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OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

Preliminary Assessment of the Radiological Impact for Individual Waste Management Areas at the Oak Ridge National Laboratory: Status Report

M. B. Sears

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Chemical Technology Division

PRELIMINARY ASSESSMENT OF THE RADIOLOGICAL IMPACT FOR INDIVIDUAL WASTE MANAGEMENT AREAS AT THE OAK RIDGE NATIONAL LABORATORY: STATUS REPORT

M. B. Sears

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ABSTRACT

A study was made to estimate the radiological impact (i.e., the potential doses) for individual waste management areas at the Oak Ridge National Laboratory and to rank the areas for remedial action based on the off-site doses that result from these discharges to White Oak Creek.

Dose estimates are given for the drinking water pathway based on known discharges from White Oak Dam. Estimates are also made of doses for eating fish caught in the Clinch River near the confluence with White Oak Creek. The results of a search for data concerning the discharges of ^{90}Sr, ^{3}H, ^{137}Cs, and ^{60}Co from individual waste management areas are presented. A qualitative assessment is presented, and areas are ranked for remedial investigation based on the available information.

1. INTRODUCTION AND SUMMARY

Discharges and seepage of radioactive materials to surface streams result from current operations and residual effects of past activities at the Oak Ridge National Laboratory (ORNL). New regulatory requirements make it necessary to assess the effectiveness of the ORNL waste disposal units and to determine the need for corrective action.

The objectives of this subtask under the Remedial Action Program are to estimate the radiological impact (i.e., the potential doses) for the individual waste management sites or areas and to rank the sites for remedial action based on the doses. This study concerns the off-site dose to the general public resulting from current discharges to surface streams in the White Oak Creek watershed.

Estimates of the 50-year dose commitment to a maximally exposed individual were calculated for the drinking water pathway of exposure based on known 1984 and 1985 releases at White Oak Dam. For drinking the water at White Oak Dam (the site boundary), the effective total-body dose was about 45 mrem. White Oak Creek is not a drinking water source; this is a worst case assumption. After dilution (assuming complete mixing), the effective total-body dose commitment from drinking Clinch River water near the confluence with White Oak Creek was ~0.15 mrem based on discharges in 1984 and 1985. The highest organ dose is to the bone. For drinking the water at White Oak Dam the bone doses were 132 and 208, respectively, based on discharges in 1984 and 1985. The bone doses from drinking Clinch River water at the confluence with White Oak Creek were 0.4 and 0.7 mrem, respectively.

The year 1984 was relatively representative for discharges of radioactive materials to surface streams. Precipitation was closest to the average of recent years, and operating releases were relatively stable. The 1985 releases were not typical because (1) the break in the low-level waste (LLW) servicing Building 3074 and the spill from the ventilation filter pit at Building 3517 resulted in higher-than-normal ^{90}Sr releases from the central ORNL complex in Bethel Valley, and (2) the precipitation was below normal, reducing seepage from the solid waste storage areas (SWSAs).

The ORNL Department of Environmental Management (DEM) collects and analyzes fish from the Clinch River. The highest doses (~1 mrem effective total-body in 1985) are from eating fish caught near the confluence with White Oak Creek.

The nuclides that are important as source terms were defined based on the dose calculations for the total discharges measured at White Oak Dam. Major contributors to the effective total-body dose from drinking water are ^{3}H (~70% and ~50% for 1984 and 1985, respectively) