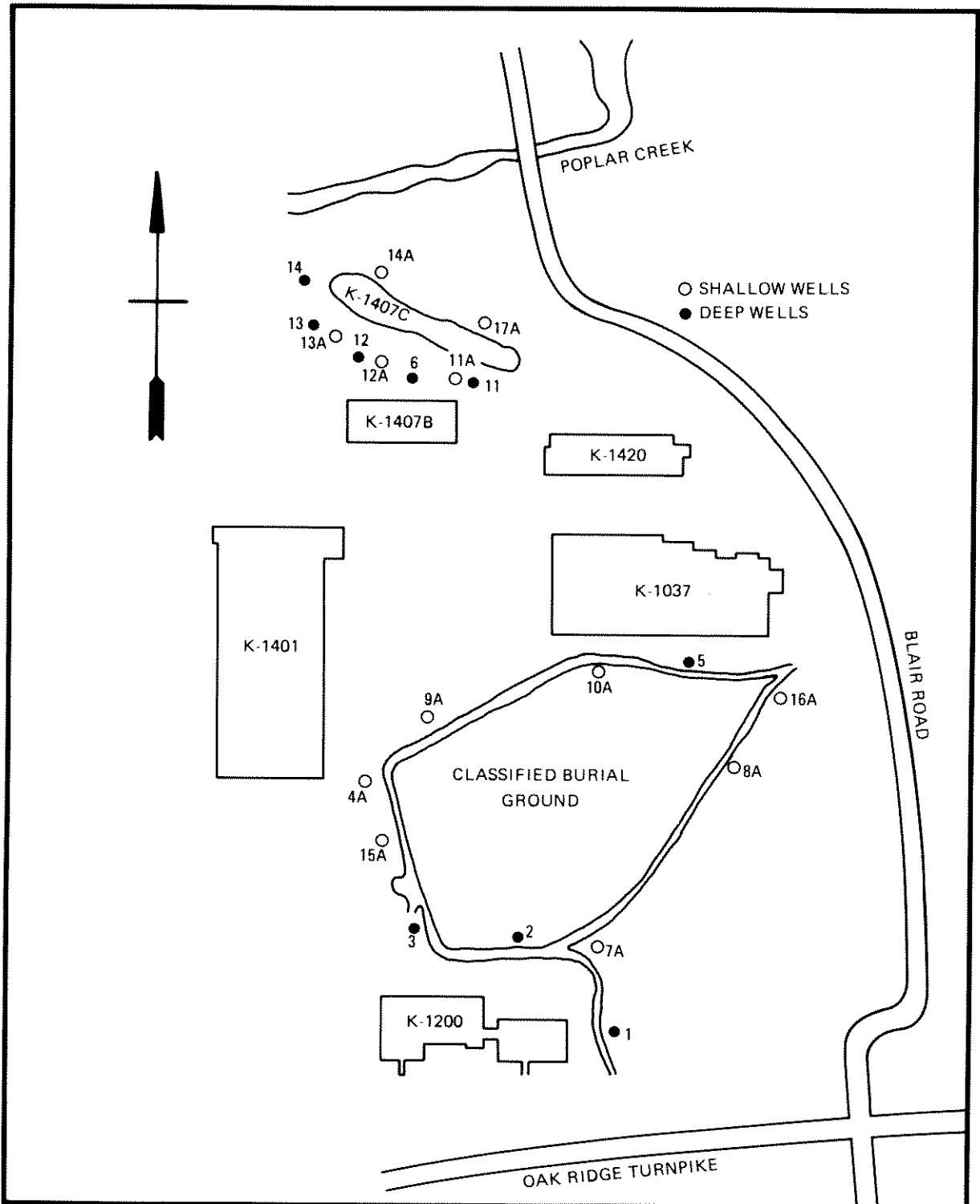


Fig. 36. Groundwater monitoring well locations at ORGDP.

Table 58. 1984 groundwater monitoring—ORGDP classified burial ground^a shallow wells

Parameter	Concentration (mg/L)		
	Max	Min	Av
Ag ^b	0.04	< 0.01	< 0.014
As ^c	< 0.005	< 0.004	< 0.005
Ba ^c	0.40	< 0.01	< 0.17
Ca ^c	63	8.0	35
Cd ^b	0.012	< 0.003	< 0.003
Cl ^{-c}	9.6	1.4	3.9
Cr ^b	0.06	< 0.01	< 0.02
Cu ^b	0.14	< 0.004	< 0.030
Fe ^c	110	6.0	53
F ^{-b}	0.44	0.13	0.24
Hg ^b	< 0.001	< 0.001	< 0.001
Mn ^b	4.63	0.15	1.6
Ni ^b	0.05	< 0.01	< 0.02
NO ₃ ^{-c}	< 0.5	< 0.5	< 0.5
Pb ^b	0.009	< 0.004	< 0.005
Se ^c	< 0.005	< 0.005	< 0.005
SO ₄ ^{2-c}	680	5.0	140
TOC ^b	85	4.0	31
U ^b	0.008	< 0.001	< 0.004
Zn ^b	1.45	0.03	0.28
pH ^b	8.1	6.7	
Methyl ethyl ketone ^d	< 0.01	< 0.01	< 0.01
Freon-113 ^d	0.02	< 0.01	< 0.01
Freon-123 ^d	0.05	< 0.01	< 0.01
Trichloroethylene ^b	0.01	< 0.002	< 0.01

^aSee Fig. 36.

^bAverage concentration of samples taken from seven wells, April and October.

^cAverage concentration of samples taken from seven wells, April.

^dAverage concentration of samples taken from seven wells, October.

removed by processes of metabolism or radioactive decay; thus, the estimates for internal dose are called "dose commitments," because they are obtained by integrating over the assumed lifetime (70 years) of the exposed individual.¹

The radiation doses to the total body and to the internal organs from external exposure to penetrating radiation are approximately equal, but they vary considerably for internal exposures because some radionuclides concentrate in certain organs of the body. For this reason, estimates of radiation to the major organs such as, but not limited to, thyroid, lungs, bone, liver, kidneys, and gastrointestinal tract were considered for various pathways of exposure. These estimates were based on parameters applicable to an average adult.¹⁵ The population dose estimate in person-rem is the sum of the committed effective dose equivalents to exposed individuals within an 80-km radius of the DOE Oak Ridge facilities.

Table 59. 1984 groundwater monitoring—ORGDP classified burial ground^a deep wells

Parameter	Concentration (mg/L)		
	Max	Min	Av
Ag ^b	< 0.01	< 0.01	< 0.01
As ^b	0.006	< 0.005	< 0.005
Ba ^b	0.32	0.16	0.22
Ca ^b	140	40	81
Cd ^c	0.009	< 0.002	< 0.003
Cl ^{-b}	55	1.5	30
Cr ^c	0.27	< 0.01	< 0.04
Cu ^c	0.02	< 0.004	< 0.01
Fe ^b	42	4.7	14
F ^{-c}	0.40	< 0.10	< 0.21
Hg ^c	< 0.001	< 0.001	< 0.001
Mn ^c	6.7	0.22	2.2
Ni ^c	0.65	< 0.01	< 0.11
NO ₃ ^{-b}	< 0.5	< 0.5	< 0.5
Pb ^c	0.005	< 0.004	< 0.004
Se ^b	< 0.005	< 0.005	< 0.005
SO ₄ ^{2-b}	34	11	19
TOC ^{c,d}	180	12	63
U ^c	< 0.005	< 0.001	< 0.003
Zn ^c	1.1	0.05	0.26
pH ^c	7.9	6.9	
1,1-Dichloroethane ^e	0.07	< 0.005	< 0.02
Tetrachloroethylene ^c	0.03	< 0.01	< 0.01
Freon-123 ^e	0.12	< 0.01	< 0.02
Freon-113 ^e	1.10	< 0.01	< 0.08
1,1,1-Trichloroethane ^c	< 0.01	< 0.01	< 0.01
Benzene ^e	0.02	< 0.01	< 0.01
1,2-Dichloroethane ^e	< 0.003	< 0.003	< 0.003

^aSee Fig. 36.

^bAverage concentration of samples taken from four wells, April.

^cAverage concentration of samples taken from four wells, April and October.

^dTotal organic carbon.

^eAverage concentration of samples taken from four wells, October.

**Table 60. 1984 groundwater monitoring—ORGDP
K-1407-C holding pond^a shallow wells**

Parameter	Concentration (mg/L)		
	Max	Min	Av
Ag ^b	< 0.01	< 0.01	< 0.01
As ^b	0.005	< .005	< 0.005
Ba ^b	0.81	< 0.01	< 0.22
Ca ^b	290	56	130
Cd ^c	0.005	< 0.001	< 0.002
Cl ^{-b}	130	6.0	46
Cr ^c	0.03	< 0.01	< 0.01
Cu ^c	0.14	< 0.004	< 0.026
Fe ^b	64	4.0	32
F ^{-c}	0.78	< 0.10	< 0.22
Hg ^c	< 0.001	< 0.001	< 0.001
Mn ^c	12	0.36	3.9
Ni ^c	0.21	< 0.01	< 0.04
NO ₃ ^{-b}	6.0	< 0.5	< 1.9
Pb ^c	0.11	< 0.004	< 0.02
Se ^b	< 0.005	< 0.005	< 0.005
SO ₄ ^{2--b}	800	6.0	170
TOC ^{c,d}	81	5.0	29
U ^c	0.006	< 0.005	< 0.003
Zn ^c	0.65	0.03	0.19
pH ^c	7.7	7.0	
Trichloroethylene ^e	0.01	< 0.002	< 0.002
1,2-dichloroethane ^e	< 0.003	< 0.003	< 0.003
Methylene chloride ^c	0.01	< 0.01	< 0.01
1,1,1-Trichloroethane ^c	< 0.01	< .01	< 0.01
Tetrachloroethylene ^e	< 0.01	< 0.01	< 0.01
Other halomethanes ^e	< 0.01	< 0.01	< 0.01

^aSee Fig. 36.

^bAverage concentration of samples taken from five wells, April.

^cAverage concentration of samples taken from five wells, April and October.

^dTotal organic carbon.

^eAverage concentration of samples taken from five wells, October.

**Table 61. 1984 groundwater monitoring—ORGDP K-1407-C
holding pond^a deep wells**

Parameter	Concentration (mg/L)		
	Max	Min	Av
Ag ^b	< 0.01	< 0.01	< 0.01
As ^b	< 0.005	< 0.005	< 0.005
Ba ^b	0.25	< 0.10	< 0.14
Ca ^b	200	85	130
Cd ^c	< 0.002	< 0.002	< 0.002
Cl ^{-b}	99	27	65
Cr ^c	< 0.01	< 0.01	< 0.01
Cu ^c	0.024	< 0.004	< 0.01
Fe ^b	20	4.0	12
F ^{-c}	1.30	< 0.10	< 0.29
Hg ^c	< 0.001	< 0.001	< 0.001
Mn ^c	4.2	0.40	2.1
Ni ^c	0.03	< 0.01	< 0.02
NO ₃ ^{-b}	< 0.50	< 0.50	< 0.50
Pb ^c	0.050	< 0.004	< 0.009
Se ^b	< 0.005	< 0.005	< 0.005
SO ₄ ^{2-b}	250	11	71
TOC ^{c,d}	92	8.0	46
U ^c	0.009	0.001	0.004
Zn ^c	0.34	0.03	0.10
pH ^c	8.1	7.0	
Freon-113 ^e	< 0.01	< 0.01	< 0.01
Freon-123 ^e	< 0.01	< 0.01	< 0.01
Trichloroethylene ^c	0.040	< 0.002	< 0.01
1,2-Dichloroethane ^e	< 0.003	< 0.003	< 0.003
Methylene chloride ^c	< 0.01	< 0.01	< 0.01
Trans-1,2-Dichloroethylene ^e	0.02	< 0.01	< 0.01
1,1,1-Trichloroethane ^c	< 0.01	< 0.01	< 0.01
Tetrachloroethylene ^c	< 0.03	< 0.01	< 0.01
Other halomethanes	< 0.01	< 0.01	< 0.01

^aSee Fig. 36.

^bAverage concentration of samples taken from five wells, April.

^cAverage concentration of samples taken from five wells, April and October.

^dTotal organic carbon.

^eAverage concentration of samples taken from five wells, October.

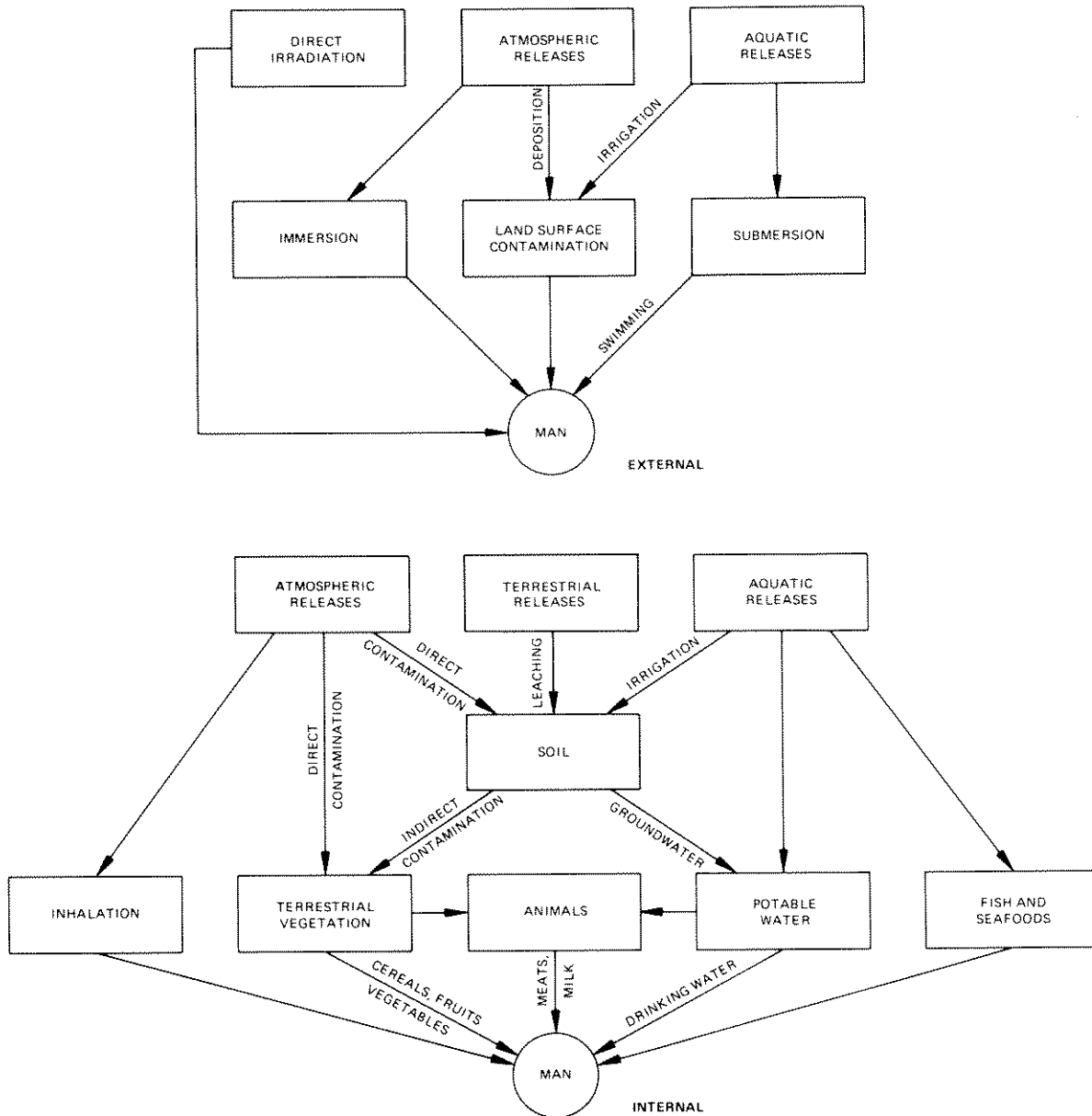


Fig. 37. Exposure pathways to man.

Gaseous effluents are discharged from several locations within each of the DOE facilities in Oak Ridge. For purposes of calculation, the gaseous discharges are assumed to occur from only one vent each at Y-12 and ORNL and two vents at ORGDP. As suggested by the EPA, no plume rise resulting from momentum (zero velocity stack discharge) was incorporated into the modeling program. Meteorological data collected at the ORNL plant in 1984 were used for dispersion calculations for the ORNL and Y-12 sites; meteorological wind data at ORGDP collected in 1984 were used for the ORGDP site (Fig. 38). Concentrations of radionuclides in air and deposited on the ground were estimated at distances up to 80 km from the DOE facilities using the Gaussian plume

Table 62. Summary of the estimated radiation dose to an adult during 1984 at locations of maximum exposure

Pathway	Location	Dose equivalent ^a (millirem)	Critical organ (millirem)
Gaseous effluents Inhalation plus direct radiation from air, ground, and food chains	Nearest resident to site boundary	4.6	15 (lung)
Terrestrial food chain (milk only)	Milk sampling stations (⁹⁰ Sr)	0.01	0.07 (endosteal cells)
Liquid effluents Aquatic food chain (fish) ^b	Clinch-Tennessee River System (⁹⁰ Sr)	1.1	2.1 (endosteal cells)
Drinking water ^c	Kingston, Tennessee (⁹⁰ Sr)	0.2	0.5 (endosteal cells)
Direct radiation along water, shores, and mud flats ^d	Downstream from White Oak Creek near experimental Cs field plots	5.9	

^aSeventy-year committed effective dose equivalent. This dose is obtained by summing the weighted doses to each of a set of selected principal organs and obtaining the equivalent uniform body dose that would produce the equivalent amount of risk. The annual effective dose equivalent to humans from natural background is 190 millirem, based on the United Nations Scientific Committee in the Effects of Atomic Radiation's 1984 *Ionizing Radiation: Sources and Effects*, N.Y.

^bBased on the highest annual average concentration in fish flesh and its consumption.

^cBased on the analysis of treated water.

^dDirect annual radiation exposure for 1984, assuming a residence time of 240 h/year.

model developed by Pasquill²¹ and Gifford²² that has been incorporated in a computer program.²³⁻²⁶ The deposition velocities used in the calculations were 0.0 cm/s for krypton and xenon, 0.2 cm/s for ¹³¹I, and 0.1 cm/s for particulates.^{27,28} Wind rose data from 30- and 100-m elevations on a tower at ORNL in Bethel Valley are shown in Figs. 39 and 40.

Maximum Potential Exposure

The point of maximum potential ("fence-post") direct radiation exposure on a site boundary is located along the bank of the Clinch River adjacent to an experimental plot in the ¹³⁷Cs field. The maximum dose results primarily from "sky shine" from the plot. This dose was calculated to be 215 millirem, assuming that an individual remained at this point for 24 h/d for the entire year. The probability of exposure of this magnitude at this location is considered remote because the area is accessible only by boat. The total body dose to a "hypothetical maximum-exposed individual" at the same location was calculated using a more realistic upper limit residence time of 240 h/year. The

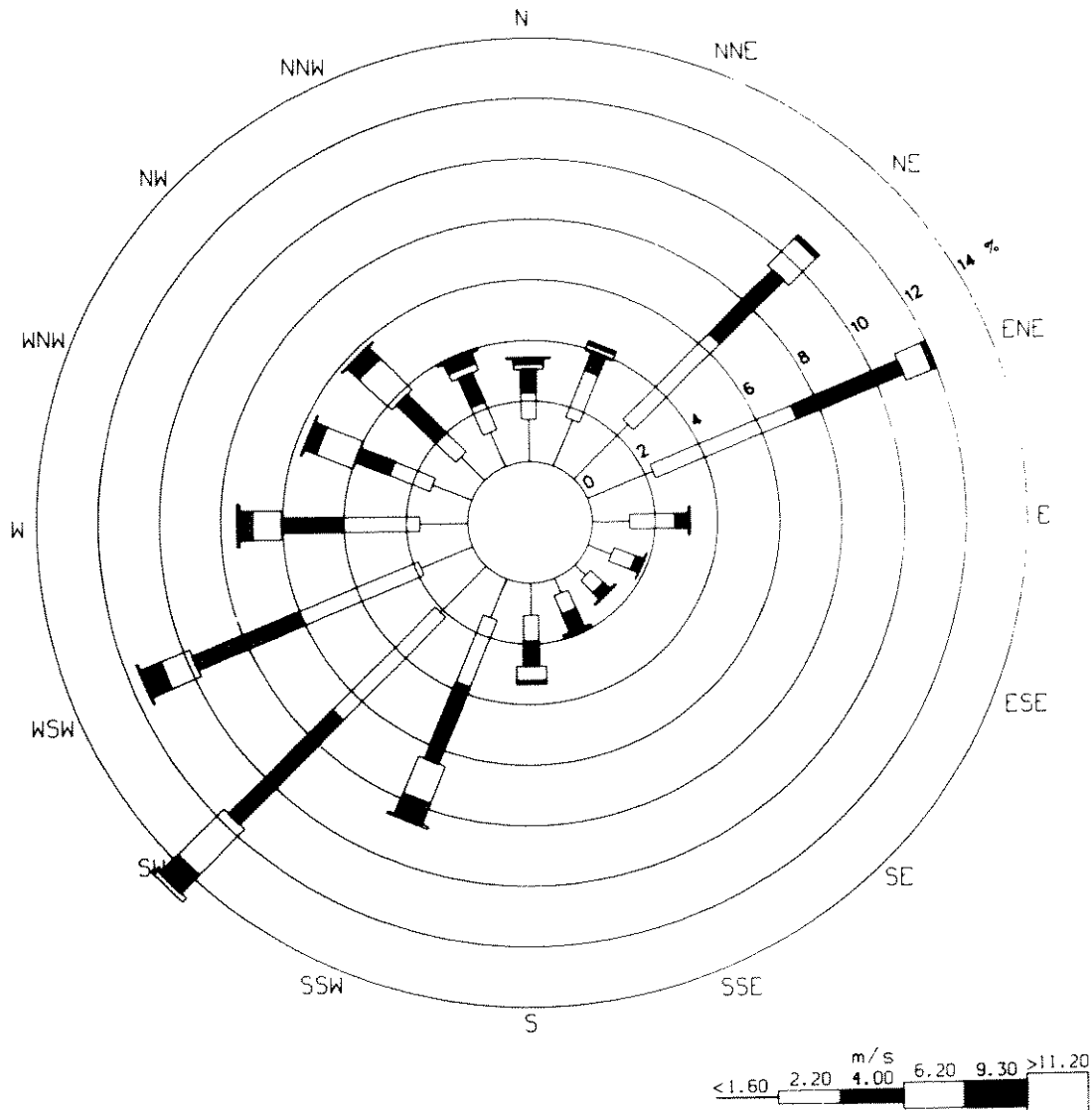


Fig. 38. Meteorological data for 1984 at 60 m for the Oak Ridge Reservation from a tower near ORGDP.

calculated dose under these conditions was 5.9 millirem, which represents a probable upper limit of exposure (Table 62).

The committed dose equivalent via inhalation to an individual continuously occupying the residence nearest the site boundary is based on an inhalation rate for the average adult of 20,000 L/d. The calculated committed dose equivalent at this location was 15 millirem to the pulmonary tissues (the critical organ) and the effective dose equivalent (weighted sum of doses to the principal organs) was 4.6 millirem (Table 62). Uranium nuclides primarily provide this dose; the Y-12 Plant contributes over 98% of the effective dose equivalent and about 99% of the pulmonary dose. The dose to the pulmonary tissues is 20% of the EPA National Emission Standard for Hazardous Air Pollutants,²⁹ which became effective in 1985.

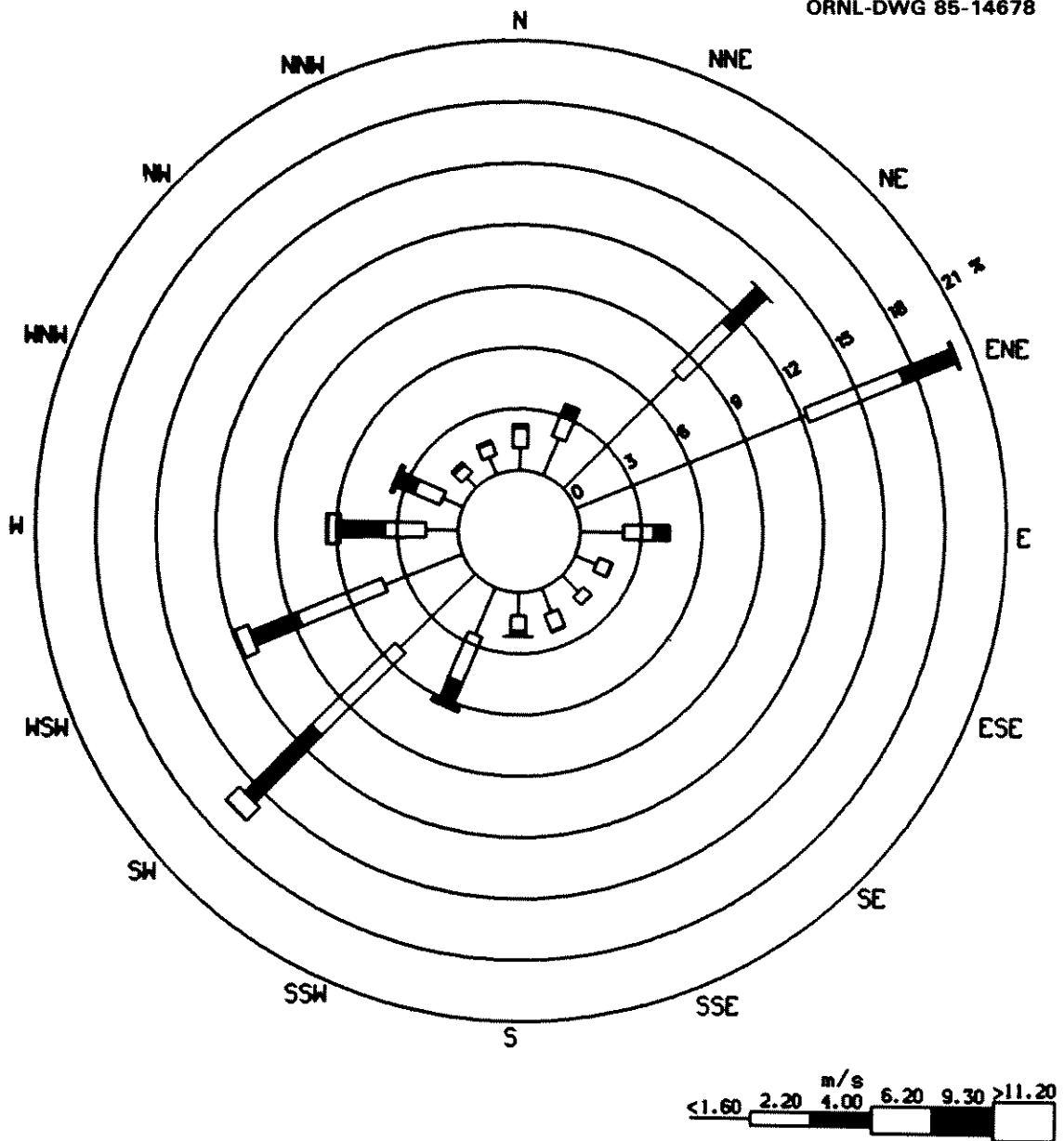


Fig. 39. Meteorological data for 1984 at 30 m for the Oak Ridge Reservation from the 100-m tower on Bethel Valley Road.

An important contribution to dose from radioactivity within the terrestrial food chain is through the atmosphere-pasture-cow-milk pathway. Measurements of ^{90}Sr , the principal radionuclide entering this pathway (Table 26), indicate that the maximum effective dose to an individual in the immediate area from ingestion of 1 L of milk per day is less than 0.01 millirem and 0.07 millirem to the critical organ, bone endosteal cells (Table 62). The average concentrations for the remote stations were assumed to be derived from background radioactivity and were subtracted from the perimeter station data. Another radionuclide of concern in milk is ^{131}I ; analysis for ^{131}I was negative.

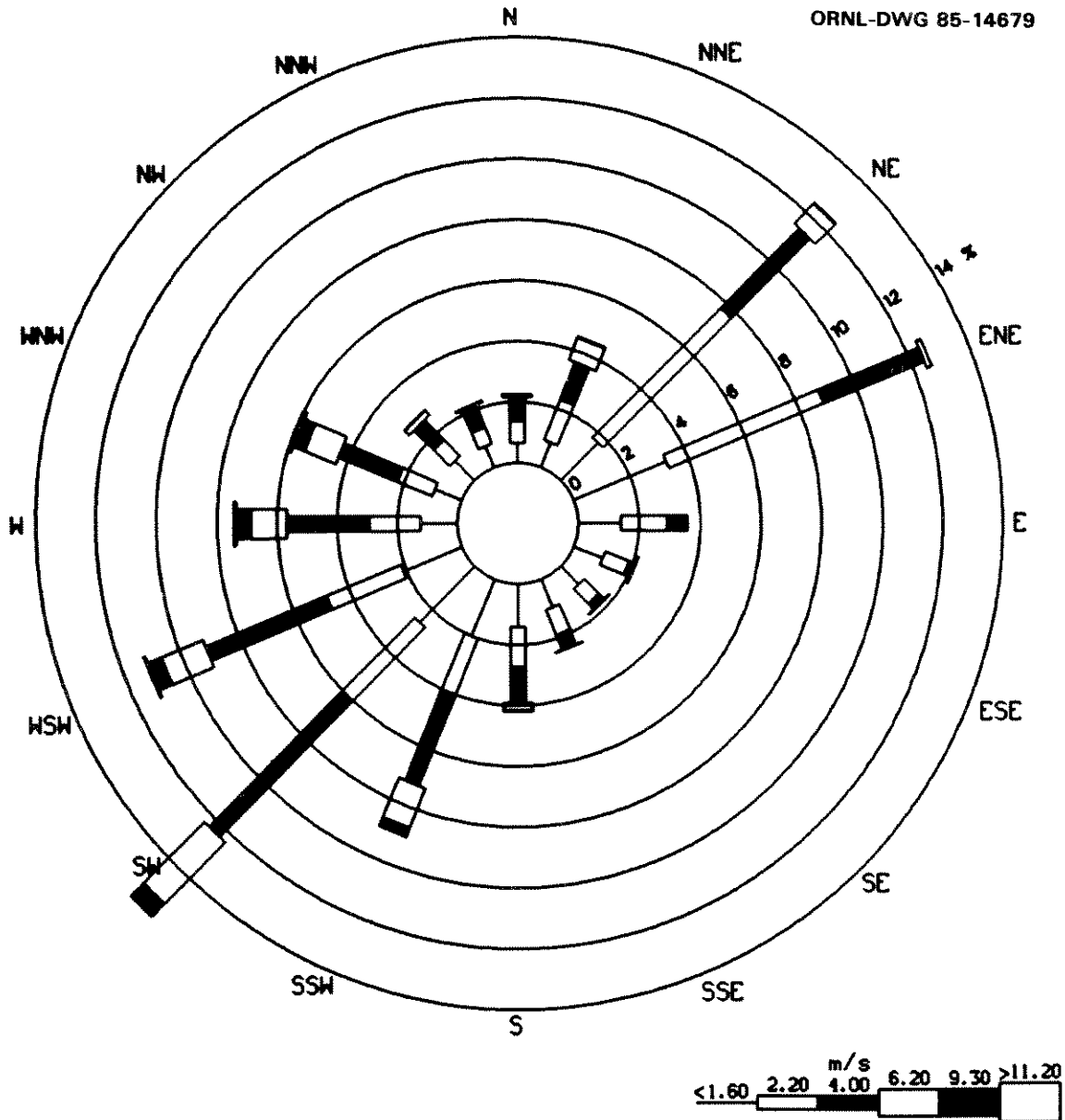


Fig. 40. Meteorological data for 1984 at 100 m for the Oak Ridge Reservation from the 100-m tower on Bethel Valley Road.

Water is sampled at White Oak Dam to determine discharges of radionuclides to the Clinch River. Based on radionuclide concentrations measured at White Oak Dam and the dilution afforded by the Clinch River (assuming complete mixing), a 0.17-millirem calculated effective dose equivalent resulted from consumption of Clinch River water containing ORNL discharges. This is based on the adult liquid requirement (2.2 L/d) and a 1984 dilution factor (ratio of Clinch River to White Oak Dam flow) of 310. Water is also sampled at the inlet to the ORGDP water plant, which is the closest (14-km) nonpublic water supply downstream from ORNL. Assuming that (1) the water is consumed at a rate of 1 L per 8-h workday and (2) the treated water contains the same amount of radionuclides as the sampled inlet water, the calculated committed effective dose equivalent would be 0.2 millirem. The public water supply closest to the DOE facilities' liquid discharges

is located about 26 km downstream from ORNL at Kingston, Tennessee. The intake to the water filtration plant is located on the Tennessee River about 0.5 mile upstream from the confluence of the Clinch and Tennessee rivers. Normally, Tennessee River water is used for the Kingston water supply, but under certain conditions backflow can occur. Under backflow conditions, Clinch River water may move upstream in the Tennessee River and be used as the source of water for the Kingston filtration plant. Measurements of treated river water samples taken at the Kingston filtration plant indicated that the maximum dose resulting from the ingestion of the adult daily requirement (2.2 L/d) is 0.5 millirem to the bone's endosteal cells and 0.2 millirem for the committed effective dose equivalent. The annual effective dose equivalent from drinking ORNL tap water (derived from Melton Hill Lake) was the same as that for Kingston (Table 62).

Estimates of the dose commitment to an adult from ingestion of 17 kg of fish flesh per year were calculated. An annual consumption rate of about 2.5 times the national average is used because of the popularity of fishing in East Tennessee. From the analysis of edible parts of the fish, the maximum possible organ dose commitment to an individual is estimated to be 20 millirem to the endosteal cells. This dose was estimated using shad collected at CRM 12.0 during the fourth quarter of 1984. The primary radionuclides contributing to the organ (endosteal cells) dose are ^{234}U and ^{239}Pu . The effective dose equivalent from ingestion of this fish sample would be 1.0 millirem. The maximum effective dose equivalent was calculated to be 2.7 millirem from ingestion of bluegill caught at CRM 12.0 during the second quarter of 1984. The primary radionuclides contributing to this dose were ^{137}Cs and ^{234}U . (Maximum concentrations of radionuclides are assumed to exist in the fish ingested by humans every quarter.)

A better estimate of the maximum potential dose from the aquatic (fish) pathway is derived from the annual average effective dose equivalents. The highest annual average effective dose equivalent was 1.1 millirem from the ingestion of bass collected at CRM 20.8 (Table 28). The radionuclides contributing primarily to this dose were ^{137}Cs and ^{90}Sr . Ingestion of this bass sample would

Fish samples taken from Melton Hill Lake (CRM 25.0) were analyzed to determine background conditions. Bass caught and consumed from this location would yield an effective dose equivalent of 0.04 millirem. Fish caught from other locations in the Clinch River and ingested would result in significantly lower effective doses than the annual average dose from bass at CRM 20.8, except for bluegill from CRM 12.0, which yielded an effective dose of 1.0 millirem (Fig. 41).

Because individuals in the past have been known to consume fish patties prepared by grinding the fish flesh and bone,⁸ a study was conducted in 1984 to assess the impact of ingestion of Clinch River carp patties. The patties were assumed to contain all bones (including back and rib) but not including the head, skin, and fins. Because no data are available on the quantities of carp patties that might be consumed by an individual in a year, the results are expressed in committed effective dose equivalent or committed dose equivalent to the bone (endosteal cells) per kilogram of fish patty consumed (Table 29). As would be expected, carp caught at CRM 20.8 (the confluence with White Oak Creek) had the highest concentration of ^{90}Sr . Consumption of 1 kg of fish patties containing the maximum amount of ^{90}Sr would result in a committed effective dose equivalent of 1.4 millirem (Table 29) and a committed dose equivalent to the bone (endosteal cells) of 15 millirem. A kilogram of patties containing average concentrations found at this location would result in a committed effective dose equivalent of 0.4 millirem (Table 29) and a committed dose equivalent to bone (endosteal cells) of 4.3 millirem. In Table 29, dose commitments attributable to consuming patties from carp taken at other locations would result in much lower dose commitments. The overall impact of the consumption of carp patties is expected to be low because only a small amount of

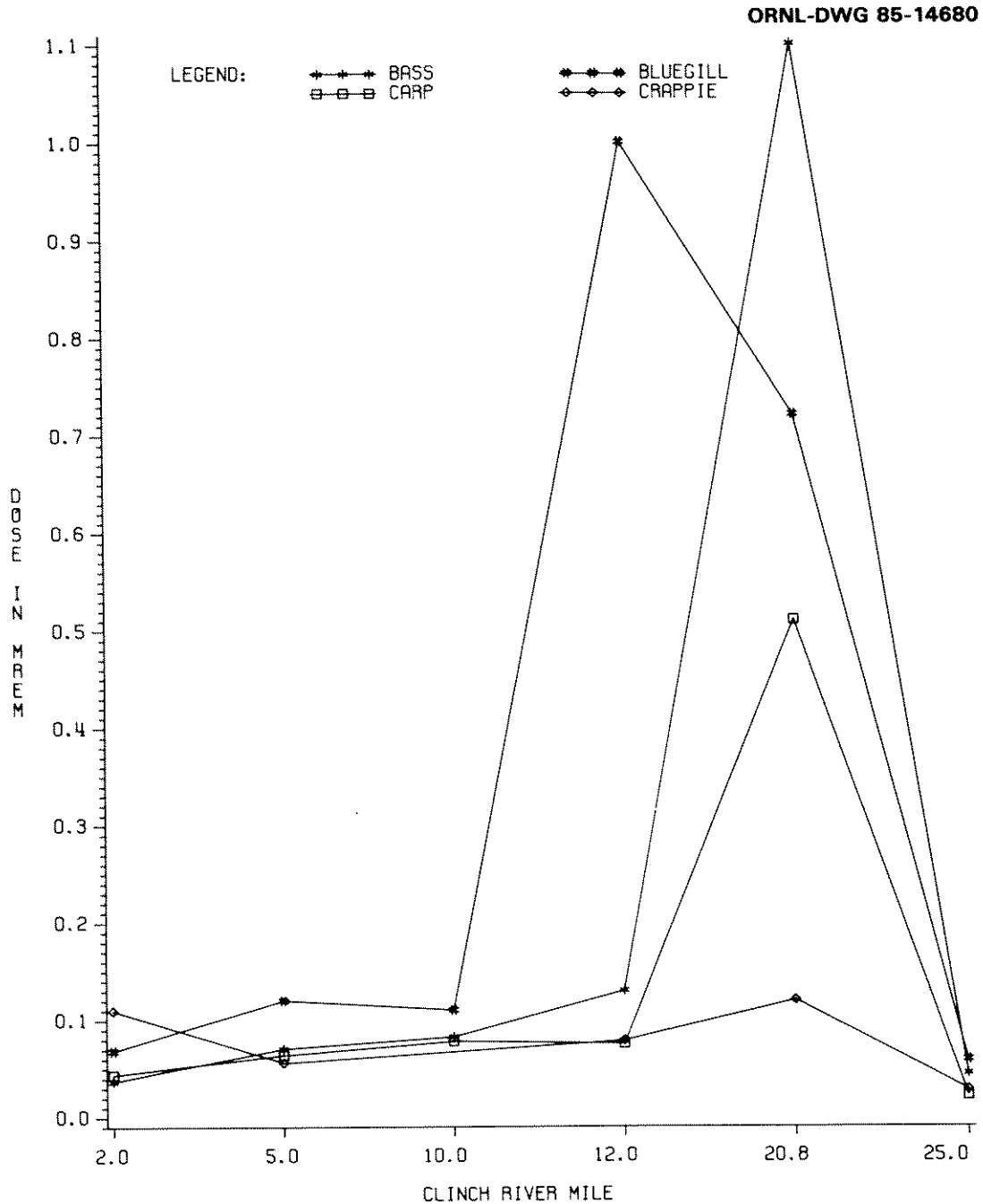


Fig. 41. Effective dose equivalent from ingestion of Clinch River fish.

commercial fishing takes place above CRM 12.0 and, of that, only a small portion would likely be consumed as patties.

The dose equivalents calculated for 1984 from each pathway (Table 62) are similar to those estimated for 1983. The doses to the critical organ for 1984 are much lower than 1983 estimates because of differences in dose conversion factors. Revised ICRP methods have been used to estimate doses to the endosteal cells on the outside of the bone rather than to the bone itself.

Dose to the Population

As a group, the Oak Ridge population received the largest average individual committed effective dose equivalent (1.6 millirem). The average dose commitment to the pulmonary tissues of an Oak Ridge resident was 5.4 millirem. The maximum potential dose commitment to an Oak Ridge resident was calculated to be 15 millirem to the pulmonary tissues. This dose is 20% of the EPA National Emission Standard for Hazardous Air Pollutants.²⁹ These doses are similar to those for 1983. Differences in the two years are primarily the result of differences in meteorological conditions and methods of calculation.

The cumulative committed effective dose equivalent to the population within an 80-km radius of the Oak Ridge facilities (from the total 1984 plant effluents) was calculated to be 120 person-rem. About 67% can be attributed to Y-12, 30% to ORNL, and 3% to ORGDP. The cumulative dose was calculated using the population distribution and densities in Fig. 1 and assuming that 30% of the food consumed by the Oak Ridge population is grown in the area. This dose may be compared with an estimated 164,000 person-rem to the same population from natural background radiation. About 30% of the collective dose to 80-km population from the DOE Oak Ridge facility effluents is estimated to be absorbed by the Oak Ridge population.

SPECIAL STUDIES

This section of the report contains abstracts or brief summaries of special studies that have been conducted or are continuing that are related to the environmental monitoring activities of the DOE Oak Ridge facilities. References are provided for completed studies in which additional details may be found.

Y-12 Plant Air Monitoring Programs

To assess accurately the effect of Y-12 Plant operations on the region's ambient air quality, the Y-12 Plant currently has in place a comprehensive air pollution monitoring program.³⁰ This program is expected to grow significantly in the next five years as the Y-12 Plant obtains hundreds of air pollution operating permits and new emission sources are added and modified. In addition, recently enacted, proposed, or considered changes in air pollution regulations,²⁹ such as the expansion in hazardous air pollution regulations and the regulation of airborne radionuclides, may significantly increase the air pollution monitoring requirements of the Y-12 Plant in the near future.

Air pollution monitoring at the Y-12 Plant involves three distinct, but interrelated, monitoring methods. The first method, mandated by the Clean Air Act,³¹ is source-emission or stack testing. This procedure is required to ensure that air pollution control devices are operating efficiently and that permitted emission rates (as contained within the source operating permit) are not exceeded. This method of air pollution testing is very important because it specifically determines the state of compliance with emission limitations for individual air pollution point sources.

The remaining two methods of air pollution monitoring, ambient air and atmospheric dispersion modeling, attempt to determine the impact of plant operations on the region's air quality.

In 1984 the Y-12 Plant made significant strides in defining the physical and chemical characteristics of airborne releases emitted from production stacks. The "Stack Catalog Project," initiated in 1984, was undertaken to provide an overall inventory and evaluation of the Y-12 Plant's many stacks. Efforts are continuing to maintain an up-to-date inventory of the Y-12 Plant's ventilation systems to account for emissions stemming from inside the plant boundaries. However, the current emphasis of the *Y-12 Plant Five-Year Environmental Monitoring Plan*³⁰ is on upgrading controls on existing air pollution sources to further reduce emissions of contaminants into the atmosphere; a number of capital projects are currently planned or under way at the Y-12 Plant that will reduce emissions of air contaminants into the atmosphere. One of these projects, the Y-12 Steam Plant Improvement—Emissions Control Project, is currently under way to bring the Y-12 steam plant into compliance with the Clean Air Act³¹ and the Tennessee State Implementation Plan.³² New, high-efficiency, fabric-filter baghouses were installed in 1984 on two of the steam plant's four pulverized coal boilers for particulate (fly ash) control. Construction is currently under way to retrofit the remaining two boilers with two additional fabric-filter baghouses as part of this project.

Opacity of the steam plant stack emissions is continuously monitored using light photometry. During 1984, readings prior to baghouse installation indicated that visible emissions exceeded state-imposed limits, whereas opacity measurements taken following baghouse retrofit were well within compliance limits. Emission testing that took place in 1984 for the two boilers having operational fabric-filter baghouses will continue in 1985 to ensure that full compliance with particulate and SO₂ emissions standards is achieved.

Many of the stacks located in the enriched uranium processing areas of the Y-12 Plant are equipped with continuous isokinetic rake-type samplers. A Stack Characterization Project, initiated in 1984, involves the simultaneous sampling of a number of the radionuclide-emitting stacks by continuous rake-type sampling and EPA Method-5 particulate sampling.³³ This project was being conducted to compare results from these two methods of monitoring radionuclide particulate matter and to determine which of the existing radionuclide stack monitoring equipment should be upgraded or replaced as part of the effort to accurately monitor all of the Y-12 Plant's radionuclide sources.

To meet the goal of installing continuous radionuclide stack samplers on all of the Y-12 Plant's radionuclide-emitting sources, various capital projects contain funding specifically directed to the procurement of monitoring equipment. Continuous isokinetic air sampling systems are being installed on the Y-12 Plant's larger radionuclide emitters, and additional constant rate air sampling monitors are being placed on remaining process stacks.

Although much effort is being directed toward minimizing releases of particulate matter, work is also under way to reduce atmospheric emissions of volatile organic compounds from Y-12 Plant operations. A project has recently been initiated that will provide piping and process equipment necessary to replace the use of perchloroethylene as a machine coolant in the major enriched uranium machine shop. A new propylene glycol-water mixture will be used to replace the volatile perchloroethylene coolant, thereby eliminating emission of many tons of volatile organic compounds currently emitted each year at the Y-12 Plant.

Depleted uranium machine turnings or chips are currently disposed by shallow land burial in the Bear Creek Burial Grounds. The chips are pyrophoric, and their disposal occasionally results in fire. The Complaint and Order issued by TDHE directed the Y-12 Plant to cease disposal of these materials in the Bear Creek Burial Grounds because of potential groundwater contamination. The depleted uranium chips will be sent to the Uranium Chip Oxidizer Facility, which will be completed in 1985. Oxide from this facility will be sent to the Uranium Oxide and Bulk Metal Storage Vaults. The Uranium Chip Oxidizer Facility will reduce the volume of depleted uranium to a stable oxide form. The facility will consist of six uranium chip oxidizers and an off-gas treatment system consisting of a 95% prefilter, a HEPA filter, a draft fan, and an exhaust stack.

Atmospheric dispersion modeling will play an important role in the Y-12 Plant's Air Pollution Control Program. Computer-aided atmospheric dispersion modeling provides a valuable tool for determining long-range transport of air contaminants and predicting downwind ground-level concentration of materials near a source. Air pollution modeling will enable the Y-12 Plant to model emergencies and estimated effects on employees and population centers downwind of the plant. Dispersion modeling is also required in the calculation of dose equivalent rates for compliance with EPA radionuclide emissions.²⁹

To provide meteorological data, two meteorological towers will be installed at the Y-12 Plant that have automated data collection and solid-state telemetry data-transfer to a computer. A 100-m tower is under construction near the east boundary of the plant and will contain instrumentation at the 10-, 30-, and 100-m levels as well as ground level. A 60-m tower just west of the Y-12 Plant is planned that will have monitors at 10-m, 60-m, and ground levels. Wind and other meteorological parameters will be monitored to provide data on the stability class of the atmosphere as well as wind speed and direction data essential for reliable air pollution dispersion modeling. As data from the meteorological towers and various process stacks are obtained, the Y-12 Plant, in conjunction with ORNL, will examine the development of an atmospheric dispersion modeling program for Bear Creek Valley.

Y-12 Plant Surface Water Monitoring Program

The May 1983 Memorandum of Understanding (MOU)³⁴ and subsequent Complaint and Order³⁵ signed by DOE and the regulatory agencies agreed that necessary actions would be taken to bring the Y-12 Plant into regulatory compliance. In an effort to comply with the MOU, several water pollution control and monitoring programs were pursued during 1984.

Upon issuance of the MOU, a program was initiated for the elimination of process waste discharges to Upper East Fork Poplar Creek (UEFPC). This program identified 162 waste streams emptying into UEFPC, including 22 streams from the ORNL operations at the Y-12 Plant. Of the 140 discharges from Y-12 activities, 104 streams are no longer released to the creek. In March 1984 all waste discharges to the S-3 ponds were stopped. Currently, planning, design, or construction of seven wastewater treatment facilities is under way; use of the facilities will eliminate the need to discharge untreated/unpermitted process wastewaters.

In April 1984 the Y-12 Plant submitted revised NPDES permit applications. The revised NPDES permit is expected to become effective in mid-1985.

The revised NPDES permit for the Y-12 Plant imposes a variety of environmental monitoring and analytical requirements for compliance. Scheduled monitoring will begin at 236 locations categorized as follows:

- storm sewer outfalls
- cooling towers
- untreated process streams to continue
- untreated process streams to be eliminated
- wastewater treatment plants
- quarries
- surface streams
- oil retention ponds
- fly ash sluice water
- water/oil separator
- miscellaneous discharges

Biological monitoring will be initiated during 1985 and conducted for at least the next five years. Results of in-stream biological sampling of UEFPC will determine if the uses for which this stream is classified by the State of Tennessee are being maintained and protected. The new NPDES permit also requires a Toxic Control and Monitoring Program (TCMP) for most of the wastewater treatment facilities, cooling tower water, and all untreated process wastewater outfalls. The TCMP uses sensitive aquatic organisms to indicate the toxicity of various effluents. Results of this program will determine whether effluent limitations at treatment facilities will become more stringent and whether untreated outfalls may continue to be discharged without collection and treatment.

The Best Management Practices (BMP) plan, as specified by the NPDES permit, requires periodic sampling of certain outfalls to verify the use of best management practices. This sampling will be in addition to any required sampling outlined in the permit. Design was initiated in 1984 on the NPDES Monitoring and Sampling Stations program. Sixteen monitoring and/or sampling stations

are to be constructed in UEFPC and storm sewers within the Y-12 Plant boundaries. These stations will be used to characterize area source contamination. This system will provide "real-time" data to central locations and give early indications of possible spills. Capability will also exist to analyze a large variety of pollutants and to indicate the mass flux of pollutants of UEFPC.

Until the revised NPDES permit becomes effective, the Y-12 Plant will continue to operate under the old permit. The current permitted discharge locations, permit limitations, and the compliance record for CY 1984 are reported in Table 23.

Radiological and PCB monitoring are conducted in conjunction with the NPDES monitoring. A sampling program has been initiated to identify and verify specific types of radioactivity at various discharges. After the initial sampling program is complete, a detailed proposal will be developed for facilities that may discharge radioactivity. The PCB monitoring program currently involves specific locations where PCB contamination is known; however, a proposal will be developed during 1985 to evaluate the entire plant and identify other possible sources of PCB contamination.

Environmental concern regarding mercury at the Y-12 Plant has necessitated developing an on-line monitor to measure the mercury concentrations in East Fork Poplar Creek, which originates within the plant boundary. The monitor is able to (1) operate unattended round-the-clock, (2) transmit data to a remote central monitoring facility, (3) operate routinely in the 1- to 10- $\mu\text{g}/\text{L}$ range, and (4) ultimately, detect $<0.1 \mu\text{g}/\text{L}$ mercury. The system will monitor two locations on the streams (i.e., the entrance and exit of New Hope Pond) every hour and can be adjusted to monitor both locations every 15 min. The monitor is scheduled to go on-line early in 1985.

Sources and Discharges of Mercury in Surface Water at the Y-12 Plant

An investigation of sources and discharges of mercury in Y-12 Plant surface drainage water was conducted to effectively plan and guide remedial actions to reduce aquatic losses of mercury from the Plant. The specific objectives of the study were (1) to identify and quantitate chronic and episodic sources of mercury that continue to contaminate Y-12 drainage water and (2) to determine whether New Hope Pond is acting as a net source or a net sink for mercury emanating from the Y-12 Plant. Comprehensive surveys directed at localizing buildings and areas within the Y-12 Plant that contribute significant amounts of mercury to drainage water revealed elevated mercury concentrations and discharges in the vicinity of nearly all buildings and areas where mercury was formerly used or spilled. These discharges arise largely because residual deposits of metallic mercury located in the drainage system are being slowly solubilized or resuspended by otherwise uncontaminated groundwater and process water that flows through the drainage system en route to UEFPC. Studies at New Hope Pond have shown that the pond traps about 50% of the mercury carried into it by Y-12 Plant drainage water. Even during storm runoff from the Y-12 Plant site and during Y-12 Plant upsets (e.g., waterline breaks), effluent mercury concentrations at New Hope Pond have been lower than influent concentrations, attesting to the value of the Pond as a trap for mercury. The trap efficiency of New Hope Pond is expected to be improved by dredging planned for 1985.

Investigation of Subsurface Mercury at the Y-12 Plant

An investigation of the fate of spills and leaks of elemental mercury that occurred in the past at the Y-12 Plant has been carried out through a multiphased well-installation and soil-boring program. The overall program resulted in the installation of a 43-well monitoring network and the

analysis of 430 soil/mud and 113 groundwater samples for mercury content. In addition, 59 analyses for uranium in groundwater were made, and 132 anion and cation analyses were run. Results of mercury analyses of soils and fill indicate that high concentrations (up to 1% by weight) of mercury occur in the shallow-earth materials at several sites within the plant, but the estimated total quantity leached during the past 30 years (~138 kg) represents only about 2% of the amount estimated to have been lost to the ground. Estimates are based on analysis and known solubility of mercury in water, compared with knowledge of spills, leaks, and soil contaminant levels. Results of mercury analyses of groundwater indicated that mercury does not appear to be moving in significant quantities in an aqueous phase: the highest soluble concentrations found (~1 µg/L) were limited to three wells. The analyses of the groundwater samples from the total well network for other chemical constituents revealed the presence of several contaminant plumes within the plant, including sulfates from a large coal pile, nitrates from liquid waste disposal operations, and chlorides from several sources, as well as general increases of electrical conductance (an inorganic pollutant indicator) and alkalinity. Complete results of the investigation can be found in ORNL/TM-9092.³⁶

Y-12 Plant Sanitary Wastewater Characterization Study

The Y-12 Plant sanitary sewers discharge domestic wastewaters to the City of Oak Ridge sewer system. Treatment is provided by the Oak Ridge Wastewater Treatment Plant, located in the western part of the city near East Fork Poplar Creek, which receives its effluents.

Preliminary monitoring of treatment plant sludge indicates uranium concentrations at or above background levels. Current disposition of the City of Oak Ridge sludge is land application on DOE property (see "Contamination of the Oak Ridge Sewage Sludge Land-Farming Site," this section). The presence of trace uranium in the sludge has led to an increased interest in evaluating the sanitary sewer waste flows leaving the Y-12 Plant. In August 1984, a monitoring program was initiated to determine if the Y-12 Plant is a significant contributor of uranium and other metals observed in the Oak Ridge sludge.

Portable automatic samplers are being used by the Y-12 Plant Environmental Monitoring Group to collect 24-h composite samples. Four monitoring locations include the sewer lines serving the Plant's west area, the Plant's east area, the Valley Industrial Park, and the Scarboro Road sewer main. These sewer lines converge near the intersection of Bear Creek and Scarboro roads. On the Scarboro Road line, the City of Oak Ridge operates a flow-metering station that receives all flows from the Y-12 Plant and the Valley Industrial Park. According to billing records for 1984, the wastewater flow through the meter ranged from a monthly low of 68 E6 L (18 E6 gal) to a monthly high of 95 E6 L (25 E6 gal). Although flows are highly variable, they represent an approximate 15% flow contribution to the City of Oak Ridge system.

Connections and discharges to the municipal sewer system are regulated by a Sewer Use Ordinance³⁷ adopted by the City Council and administered by the Oak Ridge Department of Public Works. This ordinance limits the discharge of specific pollutants to the Oak Ridge system and sets forth stringent Protection Criteria³⁷ for industrial wastewater flows. The Protection Criteria establish limitations on specific metals and organic pollutants. The ordinance also requires the incorporation of the latest state criteria or EPA categorical standards as the regulatory agencies promulgate new pretreatment standards for publicly owned treatment works.

Based on data obtained in 1984, the Y-12 Plant sewer discharges are in compliance with both the municipal ordinance for conventional domestic pollutants and anticipated EPA Pretreatment

Standards.³⁷ Several metal pollutants (copper, zinc, iron, magnesium, and cadmium) are slightly in excess of the current Protection Criteria limits.

Composite sampling will continue in 1985 to enable full compliance verification. Requests for new connections to the Y-12 Plant's sanitary sewer system are reviewed for compliance with City of Oak Ridge Protection Criteria³⁷ and EPA Pretreatment Standards. Plans also include implementation of BMP to reduce Y-12 Plant discharge of pollutants of concern to the City of Oak Ridge.

Development of a Remedial Action Plan for Bear Creek Valley

The DOE is currently conducting a series of investigations at the Y-12 Plant concerning contamination of several waste disposal areas in Bear Creek Valley. The investigations were initiated in 1983 when the TDHE expressed concern over the presence of contaminants in Bear Creek and requested DOE to determine if the contaminants present could be adversely affecting fish, other aquatic organisms, and the water quality of the stream. The principal finding of the investigation thus far is that there is no imminent hazard or risk to public health, but that the contamination will require remedial actions to minimize potential adverse impacts.³⁸

The evidence shows concentrations of volatile organic compounds in Bear Creek and some of its tributaries and indicates that these same compounds, together with above-background concentrations of metals and other waste constituents, are present in the shallow groundwater system immediately adjacent to the waste disposal facilities. The contaminated groundwater is moving very slowly and has not been detected at distances greater than about 305 m (1000 ft) from any waste source. No wells are used for drinking water purposes in Bear Creek Valley nor is water taken directly from Bear Creek for this purpose.

As part of the large program aimed at developing and implementing a remedial action plan for Bear Creek Valley, staff in the Environmental Sciences Division at ORNL are conducting studies to characterize the (1) soils and sediments, (2) hydrology, and (3) ecology of the Bear Creek watershed. Data collected in these studies, which were initiated in 1984, will form the basis of a document to be published in 1985.

Soils and sediments in Bear Creek Valley are being characterized with respect to the nature and degree of contamination from historical waste disposal operations. The objectives of this investigation are (1) to establish the expected natural range of concentrations for noncontaminated soils and sediments in this valley, (2) to define spatial patterns, if any, in contamination in Bear Creek Valley such that sources and transport pathways can be identified, and (3) to characterize the geochemical properties of Bear Creek Valley soils and sediments that may enhance or diminish sorption of contaminants.

One of the critical questions concerning water movement in Bear Creek Valley is the relationship between surface water and groundwater flow systems. Hydrologic studies to address that issue involved the establishment of a series of sites along Bear Creek and its tributaries to measure flow and differential changes in flow along the course of the stream. Measurements have been taken at weekly intervals since late March 1984. One important finding is that several sections of the stream channel lose water to the groundwater system and are dry for significant periods of the year. Another observation is that springs along the base of Chestnut Ridge on the south side of the valley are major sources of water to Bear Creek and may be points where creek water that has infiltrated to the ground upstream is returned to the surface water system.

To evaluate various alternatives for remedial action, ecological studies are being conducted to (1) characterize the existing environment in Bear Creek and (2) provide information on the identity

and source(s) of contaminants in Bear Creek Valley that are toxic to biota. The approach involves a combination of field and laboratory studies. Extensive field sampling is being used to describe the distribution and abundance of benthic invertebrates and fishes in Bear Creek and to document existing impacts on these biota. In addition, diagnostic laboratory bioassays are being performed on water samples collected from various sites in Bear Creek watershed to identify the origin of the toxic substances.

ORGDP Groundwater Monitoring Program

ORNL Environmental Sciences Division and Energy Division personnel are providing multidiscipline support to the ORGDP Environmental Management Department in establishing a formal groundwater monitoring program. This support includes updating the geologic map of ORGDP, conducting a streambed survey to locate nonpoint sources of surface water contamination, and providing general environmental engineering technical support. Based on this support, a consultant/contractor will design the actual groundwater monitoring plan and install the required wells. ORNL personnel will be involved in reviewing the consultant's plan and evaluating the results of the assessment of groundwater quality. The current schedule calls for completion of the initial assessment of groundwater quality at ORGDP Resource Conservation and Recovery Act (RCRA)³⁹ facilities around the end of FY 1987.

Contamination of the Oak Ridge Sewage Sludge Land-Farming Site

In 1978 negotiations were initiated between the City of Oak Ridge and the DOE Oak Ridge Operations Office to consider the land disposal of treated sludge from a new city sewage treatment plant, which was scheduled for completion in 1983. The sludge was to be placed on several parcels of land [607 ha (~1500 acres)] located within the DOE ORR for a trial period of five years. The sludge was to be used as a nitrogen and phosphorus nutrient supplement for tree planting operations on poor-quality forest sites within the ORR. The initial sludge disposal site consisted of 26 ha (65 acres) located on the southeast side of Chestnut Ridge, bordered on the south by the old Bethel Valley Road and on the west by Mount Vernon Road. Deposition on this site was begun in November 1983.

On March 22, 1984, it was learned that some of the deposited sludge is contaminated with various radionuclides, primarily ⁶⁰Co and ¹³⁷Cs. Disposal of sludge on the 26 ha (65-acre) site was temporarily halted on March 25, 1984, and a comprehensive sampling and monitoring study was initiated on March 30, 1984.⁴⁰

A systematic random sampling design was used to characterize the entire disposal site [26 ha (~65 acres)]. Eleven transects were run perpendicular to the surface flow gradient. Soil cores were collected in 1984 on March 31 and April 1 along each transect for a total of 117 cores extracted to various depths, depending on the penetrability of the soil layer. The upper 7.6 cm (3 in.) of the core was considered most likely to represent the previously broadcast sludge; the middle portion, the tilled soil mixed with sludge; and the bottom portion, the undisturbed subsurface layer.

Samples were analyzed for gamma activity, principally from ¹³⁷Cs and ⁶⁰Co, in all top- and middle-layer samples. Alpha and beta activity analyses were performed on a random sampling of the extracted cores, consisting of 25% of the top portions of the cores (30 samples). Samples were analyzed for ⁹⁰Sr, ²³⁴U, ²³⁵U, ²³⁸U, ²³⁸Pu, and ²³⁹Pu.

Most of the radioactivity was determined to be in the upper 7.6 cm (3 in.) of soil. A total of 170 mCi of activity was estimated to be present in the top 7.6 cm (3-in.) layer of the 26-ha (65-acre) site, 69% of which was contributed by ^{60}Co and ^{137}Cs , 23% by ^{234}U and ^{90}Sr , and 8% by other minor radionuclides.

Following the data assessment, calculations were made to delineate the potential dose that might be received from exposure to the contaminated area via five different environmental pathways: (1) direct radiation from the field, (2) inhalation of dust emissions from the sludge disposal area, (3) ingestion of water resulting from radionuclides being leached from the soil and transported via surface runoff into Melton Hill Lake, (4) ingestion of fish caught in Melton Hill Lake, and (5) ingestion of meat from deer that might graze on the contaminated site.⁴¹

Results of analyses from these five pathways are shown in Table 63. The annual dose was calculated to be 4.2 millirem to the endosteal cells (critical organ). The effective dose equivalent was 1.1 millirem. Most of the effective dose commitment was the result of fish consumption; a secondary contribution resulted from water consumed through swimming. The nuclides contributing most of the dose were ^{90}Sr and ^{137}Cs .

**Table 63. Oak Ridge Sewage Sludge Disposal Site:
Summary of 1984 dose commitments by pathway^a to
a maximally exposed member of the public**

Pathway	Endosteal cells (millirem/year)	Effective dose equivalent (millirem/year)
Direct radiation	<i>b</i>	<i>b</i>
Direct inhalation	2.0E-3	5.5E-4
Water ingestion	2.8E-2	3.7E-3
Fish ingestion	4.1	1.1
Deer meat ingestion	8.7E-3	2.1E-3
Total	4.2	1.1

^aBackground has been subtracted from all dose commitments.

^bMeasured values were the same as background levels on the old Bethel Valley Road.

Oak Ridge Reservation Deer Population

The white-tailed deer population on the ORR has been increasing rapidly over the past 15 years, from an estimated 300 animals in 1969 to over 8000 in 1984. During the same period, the number of deer-vehicle collisions per year has risen from 1 to 255 (Fig. 42). These collisions represent a significant traffic hazard not only to Energy Systems employees but also to the general public using ORR roadways.

DOE and ORNL personnel, with assistance from the Tennessee Wildlife Resources Agency (TWRA), have initiated a number of projects aimed at increasing public awareness of the potential hazard and reducing the deer herd. Steps include "deer-crossing" warning signs on all major roads and numerous articles in newspapers about deer-vehicle collisions and deer habits. Reduction of the herd focuses primarily on TWRA's trapping and removing animals from the area for stocking in the various wildlife management areas in the state; however, little impact has been made on the

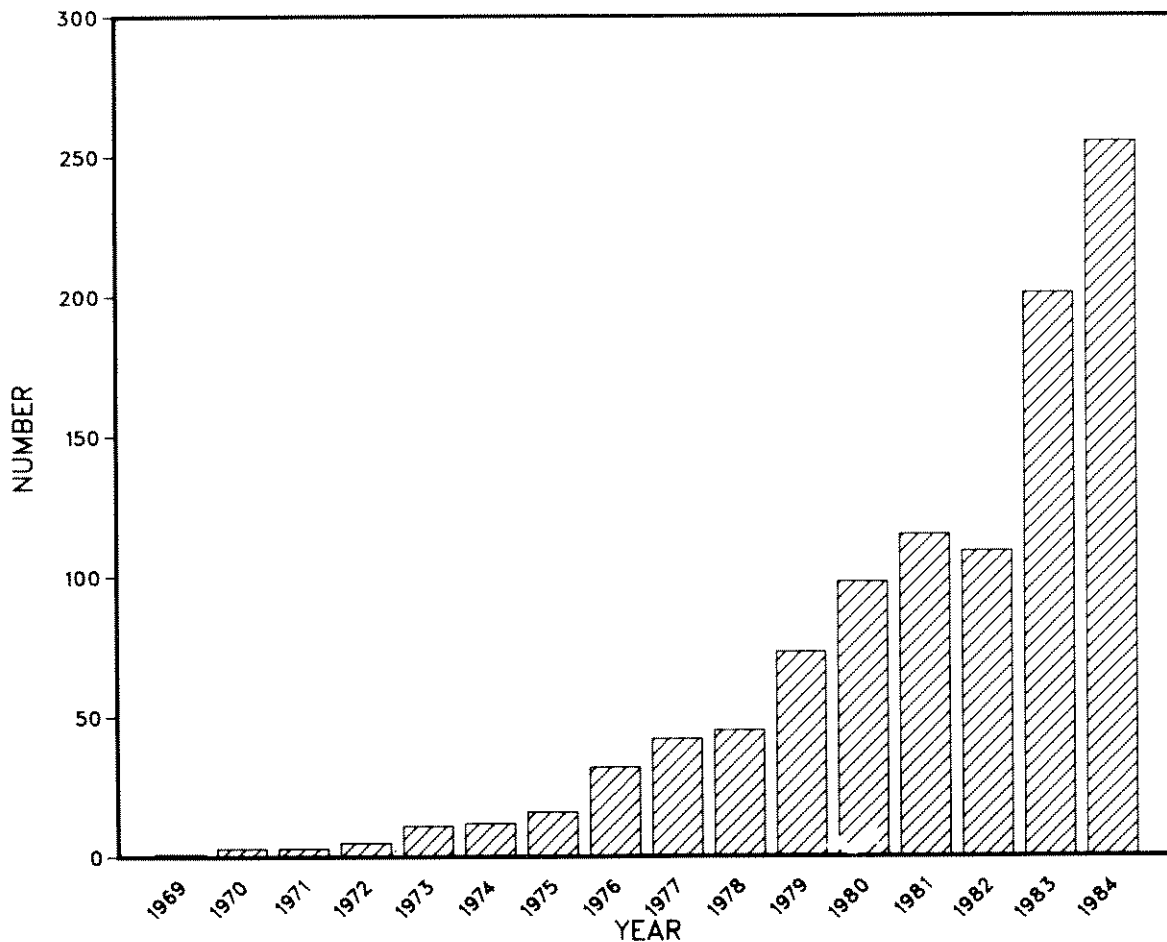


Fig. 42. Total deer killed on the Oak Ridge Reservation.

local herd since this effort was begun in 1978—only about 300 animals have been removed from the ORR.

Continued personal property losses and the increasing potential for human injury have prompted the DOE to take a more aggressive approach to solving this problem. Acting on a recommendation by the Oak Ridge Reservation Resource Management Committee, DOE and TWRA entered into a cooperative agreement on November 30, 1984,⁴² establishing the Oak Ridge Wildlife Management Area. This agreement will expand the number of options that can be used in herd reduction and subsequent management of the herd at a population level consistent with available habitat. It will also enable DOE and TWRA to work together to manage the ORR for other wildlife species and carry out wildlife-oriented research and demonstration projects.

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Appendix A

QUALITY ASSURANCE

Radiological

All the analytical laboratories at the Oak Ridge plants maintain internal control programs that use known solutions of radionuclides for calibration, instrument checks, and general procedure control. Certified standards from other DOE laboratories or from the National Bureau of Standards are often used in such control work.

A very significant externally operated program is the Quality Assurance Program administered by the DOE Environmental Measurements Laboratory (EML) in New York. All the plant laboratories participate in this program, which currently provides quarterly samples of five types of environmental media—soil, water, air filters, vegetation, and animal tissue—each containing from five to nine radionuclides at levels known to EML. Analytical results are returned each quarter to EML, where statistical evaluation is made and periodic reports are issued to each participant, showing how the participants' results compare with the established values and with the results of other laboratories. Participation is mandatory for parameters of concern to the particular plant and optional for parameters that do not apply.

The laboratories at the Oak Ridge plants are also general participants in voluntary national radionuclide QA programs administered by other DOE sites, especially Los Alamos, New Mexico. ORNL is especially active in such programs because of its range of radionuclide interest; its analytical performance has been excellent.

During 1984, ORNL participated in the Seventh International Environmental Dosimeter Inter-comparison Project. The ORNL means for the pre-irradiated, field, and laboratory dosimeters fell within the confidence interval for the standards.

Chemical

All the analytical laboratories have established internal programs designed to provide reliable calibration of instruments and evaluation of analyst performance in the measurement of a wide range of chemical pollutants in environmental media.

Another effective external quality control program is also in place; it uses certified solutions purchased from a commercial source. Monthly samples that contain a host of common pollutants, including trace metals, residual chlorine, cyanide, phenol, nitrogen, organic carbon, grease and oil, minerals and other impurities—all at environmental levels certified by the vendor, are sent to each laboratory quality control officer. Obtained as from unknown samples in the laboratory, the analytical results are transmitted to the Y-12 Plant Quality Division for statistical review. Periodic reports are sent to each of the four laboratories that compare results with the certified values and with those of the other laboratories.

All the plant laboratories participate in the National Quality Assurance Program, administered by the EPA to support the NPDES. Known standards are submitted, on a request basis, to the laboratories for analysis of parameters designated in the current permits. Results are sent to the TDHE, where evaluation and follow-up on deficiencies at specific laboratories are coordinated. All laboratories generally perform within the EPA's acceptance range on all permit parameters. ORNL results, for example, fell within 10% of the known values in 1984, which were acceptable to the regulators.

General

The Four-Plant Committee on Environmental Analysis was established in 1977 to provide a uniform basis for measuring environmental pollutants and to ensure that measurement sensitivity, quality, and methodology remain in accord with the federal and state requirements for environmental monitoring. The resulting Environmental and Effluent Analysis Manual emphasizes laboratory procedures used for measuring parameters that appear on the NPDES permits or air discharge permits of any of the four plants. The manual details 111 analytical procedures for water, air, sediment and soil, biota, and miscellaneous media such as oil under test for reuse. Procedures for both radiological and nonradiological parameters are included. EPA-approved analytical methods are used wherever possible.

The Four-Plant Committee on Environmental Analysis also coordinates special quality control programs of interest to all plants, such as the measurement of fluorides in air or PCBs in oil. It is also instrumental in the generation and evaluation of proposed analytical control standards, such as PCBs in waste transformer oil and ^{99}Tc in grass and in soil. The Committee has also accepted responsibility for overseeing the reliability of certain external quality control standards, including those generated and certified by a commercial source.

Quality assurance in environmental monitoring has become a well accepted responsibility at all of the plants. The program at ORNL is especially developed to keep pace with the broad surveillance responsibilities assumed by that facility for both radiological and nonradiological monitoring in the Oak Ridge area. The Department of Environmental Management (DEM) at ORNL has initiated a quality assurance program to ensure that a high degree of accuracy and reliability is maintained in its surveillance activities. The program in effect at ORNL consists of quality control of techniques and procedures and includes the establishment of a detailed written description of all activities pertaining to the DEM. This includes:

1. operating procedures for each activity;
2. inspection lists of operating and maintenance activities;
3. check-off frequency lists for all quality assurance steps, such as schedules for equipment inspection and test control;
4. documentation of compliance of quality assurance procedures;
5. participation in intralaboratory and interlaboratory sample-exchange programs;
6. evaluation of the adequacy of sample preparation work and data analysis; and
7. identification of the role, responsibilities, and authority of each staff member as related to quality assurance.

Figure A.1 is a schematic diagram showing a flow chart of this quality assurance program. A more detailed discussion of the ORNL quality assurance program is presented elsewhere.^{A1}

EPA Quality Assurance Performance Audit

During the week of June 18, 1984, representatives of the EPA Region IV conducted a performance audit to assess the reliability of the environmental monitoring data base being generated by the DOE Y-12 Plant and the ORAU facility in Oak Ridge. Staff of the TDHE participated in the audit but did not generate a separate inspection report. The Y-12 Plant is involved in extensive

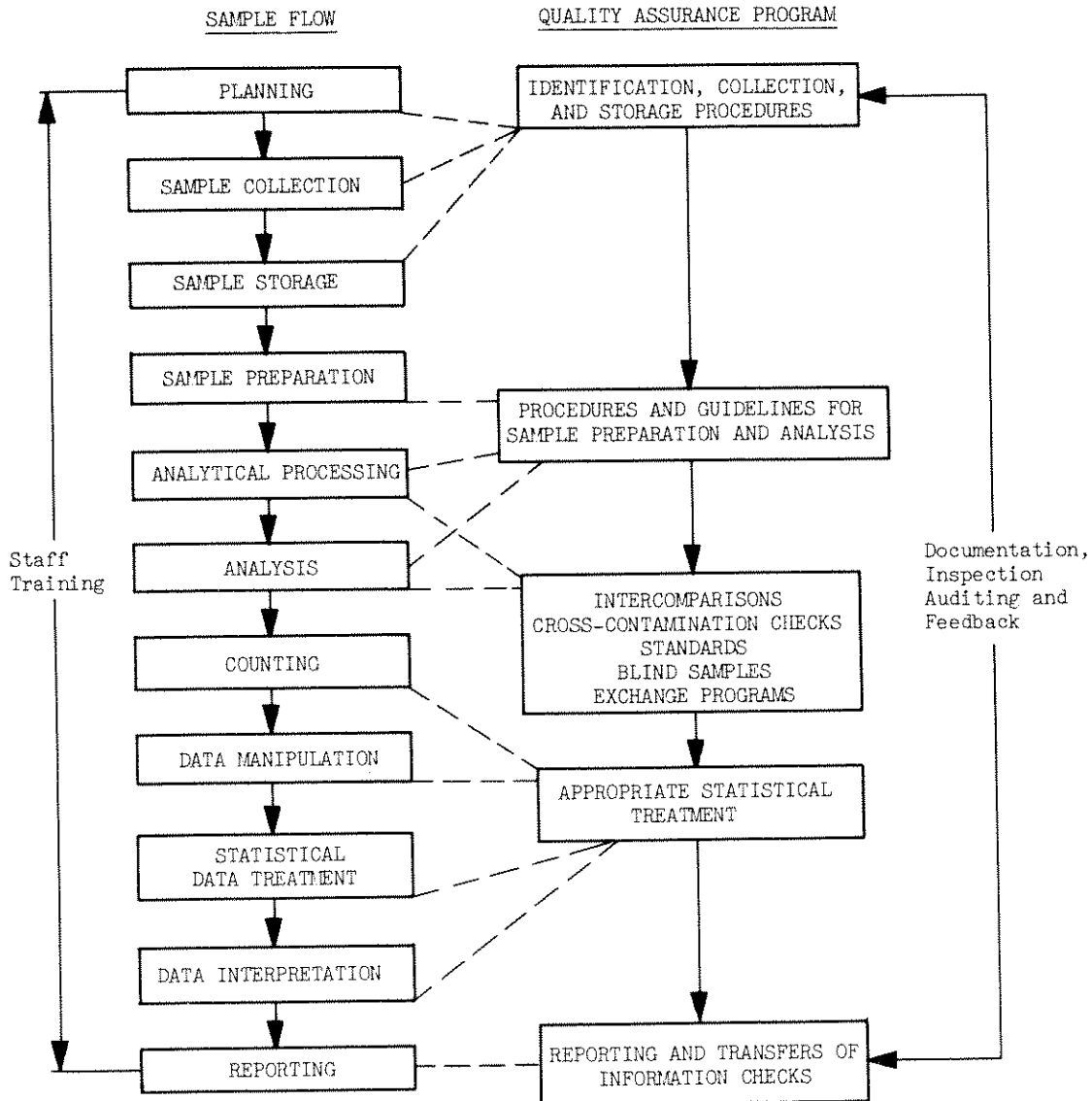


Fig. A.1. Flow chart of QA program.

sampling and analysis programs related to pollution control, and ORAU is examining the extent of pollutant migration to the community of Oak Ridge, downstream on the East Fork of Poplar Creek. Monitoring data collected in these efforts will serve as the basis for planning any environmental remedial actions, as agreed upon in the MOU between DOE and the EPA/TDHE, dated May 26, 1983.

The audit covered the field monitoring and laboratory analytical programs conducted by the Y-12 Plant, ORAU, and ORNL for soil and sediments associated with the Y-12 Plant or the Oak Ridge community and for groundwater and NPDES outfalls related to the Y-12 Plant. Separate groups inspected the field methodologies and the laboratory support functions.

The audit team found no evidence that any portion of the environmental data base should be invalidated, although it made several recommendations for strengthening the quality of the program. With all of the DOE Oak Ridge facilities conducting similar programs of monitoring

NPDES effluents, groundwaters, soils and sediments, the auditors recommended that a unified document be generated to standardize the sampling methodology. A task team, including representatives of all the Oak Ridge facilities, was subsequently formed, which organized efforts under an action plan for a completed document during 1985. This work is expected to result in a collection of methods, based on recommendations by ASTM and by EPA, which may serve as a standard for other DOE facilities.

The EPA audit found that the laboratories that support the monitoring programs are providing results of generally good quality; however, several recommendations were made. Full isolation of the low-level environmental measurement work was recommended for the Y-12 Plant laboratory; the plant is moving toward that objective. Some deficiencies in sample preservation and holding times were noted, and these have been corrected. Increased emphasis on quality assurance documentation, records retention, and other minor deficiencies have been instituted at the Y-12 Plant laboratory. The ORAU laboratory has also improved its quality assurance procedures and has satisfied the EPA on analytical methodology since the 1984 audit. More interplant sample exchange is being implemented as a result of the EPA recommendations, and several reference materials, particularly contaminated soils, are being developed for general use in laboratory quality control.

The improvements in field methodologies and analytical methodologies will continue and will be subjected to internal inspections on a timely basis. It is also expected that the EPA/TDHE audit of 1984 will be followed by other inspections to document that compliance with regulations is complete.

Other Audit Activities

All of the DOE Oak Ridge facilities have been increasingly subjected to environmental program audits. Such audits and reviews are conducted to verify that applicable elements of the environmental program are effectively developed, documented, and implemented.

The ORNL program was examined in 1984 by DOE Headquarters, DOE-ORO, EPA-Region IV, and the National Research Council. DOE-ORO also conducted a "Vulnerability Assessment" of the program. Additional audits were conducted by the ORNL Plant QA Committee and by the Martin Marietta Energy Systems Central Staff committee.

The ORGDP environmental program was examined in 1984 by DOE-ORO, and its air pollution monitoring and protection program was audited by the TDHE. The plant's full program, including the analytical support work, was audited by the Energy Systems Central Staff committee. An additional audit of the analytical program was conducted by a Y-12 committee because considerable Y-12 work is currently supported by the ORGDP laboratory.

The Y-12 Plant's environmental monitoring programs were audited by DOE-ORO and by the Y-12 Environmental Compliance Department. The TDHE made a QA inspection regarding the environmental aspects of Kerr Hollow and Rogers Quarries. TDHE also conducted quarterly performance audits of the SO₂ monitors at Y-12.

The above audits, conducted in addition to the EPA/TDHE audit of June 1984, often required several days each and, in some cases, more than one visit was required. In addition to the environmental monitoring program audits, the Hazardous and Solid Waste Management programs at all installations were examined by most of the outside agencies and internal committees mentioned above—particular emphasis is placed on the environmental protection aspects of those programs.

REFERENCE FOR APPENDIX A

A1. T. W. Oakes, K. E. Shank, and J. S. Eldridge, "Quality Assurance Applied to an Environmental Surveillance Program," p. 226 in *Conference Proceedings of the 4th Joint Conference on Sensing of Environmental Pollutants*, New Orleans, Nov. 6-11, 1977.

Appendix B

DEFINITIONS, UNITS, PREFIXES, ABBREVIATIONS, AND ACRONYMS

Definitions

Committed dose equivalent—The dose equivalent received for a period of 70 years resulting from the intake or deposition of a radionuclide in any one year.

Confidence interval and confidence coefficient—A confidence interval is a statement that the population parameter (usually the mean) has a value lying between two specified limits. It has the feature that, in repeated sampling, a known proportion (for instance, 95%) of the intervals computed by this method will include the population parameter. The confidence limits are the end points of the interval, and the confidence coefficient is the percentage of all possible samples of a given size yielding the confidence interval that will catch the mean. The 95% confidence coefficient for a sample can be estimated by the following: $2x\sqrt{s^2/n}$, where s^2 is the sample variance and n is the number of samples.

Critical organ—A particular organ or tissue that is likely to be of greatest importance when more than one organ is exposed because of the dose it receives, its sensitivity to radiation, or the importance to health of any damage that results.

Dose equivalent—The product of the absorbed dose to the body or an organ and the quality factor.

Effective dose equivalent—The sum of the dose equivalent received from external sources plus the sum of the committed dose equivalent to each organ multiplied by the weighting factor appropriate to each organ.

Geometric mean and standard deviation—When the variance of a population is related to the mean, a logarithmic transformation of the original data will sometimes help to stabilize the variance. A mean that is calculated on the logarithmic data and then transformed back (using the antilogarithm) to the original units is the geometric (or derived) mean.

To estimate the standard deviation about the geometric mean, the standard deviation of the logarithms is transformed back to the original data and the geometric mean is then multiplied and divided by the antilog of the standard deviation.

Quality factor—A multiplying factor for a dose equivalent to the body or an organ to allow for the additional damage caused by radiations that produce higher ionizing densities than X or gamma radiation. This factor is applicable only for purposes of radiation protection and should not be used for accidental high exposures.

Stochastic effect—Effect characterized by malignant and hereditary diseases for which the probability of an effect occurring, rather than its severity, is regarded as a function of dose without threshold.

Weighting factor—The ratio of the stochastic risk arising from exposure of a tissue to the total risk when the whole body is irradiated uniformly.

Radiation units

Unit	Definition
Curie (Ci) and Becquerel (Bq)	Units of radioactivity which are a measure of those spontaneous, energy-emitting, atomic transformations that involve changes in the state of the nuclei of radioactive atoms. 1 Ci = 3.7 E+10 Bq
Roentgen (R) and coulombs per kilogram (C/kg)	Units of exposure to radioactivity. 1 R = 2.58 E-4 C/kg
Rad and Gray (Gy)	Units of absorbed dose in any medium. 1 rad = 1 E-2 Gy
Roentgen equivalent man (rem) and Sievert (Sv)	Units of dose equivalent which account for the relative biological effectiveness of a given absorbed dose. 1 rem = 1 E-2 Sv

Unit prefixes

Factor	Prefix	Symbol
10^{15}	peta	P
10^{12}	tera	T
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^2	hecto	h
10^1	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

Elements and compounds

Ag	silver	Na	sodium
Al	aluminum	Nb	niobium
As	arsenic	NH ₃	ammonia
B	boron	Np	neptunium
Ba	barium	NH ₃ (N)	ammonia nitrogen
Be	beryllium	NO ₃ (N)	nitrate nitrogen
Br	bromine	NO ₃ ⁻	nitrate
Ca	calcium	Ni	nickel
Cd	cadmium	P	phosphorus
Ce	cerium	Pb	lead
Cl	chlorine	PO ₄ ³⁻	phosphate
Cl ⁻	chloride	Pu	plutonium
CN	cyanide	Rn	radon
Co	cobalt	Ru	ruthenium
Cr	chromium	Sb	antimony
Cs	cesium	Sc	scandium
Cu	copper	Se	selenium
F ⁻	fluoride	Si	silicon
Fe	iron	SO ₄ ²⁻	sulfate
Ga	gallium	Sr	strontium
³ H	tritium	Tc	technetium
Hf	hafnium	Th	thorium
Hg	mercury	Ti	titanium
I	iodine	U	uranium
K	potassium	V	vanadium
Kr	krypton	Xe	xenon
La	lanthanum	Y	yttrium
Li	lithium	Zn	zinc
Mg	magnesium	Zr	zirconium
Mn	manganese		
Mo	molybdenum		

Acronyms

ALARA	as low as reasonably achievable
AVLIS	atomic vapor laser isotope separation
ASTM	American Society for Testing and Materials
BMP	best management practices
BOD	biochemical oxygen demand
COD	chemical oxygen demand
DEM	Department of Environmental Management
DOE	Department of Energy
EML	Environmental Measurements Laboratory
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
FRC	Federal Radiation Council
GPP	General Plant Project
ICRP	International Commission on Radiological Protection
MBAS	methylene blue absorbing substances
MDL	minimum detectable limit
MOU	memorandum of understanding
NPDES	National Pollutant Discharge Elimination System
ORAU	Oak Ridge Associated Universities
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
ORTF	Oak Ridge Task Force
PCB	polychlorinated biphenyls
RCRA	Resource Conservation and Recovery Act
SWSA	solid waste storage area
TCMP	Toxic Control and Monitoring Program
TDHE	Tennessee Department of Health and Environment
TDS	total dissolved solids
TKN	total kjeldahl nitrogen
TOC	total organic carbon
TVA	Tennessee Valley Authority
TWRA	Tennessee Wildlife Resources Agency
UEFPC	Upper East Fork Poplar Creek

Appendix C

ENVIRONMENTAL MONITORING AND SURVEILLANCE OF THE OAK RIDGE COMMUNITY

ANNUAL REPORT FOR 1984

Historical Perspective

As a result of long-term wastewater discharges from the Y-12 Plant, East Fork Poplar Creek and its floodplain have become contaminated with materials such as mercury, uranium, thorium, chromium, and zinc at levels well above normal background. In addition, since the full extent of this contamination was not known, particularly by the City administration and the general public, considerable quantities of floodplain soils and creek sediments were used throughout the community, primarily in 1982, as topsoil for portions of the new Oak Ridge sewer system. The bulk of the mercury discharges occurred before 1960 and uranium, thorium, chromium, and zinc discharges before the mid-1970s; other pollutants have also been discharged in smaller amounts throughout the Plant's operation and have accumulated in sediments and soils to a lesser extent.

In addition to this contamination of soils and sediments, East Fork Poplar Creek fish have been found to exceed the FDA's action level for mercury. The TDHE has posted the streams, warning against fishing and swimming.

In 1983 two activities were initiated to better define the potential problem with this residual contamination. The first was a sampling program in the community to respond to citizens' requests to determine if their soil, vegetables, or well water were contaminated. At the same time, effort was directed toward defining the extent of contamination in the community, particularly along the sewer beltway.

The second activity initiated in 1983 is the interagency Oak Ridge Task Force (ORTF). This group includes representatives from DOE, EPA, TVA, the U.S. Geological Survey, and the City of Oak Ridge. It is chaired by a representative of the TDHE. The task force is collecting toxicological and environmental data with which to evaluate the potential long-term public health impact of the residual contamination and the cost vs benefit of remedial measures.

Current Activities

Sampling, which is summarized in Table C.1, continued in the Oak Ridge area; over 2600 soil, plant, and animal samples were collected. Sampling consisted of

1. Oak Ridge community—continuation of sampling of private residences for contamination;
2. Sewer Beltway— (a) a rapid scan of the entire length of the sewer beltway, (b) completion of sampling in the Civic Center area and participation in the interim cleanup effort, and (c) participation in cleanup of two small areas of contaminated soil;
3. East Fork Poplar Creek Floodplain—initiation of a rapid scan for a preliminary determination of the extent of contamination;
4. Oak Ridge Wastewater Treatment Facility and Emory Valley Road Pump Station—initiation of monitoring;
5. initiation of mercury contamination characterization study;

6. continuation of multiparameter analysis;
7. continuation of quality assurance and quality control, including meetings with EPA, completion of ORAU QA/QC documents, and participation in generating a general sampling QA/QC document for all of the ORAU and DOE/Martin Marietta Energy Systems facilities in Oak Ridge.

Table C.1. Community sampling for mercury

Category	No. of samples	Range found	Normal range
Sediment	17	0.1–110. ppm	0.3 ppm (av)
Sludge	7	0.29–2.3 ppm	
Soil	2330	0.05–2200. ppm	12 ppm ^b
Vegetation	62	9.2–510. ppb	1–123 ppb ^a
Water (well)	10	0.01–0.2 ppb ^c	0.02–0.06 ppb ^a
Other (background samples, quality assurance samples, etc.)	190		
Total	2619		

^aNational Academy of Sciences, *An Assessment of Mercury in the Environment*, Printing Office, National Academy of Sciences, Washington, D.C., 1978.

^bInterim guidelines for content of mercury in the soil as determined by the State of Tennessee, 1983.

^cPrimary drinking water standards for mercury are 0.002 mg/L or 2 ppb (40 CFR 141).

Oak Ridge Community

Oak Hills Area (Table C.2). Nine soil samples were collected from three residences, none of which exceeded the state guidelines for mercury in soil of 12 ppm. No vegetation samples were collected in this area.

Table C.2. Summary of mercury sampling from private residences in the Oak Ridge community

Residences	Garden	Yard	Soil range ^a (ppm)	Vegetable	Vegetable range ^a (ppb)	Area
3	6	2	0.08– 2.2	0		Cedar Hill
5	18	8	0.03–22.0	0		Country Club
4	4	8	0.05– 1.2	1	16	East Village
2	5	2	0.07– 7.7	4	10–40	Elm Grove
11	12	16	0.04– 0.4	3	14–32	Fairbanks Road
10	26	9	0.05– 3.5	1	110	High School
45	89	180	0.07–560	32	5.8–160 ^b	Linden School
3	3	6	0.07–0.57	0		Oak Hills
3	10	10	0.08–42.0	4	34–510 ^b	Robertsville
3	6	1	0.05– 1.1	1	17	Scarboro
2	0	11	0.11–160	0		Wiltshire Estates
7	8	11	0.07– 1.2	3	40–290 ^b	Woodland

^aNormal ranges according to the 1978 National Academy of Sciences report, *An Assessment of Mercury in the Environment*, are vegetables 1–123 ppb and soils 0.01–4.7 ppm.

^bThe vegetation with the higher values were collected on the East Fork Poplar Creek floodplain.

Country Club Area (Table C.2). Sampling in this area consisted of 26 soil samples taken from private residence gardens and yards on the edge of the East Fork Poplar Creek floodplain. No vegetation sample was collected. Only soil samples collected at the edge of the East Fork Poplar Creek floodplain exceeded the state guideline levels for mercury.

East Village Area (Table C.2). Twelve soil samples were collected from four residences; all were below the state guidelines for mercury. One white-cabbage sample was collected with a soil sample collected at the same time and location.

Elm Grove Area (Table C.2). Seven soil samples were collected from two residences, none of which exceeded the state guidelines for mercury. Four vegetation samples consisting of lettuce, squash, turnip leaves, and turnip bulb were collected with soil samples collected at the same time and location.

Fairbanks Road Area (Table C.2). Twenty-eight soil samples were collected from eleven residences; sample mercury concentrations were all below the state guidelines. Three vegetation samples consisting of tomatoes and broccoli were collected with soil samples collected at the same time and location.

High School Area (Table C.2). Thirty-five soil samples were collected from ten residences. None of the soil samples showed mercury concentrations exceeding the state guidelines. One lettuce sample was collected.

Linden School Area (Table C.2). Forty-five residences were sampled, and 89 garden and 180 yard soil samples were collected. Several yard soil samples showed mercury concentrations exceeding the state guidelines for mercury. However, all of the contaminated samples were collected from a single residence. Because of the distance of the residence from the floodplain, these levels are believed to be derived from imported contaminated floodplain soil. In addition to the soil samples, 32 vegetable samples were collected—onion leaf, onion bulb, lettuce, strawberries, potatoes, green beans, eggplant, green pepper, white cabbage, corn, grapes, okra, red cabbage, tomatoes, zucchini, and yellow squash in which soil samples collected at the same times and locations.

Oak Hills Area (Table C.2). Nine samples were collected from private residence gardens and yard areas. None of the soil samples exceeded the state guidelines for mercury of 12 ppm.

Robertsville Junior High Area (Table C.2). Twenty soil samples were collected from three residences; one residence showed soil mercury concentrations greater than the state guideline levels. Because of the distance of the residences from the floodplain, it is believed the contamination was the result of imported contaminated soil from the East Fork Poplar Creek floodplain.

Scarboro Area (Table C.2). Seven soil samples were collected from three residences, none of which exceeded the state guidelines for mercury. One green pepper sample was collected.

Wiltshire Estates Area (Table C.2). Eleven yard soil samples were collected from two residences. Samples from one residence exceeded the state guidelines for mercury. The yard from which these samples were collected was located on the East Fork Poplar Creek floodplain. No vegetation samples were collected in this area.

Woodland Area (Table C.2). Nineteen soil samples were collected from seven residences, none of which exceeded the state guidelines for mercury. Three vegetation samples—tomatoes, green peppers, and cucumbers—along with soil samples were collected at the same time and location.

Sewer Beltway

Rapid Scan. During the construction of the sewer beltway, contaminated soil from the East Fork Poplar Creek floodplain was imported for backfill and used as topsoil. Few records were maintained

to document the location of this contaminated soil. To gain an overview of the extent and nature of the beltway contamination, a rapid scan sampling program was initiated and completed in the spring of 1984. Sampling consisted of a radiation survey walkover covering the entire sewer beltway and collection of surface soil samples every 100 m along the beltway centerline. Additional soil samples were collected wherever radiation levels were elevated because of an assumed correlation between mercury and uranium. It was during the course of a radiation survey that radioactive contamination in the soil was discovered on Emory Valley Road. One hundred and eighty soil samples were collected in this sampling regimen; 79 samples exceeded the state guideline (12 ppm) for mercury in soil. This sampling regimen revealed several unsuspected areas of contamination.

Interim Remedial Action. The contaminated areas on the sewer beltway at the Oak Ridge Civic Center were of immediate concern because of their heavy public use, especially by children. Because of this concern, a detailed study of this area was undertaken and completed in the spring of 1984. It was determined with the assistance of EPA that the soil should be removed and that the cleanup criteria would be to remove any soil with mercury concentrations greater than 100 ppm and to continue the cleanup until the soil mercury concentration was 10 ppm or less. Five hundred and fifty-three samples were collected from the contaminated sites at the Civic Center to confirm that the cleanup criteria were met.

The same criteria were applied to cleanup of two small contaminated areas, one at the Southfield Apartments and a second on a soil pile on Emory Valley Road. Here a total of ten soil samples were collected from the area at Southfield Apartments and eight from Emory Valley Road to confirm the cleanup criteria had been met.

After the contaminated soil had been removed, clean soil was used to fill the excavated areas at the Civic Center, Southfield Apartments, and Emory Valley Road.

East Fork Poplar Creek Floodplain

Initial sampling design of the East Fork Poplar Creek floodplain was to establish transects across the creek every 100 m. Transects traverse the entire floodplain, and surface soil samples were to be collected every 50 m, or at closer intervals if the transect is less than 100 m. After initial sampling is completed, a detailed sampling will be undertaken at locations that show elevated mercury levels (currently this criterion is 100 ppm). However, this sequence of events was modified during the summer because one of the property owners requested a detailed sampling of his floodplain (not residential). The sampling grid was 650 m long, and the width extended beyond the floodplain edge. Three hundred and ten soil samples were collected having a range of soil mercury concentrations of <1–2100 ppm. The upper limit of this range is the highest soil mercury levels seen in this study to date. Several vegetation samples were collected having mercury concentrations ranging from 34–510 ppb. The upper value was a grass sample collected near the soil sample showing mercury concentrations of 2100 ppm.

In the fall of 1984, the 100-m transect portion of the survey was begun. The study began where the East Fork Poplar Creek crosses the Oak Ridge Turnpike to reenter the DOE reservation near the west end of the city. The transects were conducted eastward from that point and then followed roughly 23 km of the stream to where it initially leaves the Y-12 reservation. During 1984 a total of 172 soil samples were collected transecting 2.5 km of the creek.

Oak Ridge Wastewater Treatment Facility and Emory Valley Road Pump Station

During the rapid survey of the sewer beltway, an area of high radioactivity (^{134}Cs , ^{137}Cs , and ^{60}Co) was discovered on Emory Valley Road. It was believed the source of this contamination was a

local private business. This discovery led to a concern that the contamination was on-going and contaminating the sewer system. To monitor this potential problem, an in-line radiation detector was installed as an in-stream sewage monitor. In addition, an automatic water sampler was put in place. These were installed at the pump house, which was routinely visited for equipment maintenance. Water samples were brought to the laboratory and counted. This study yielded 44 water samples in which one or more of the previously mentioned radionuclides exceeded background. However, none of the measured parameters exceeded the most restrictive case identified in the Code of Federal Regulations as 10 CFR 20.

As a result of the contamination on Emory Valley Road, sampling of the Oak Ridge Wastewater Treatment Facility began in April 1984. Sewage sludge was routinely monitored for ^{137}Cs and ^{60}Co before being transported to a disposal site. The sludge was also periodically tested for mercury and the other parameters identified in the multiparameter analysis section.

Since the radiation monitoring began in April, the concentration of ^{137}Cs and ^{60}Co in the sludge has declined from 7.1 and 23 pCi/mL to 2.36 and 7.35 pCi/mL, respectively. During this time, there were three cases where a sudden spike of ^{137}Cs and ^{60}Co appeared. The reason for this has not been determined.

Characterization of the Nature of the Mercury Contamination in the Soil

The characterization of the mercury present in floodplain soils has been of interest to the ORTF. In August 1984, small black particles were discovered to be associated with mercury-contaminated soils but not with uncontaminated soils. A strong positive correlation was observed between the black particles and the concentration of mercury. Thus, it was suspected that the mercury is directly attached in some fashion to these particles. It was also noted that when contaminated soils were heated both the black particles and the mercury were lost. This loss of black particles at these temperatures implies they may be organic in nature. The organic composition has yet to be determined. At that time, it was hypothesized that the mercury could be attached to these organic particles via some sort of sulfur bond. However, subsequent leaching and heating experiments and comparing the results to similarly treated HgS have not supported the sulfur-bond hypothesis.

Further experimentation on these particles indicate that the mercury is probably not organically bound, nor is it elemental. This finding indicates that the substance is probably an inorganic mercury compound (probably excluding HgS) or that the mercury is somehow occluded in the black matrix.

Multiparameter Analysis

Because of concerns that other contaminants besides mercury were released from the Y-12 plant, multiparameter analyses have been run on a subset of soil samples that indicate mercury contamination. These additional analyses included several radiochemical parameters (uranium and thorium) as well as those for barium, lead, arsenic, chromium, silver, selenium, beryllium, other metals, methyl-mercury, and PCBs (Tables C.3–C.9). The total soil mercury concentrations in this multiparameter study ranged from 130–480 ppm; no sample showed methyl-mercury above the detection limit of 0.1 ppm.

For comparison, several soil samples that showed mercury levels at background were submitted for multiparameter analysis. The results of these analyses are summarized in Table C.10.

Table C.3. Multiparameter analyses of residential soils

Log No.	Gross α (pCi/g)	Gross β (pCi/g)	Hg ^a (ppm)	U (ppm)	Th (ppm)	Ba (ppm)	Cr (ppm)	As (ppm)	Se (ppm)	Ag (ppm)	Cd ^b (ppm)	Pb ^b (ppm)	Be ^b
84-1076	12	53	550 \pm 30 560	40 \pm 2	60 \pm 4	500 \pm 50	100 \pm 6	11 \pm 1	1.6 \pm 0.4	15 \pm 1	24	110	2.3
84-1082	6	46	230 \pm 10 220	16 \pm 1	37 \pm 2	350 \pm 40	80 \pm 5	10 \pm 1	2.8 \pm 1.0	8.6 \pm 1.0	10	150	2.9
84-2014	80	6	90 \pm 5 110	9.0 \pm 0.7	12 \pm 1	350 \pm 30	73 \pm 5	8.0 \pm 0.5	< 1	4.7 \pm 0.8	4	740	2.4
84-2016	97	7	75 \pm 5 86	27 \pm 2	11 \pm 1	420 \pm 40	73 \pm 5	6.7 \pm 0.4	< 1	19 \pm 1	6	55	2.7

^aWhere Hg sample has two sets of results, the latest results are listed first.

^bDetermined by Atomic Absorption.

Table C.4. Civic Center soils^a
(Multiparameter analyses)

Log No.	Gross α (pCi/g)	Gross β (pCi/g)	Hg ^b (ppm)	U (ppm)	Th (ppm)	Ba (ppm)	Cr (ppm)	As (ppm)	Se (ppm)	Cd (ppm)	Ag (ppm)	Pb (ppm)
84-0165	9.0	39	210 ± 13 190	44 ± 3	28 ± 2	460 ± 60	98 ± 6	9.5 ± 0.6	< 3	< 6	11 ± 2	115
84-0166	11	37	250 ± 15 260	38 ± 2	24 ± 2	450 ± 60	94 ± 6	9.1 ± 0.6	< 2	< 5	14 ± 2	92
84-0167	8.9	34	150 ± 9 160	29 ± 2	21 ± 1	490 ± 70	86 ± 6	8.3 ± 0.5	< 3	< 6	7.0 ± 2.0	89
84-0168	12	44	230 ± 14 240	41 ± 3	27 ± 2	440 ± 60	92 ± 6	9.2 ± 0.6	< 3	< 6	13 ± 2	110
84-0169	7.2	30	130 ± 8 130	26 ± 2	20 ± 1	350 ± 50	78 ± 5	8.7 ± 0.6	< 3	< 6	5.1 ± 1.5	100
84-0170	12	42	230 ± 14 240	48 ± 3	29 ± 2	580 ± 70	100 ± 7	9.9 ± 0.6	< 3	< 6	8.1 ± 1.8	106
84-0171	7.3	37	180 ± 10 190	35 ± 2	24 ± 1	420 ± 60	92 ± 6	9.5 ± 0.6	< 2	< 6	8.9 ± 1.6	102

^aAll elements are determined by INAA, except Pb, which is determined by x-ray fluorescence (XRF).

^bTwo sets of results for mercury; the most recent result are listed first.

Table C.5. Southfield Apartments soils^a
(Multiparameter analyses)

Log No.	Gross α (pCi/g)	Gross β (pCi/g)	Hg (ppm)	U (ppm)	Th (ppm)	Ba (ppm)	Cr (ppm)	As (ppm)	Se (ppm)	Cd (ppm)	Ag (ppm)	Pb (ppm)
84-0214	12	45	420 \pm 25 410	57 \pm 3	30 \pm 2	590 \pm 60	100 \pm 7	13.3 \pm 0.8	< 3	< 7	19 \pm 3	98
84-0215	11	32	250 \pm 15 220	40 \pm 2	25 \pm 1	550 \pm 60	100 \pm 7	9.8 \pm 0.6	< 3	< 6	13 \pm 2	84
84-0232	13	39	370 \pm 22 370	47 \pm 3	27 \pm 2	520 \pm 60	95 \pm 6	9.9 \pm 0.6	< 3	< 6	12 \pm 2	92
84-0265	9.7	41	220 \pm 13 230	48 \pm 3	27 \pm 2	620 \pm 60	110 \pm 7	12.8 \pm 0.8	< 3	< 7	12 \pm 2	100
84-0339	12	44	330 \pm 20 300	48 \pm 3	29 \pm 2	550 \pm 60	94 \pm 7	11 \pm 1	< 4	< 9	12 \pm 3	120
84-0340	8.8	42	330 \pm 20 310	51 \pm 3	30 \pm 2	570 \pm 60	110 \pm 8	11 \pm 1	< 4	< 8	18 \pm 2	110
84-0341	11	48	430 \pm 30 390	53 \pm 3	28 \pm 2	640 \pm 70	110 \pm 7	12 \pm 1	< 3	< 6	15 \pm 2	100
84-0342	10	46	420 \pm 30 420	53 \pm 3	29 \pm 2	610 \pm 60	100 \pm 7	11 \pm 1	< 3	< 6	22 \pm 3	100
84-0343	14	55	300 \pm 20 270	53 \pm 3	30 \pm 2	590 \pm 60	110 \pm 8	11 \pm 1	< 3	< 6	17 \pm 2	110
84-0344	11	48	400 \pm 20 330	49 \pm 3	28 \pm 1	610 \pm 60	100 \pm 7	12 \pm 1	< 3	< 6	13 \pm 2	100
84-0345	12	46	200 \pm 10 190	45 \pm 3	26 \pm 1	600 \pm 60	110 \pm 7	12 \pm 1	< 3	< 6	18 \pm 2	92
84-0346	8.1	41	210 \pm 10 190	48 \pm 3	28 \pm 2	560 \pm 60	110 \pm 7	12 \pm 1	< 3	< 6	14 \pm 2	110
84-0347	12	43	270 \pm 20 300	48 \pm 3	28 \pm 2	520 \pm 60	100 \pm 6	11 \pm 1	3.9 \pm 1.4	< 5	16 \pm 2	96

^aAll elements are determined by INAA, except Pb, which is determined by x-ray fluorescence (XRF).

^bTwo sets of results for mercury; the most recent result are listed first.

Table C.6. Callaghan Towers soils^a
(Multiparameter analyses)

Log No.	Gross α (pCi/g)	Gross β (pCi/g)	Hg ^b (ppm)	U (ppm)	Th (ppm)	Ba (ppm)	Cr (ppm)	As (ppm)	Se (ppm)	Cd (ppm)	Ag (ppm)	Pb (ppm)
84-0388	8.3	31	260 ± 20 250	25 ± 2	20 ± 1	390 ± 60	73 ± 6	7.8 ± 0.5	< 4	< 7	7.7 ± 2.1	120
84-0389	9.7	25	180 ± 10 190	26 ± 2	19 ± 1	370 ± 50	79 ± 5	7.2 ± 0.5	< 3	< 6	< 3	70
84-0393	12	40	430 ± 30 510	56 ± 3	32 ± 2	560 ± 60	98 ± 7	12 ± 1	< 3	< 6	11 ± 2	100
84-0395	9.0	33	210 ± 10 230	29 ± 2	19 ± 1	300 ± 50	82 ± 6	8.4 ± 0.5	< 4	< 7	< 4	80
84-0397	12	39	250 ± 10 260	40 ± 3	22 ± 1	370 ± 50	96 ± 6	8.0 ± 0.5	< 3	< 6	8.0 ± 1.7	94
84-0400	14	34	350 ± 20 450	39 ± 2	21 ± 1	390 ± 50	89 ± 6	7.8 ± 0.5	< 2	< 6	11 ± 2	110
84-0406	13	37	280 ± 20 380	53 ± 3	33 ± 2	600 ± 60	100 ± 7	11 ± 1	5.1 ± 1.6	< 6	18 ± 2	110
84-0410	11	33	310 ± 20 380	46 ± 3	25 ± 2	600 ± 50	91 ± 6	9.1 ± 0.6	< 3	< 6	9.3 ± 1.8	70
84-0412	13	30	230 ± 10 250	32 ± 2	19 ± 1	300 ± 50	86 ± 6	7.4 ± 0.5	< 2	< 5	7.9 ± 1.3	58
84-0413	9.4	33	220 ± 10 280	29 ± 2	21 ± 1	400 ± 50	81 ± 5	8.2 ± 0.5	< 2	< 5	8.4 ± 1.5	70
84-0414	11	33	210 ± 10 230	32 ± 2	21 ± 1	350 ± 50	83 ± 5	7.9 ± 0.5	< 2	< 4	9.6 ± 1.2	84
84-0419	12	28	250 ± 20 300	28 ± 2	17 ± 1	200 ± 50	90 ± 6	7.8 ± 0.5	< 3	< 5	9.8 ± 1.8	85
84-0424	11	34	260 ± 20 270	45 ± 3	26 ± 2	340 ± 50	94 ± 6	8.4 ± 0.5	< 3	< 5	12 ± 2	80

Table C.6 (continued)

Log No.	Gross α (pCi/g)	Gross β (pCi/g)	Hg ^b (ppm)	U (ppm)	Th (ppm)	Ba (ppm)	Cr (ppm)	As (ppm)	Se (ppm)	Cd (ppm)	Ag (ppm)	Pb (ppm)
84-0394 ^c	12	31	250 \pm 10 200	32 \pm 2	20 \pm 1	370 \pm 60	84 \pm 6	7.7 \pm 0.5	< 3	< 6	10 \pm 2	87
84-0455 ^d	10	29	220 \pm 10 270	27 \pm 2	18 \pm 1	330 \pm 50	82 \pm 6	8.0 \pm 0.5	< 3	< 5	8.6 \pm 1.8	74
84-0456 ^e	7.7	29	140 \pm 8 180	22 \pm 1	18 \pm 1	340 \pm 50	76 \pm 5	7.8 \pm 0.5	< 2	< 5	< 2	65

Depth profile samples

^aTwo sets of results for mercury; the most recent result are listed first.

^bAll elements are determined by INAA, except Pb, which is determined by x-ray fluorescence (XRF).

^cSoil 84-0394—surface sample, grid 0,60.

^dSoil 84-0455—0-3-in. depth, grid 0,60.

^eSoil 84-0456—3-6-in. depth, grid 0,60.

Table C.7. Soil multielement analysis^a for property 564
on East Fork Poplar Creek floodplain

Log No.	Hg ^b (ppm)	U (ppm)	Th (ppm)	Ba (ppm)	Cr (ppm)	As (ppm)	Se (ppm)	Cd ¹ (ppm)	Ag (ppm)	Pb ^c (ppm)	Be ^c (ppm)
84-0866	210 ± 10 250	31 ± 2	24 ± 2	650 ± 60	78 ± 5	6.9 ± 0.4	< 2	7.6 ± 0.5	6.1 ± 1.0	70	1.6
84-0868	220 ± 10 220	43 ± 3	27 ± 2	790 ± 70	97 ± 6	8.3 ± 0.5	< 2	8.4 ± 0.5	10 ± 1	80	1.8
84-0869	240 ± 14 250	42 ± 3	25 ± 2	480 ± 60	91 ± 6	8.4 ± 0.5	< 2	8.8 ± 0.5	11 ± 1	100	2.0
84-0871	190 ± 10 210	35 ± 2	25 ± 2	450 ± 60	91 ± 6	7.3 ± 0.5	< 2	7.7 ± 0.5	11 ± 1	90	2.3
84-0877	200 ± 10 210	36 ± 2	21 ± 1	430 ± 50	91 ± 6	7.6 ± 0.5	< 2	7.5 ± 0.5	9.0 ± 1.0	80	2.2
84-1172	53 ± 3 50	10 ± 0.7	5.4 ± 0.3	200 ± 30	56 ± 4	5.6 ± 0.3	< 1	5.5 ± 0.3	< 1	75	1.0
84-1178	36 ± 2 50	23 ± 2	16 ± 1	620 ± 70	73 ± 5	6.3 ± 0.4	< 2	3.0 ± 0.2	4.8 ± 1.5	60	2.1
84-1199	270 ± 16 280	35 ± 2	29 ± 2	780 ± 80	100 ± 6	8.5 ± 0.5	4.3 ± 1.6	9.3 ± 0.5	12 ± 2	90	2.2
84-1200	2000 ± 100 2100	130 ± 8	68 ± 4	1200 ± 100	110 ± 8	16 ± 1	< 8	45 ± 2	27 ± 4	130	2.4
84-1201	215 ± 12 250	49 ± 3	29 ± 2	470 ± 60	120 ± 7	9.1 ± 0.6	< 2	9.7 ± 0.5	14 ± 2	130	2.2
84-1202	250 ± 15 290	60 ± 4	34 ± 2	450 ± 60	155 ± 10	9.5 ± 0.6	< 2	10 ± 1.0	17 ± 2	130	2.3
84-1205	220 ± 13 230	47 ± 3	25 ± 2	490 ± 60	95 ± 6	8.9 ± 0.6	4.2 ± 1.8	11 ± 1.0	12 ± 1	95	2.0
84-1206	200 ± 12 230	43 ± 3	26 ± 2	550 ± 70	100 ± 6	8.7 ± 0.5	< 2	7.8 ± 0.4	11 ± 1	110	1.6
84-1245	450 ± 30 600	71 ± 4	48 ± 3	640 ± 80	200 ± 12	12 ± 1	3.9 ± 1.4	16 ± 1.0	18 ± 2	175	2.6

Table C.7 (continued)

Log No.	Hg ^b (ppm)	U (ppm)	Th (ppm)	Ba (ppm)	Cr (ppm)	As (ppm)	Se (ppm)	Cd ^d (ppm)	Ag (ppm)	Pb ^c (ppm)	Be ^c (ppm)
84-1246	180 ± 13 230	40 ± 2	25 ± 2	550 ± 60	100 ± 6	8.1 ± 0.5	< 2	6.9 ± 0.3	11 ± 1	100	2.2
84-1249	570 ± 35 750	100 ± 6	55 ± 3	780 ± 80	160 ± 10	12 ± 1	< 2	18 ± 1.0	21 ± 2	140	2.5
84-1250	200 ± 12 230	40 ± 2	23 ± 1	540 ± 70	80 ± 5	7.4 ± 0.5	< 2	7.2 ± 0.4	8.4 ± 1.2	80	2.0
84-1251	180 ± 13 200	32 ± 2	17 ± 1	550 ± 60	66 ± 4	7.3 ± 0.5	< 2	6.7 ± 0.3	3.8 ± 1.0	75	1.6
84-1303	100 ± 6 120	36 ± 2	27 ± 2	700 ± 60	130 ± 8	9.4 ± 0.6	< 2	9.0	15 ± 1	120	2.1
84-1304	88 ± 5 120	57 ± 3	27 ± 2	650 ± 74	150 ± 60	9.7 ± 0.6	< 2	7.8	17 ± 2	130	2.0

^aDetermined by INAA.^bTwo sets of results for mercury; the most recent result are listed first.^cDetermined by atomic absorption.

Table C.8. East Fork Poplar Creek floodplain soil
(Multiparameter analyses)

	84-2571	84-2586	84-2600	84-2602	84-2628	84-2638	84-2642
Arsenic	5.6 ± 0.3	5.3 ± 0.3	6.5 ± 0.4	6.7 ± 0.4	7.4 ± 0.5	6.9 ± 0.4	6.7 ± 0.4
Barium	310 ± 40	360 ± 50	410 ± 30	400 ± 30	360 ± 40	330 ± 30	440 ± 40
Cadmium	4.7	6.9	6.0	4.8	7.4	8.4	5.7
Chromium	55 ± 3	67 ± 5	93 ± 6	100 ± 10	87 ± 5	100 ± 10	140 ± 10
Lead	45.	43	67	82	80	90	95
Mercury	140 ± 8	160 ± 10	110 ± 6	87 ± 5	190 ± 10	120 ± 10	80 ± 5
Nickel	30	59	56	44	63	48	38
Selenium	< 1	< 1	< 1	< 1	< 1	< 1	1.5 ± 0.3
Silver	1.4 ± 0.2	4.1 ± 0.3	5.0 ± 0.4	5.0 ± 0.4	4.7 ± 0.5	7.6 ± 0.6	6.1 ± 0.6
Thorium	8.8 ± 0.5	10 ± 1	15 ± 1	16 ± 1	15 ± 1	18 ± 1	16 ± 1
Uranium	17 ± 1	24 ± 2	33 ± 2	33 ± 2	30 ± 2	55 ± 3	43 ± 3
Zinc	120 ± 10.	140 ± 10	170 ± 10	160 ± 10	160 ± 10	190 ± 10	210 ± 20
Gross α^a	4.4	9.0	7.1	8.1	9.5	11	8.2
Gross β^a	24	32	33	32	36	44	37

^apiC/g.

Table C.9. Soils from property 564 near grid point 20,60—multielement analyses^a

Log No.	Hg ^b (ppm)	U (ppm)	Th (ppm)	Ba (ppm)	Cr (ppm)	As (ppm)	Se (ppm)	Cd ^l (ppm)	Ag (ppm)	Pb ^c (ppm)	Be ^c (ppm)
84-1520	320 ± 20	78 ± 5	58 ± 3	700 ± 60	140 ± 10	13 ± 1	3.7 ± 1.3	12	28 ± 2	110	1.8
	310										
84-1522	1070 ± 60	220 ± 15	100 ± 6	1200 ± 100	130 ± 8	17 ± 1	< 3	37	44 ± 3	100	3.4
	1070										
84-1523	830 ± 50	220 ± 15	77 ± 5	1100 ± 90	120 ± 8	20 ± 1	6.2 ± 1.6	21	51 ± 1	110	2.4
	830										
84-1527	200 ± 12	70 ± 4	45 ± 3	550 ± 60	140 ± 8	12 ± 1	< 2	10	22 ± 2	100	3.0
	200										
84-1529	1620 ± 100	170 ± 10	75 ± 5	1200 ± 140	110 ± 7	18 ± 1	< 3	40	26 ± 2	100	2.3
	1700										
84-1545	750 ± 40	100 ± 6	90 ± 5	580 ± 70	220 ± 10	13 ± 1	< 2	28	30 ± 2	260	
	700										
84-1546	300 ± 20	52 ± 3	40 ± 2	520 ± 60	120 ± 7	11 ± 1	< 2	13	15 ± 1	120	
	300										
84-1200 ^d	2000 ± 100	130 ± 8	68 ± 4	1200 ± 100	110 ± 8	16 ± 1	4.0 ± 1.3	45	27 ± 4	130	2.4
	2100										

^aDetermined by INAA.

^bTwo sets of results for mercury; the most recent result are listed first.

^cDetermined by atomic absorption.

^dFrom grid point 20,60.

Table C.10. Multiparameter analysis^a—background soils

Log No.	Gross α (pCi/g)	Gross β (pCi/g)	Hg ^b (ppm)	U (ppm)	Th (ppm)	Ba (ppm)	Cr (ppm)	As (ppm)	Se (ppm)	Cd (ppm)	Ag (ppm)	Pb ^c (ppm)
A&P and Southfield Apartments Areas												
84-0173	3.0	21	< 0.3 0.05	5.0 \pm 0.5	10 \pm 1	410 \pm 60	63 \pm 4	3.8 \pm 0.3	< 2	< 5	< 2	43
84-0182	4.3	20	< 0.3 0.08	3.7 \pm 0.5	11 \pm 1	480 \pm 70	67 \pm 5	6.4 \pm 0.4	< 3	< 5	< 3	35
84-0206	2.1	21	< 0.3 0.11	4.7 \pm 0.5	12 \pm 1	300 \pm 60	59 \pm 4	6.5 \pm 0.4	5.3 \pm 1.5	< 5	< 3	65
84-0208	3.2	21	< 0.3 0.15	3.5 \pm 0.4	13 \pm 1	460 \pm 50	83 \pm 5	5.9 \pm 0.4	< 3	< 5	< 3	36
84-0212	4.2	20	< 0.3 0.45	4.0 \pm 0.4	12 \pm 1	520 \pm 60	69 \pm 5	5.6 \pm 0.4	< 2	< 4	< 3	36
84-0216	2.1	18	< 0.3 0.14	4.1 \pm 0.5	13 \pm 1	250 \pm 50	64 \pm 4	6.3 \pm 0.4	< 2	< 5	< 2	48

^aAll elements are determined by INAA. Determined by x-ray fluorescence (XRF).^bTwo sets of results for mercury: first, INAA and second, Vapor Atomic Absorption Analysis (VAA).

Table C.11 summarizes the multiparameter vegetation analyses performed to date. This effort is still in its infancy and will be expanded when a better understanding of the distribution of the soil contaminants is reached.

Table C.11. East Fork Poplar Creek soil and plant^a multielement analyses
[Results in ppm (dry wt) unless otherwise noted]

	84-1049, soil (ppm)	84-1050, box elder (ppb)	84-1051, soil (ppm)	84-1052, honeysuckle (ppb)	84-1053, onion (ppb)	84-1054, grass (ppb)	84-1055, soil (ppm)	84-1056, smilax (ppb)
Arsenic	12 ± 1	< 100	14 ± 1	< 100	< 100	320	11 ± 1	230
Barium	600 ± 60	< 7000	700 ± 60	60,000	5000	5000	650 ± 70	41,000
Beryllium	2.6		8.0			300	1.1	
Cadmium	4.4	< 1600	5.7	< 2000	2900	1300	7.8	< 2500
Chromium	100 ± 6	< 2000	87 ± 6	5400	2700	7200	93 ± 6	
Copper						10,000		
Lead	46		43				53	
Lithium								
Mercury	190 ± 11	< 60	320 ± 20	< 80	180	120	230 ± 20	1300
Nickel								
Selenium	6.1 ± 1.1	< 1000	< 2	< 900	< 900	< 2000	4.4 ± 1.3	< 2000
Silver	12 ± 1	< 600	12 ± 1	< 700	< 600	< 1400	14 ± 1	< 100
Thorium	29 ± 2	< 100	20 ± 1	< 100	< 70	< 200	28 ± 2	< 100
Uranium	95 ± 5	< 100	80 ± 5	< 100	< 100	190	200 ± 10	2600
Zinc	180 ± 13		160 ± 10	43,000	40,000	36,000	190 ± 10	55,000
PCB								
MeHg								
Gross α								
Gross β								
¹³⁷ Cs								
⁶⁰ Co								

^aPlant tissue air dried at room temperature.

The ORAU hotel construction site soils were used to fill the excavations at the Civic Center and Southfield Apartments. It was important that uncontaminated soils be used, and to this end, multiparameter analyses were performed on samples collected from this construction area. The results of these analyses are presented in Table C.12. Because the data indicates the soils are not contaminated, these data will be incorporated into our background information for the Oak Ridge area.

Quality Assurance and Quality Control

In August 1984 the EPA and ORAU met in Oak Ridge to review ORAU's quality assurance procedures in this study. A second meeting was convened in Athens, Georgia, on November 2, 1984, to complete the work initiated in August. One of the outcomes of the August meeting was the

Table C.12. Multiparameter analyses profile—ORAU hotel site soils
(Results in ppm unless otherwise noted)

Element	84-2431	84-2432	84-2433	84-2434	84-2435	84-2436	84-2437
Na, %	0.23	0.24	0.25	0.09	0.10	0.10	0.10
Mg, %	0.53						
Al, %	6.2	6.9	7.1	4.9	5.6	5.6	6.1
K, %	1.8	1.9	2.0	1.0	1.2	1.2	1.0
Sc	13	13	14	7.9	10	10	10
Ti, %	0.58	0.67	0.64	0.68	0.71	0.73	0.66
V	92	100	110	70	94	84	84
Cr	70	70	74	45	55	56	56
Mn	910	920	1070	4200	3800	4300	5400
Fe, %	3.3	3.5	3.5	2.6	3.4	3.3	3.3
Co	16	16	18	17	20	22	20
Ni	25	28	31	24	25	30	35
Cu	13	16	17	9	8	8	11
Zn	90	110	150	100	100	110	120
As	6.7	7.9	6.6	6.6	7.8	8.4	8.2
Se	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Br	7.9	8.8	8.3	5.9	3.8	4.0	4.7
Rb	100	120	120	72	90	92	92
Sr	75			70			
Zr	415	330	300	440	550	520	500
Ag	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Cd	2.3	2.1	2.0	1.6	3.0	1.6	3.0
Sb		0.8	0.5	0.7	0.7	0.7	0.9
Cs	4.0	4.5	4.4	2.9	3.8	3.8	4.0
Ba	560	560	590	360	470	480	480
La	43	45	47	46	50	50	55
Ce	93	97	100	100	120	120	130
Hf	9.7	9.1	9.3	12	13	14	13
Hg	0.08	0.07	0.02	0.21	0.08	0.05	0.09
Pb	23	21	23	44	37	32	34
Th	11	12	12	11	13	14	13
U	4	3	4.7	3	3.0	3.4	2.5
PCB	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
MHg	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1

determination that the Y-12 Plant, ORNL, ORGDP, and ORAU should use comparable procedures. To this end, several meetings were held to develop a generic sampling methodologies quality control document for the four DOE Oak Ridge facilities. Representatives from each facility contributed to the writing of the draft manual, which is currently in internal review. At this same time, a sample exchange program was also implemented among the four facilities.

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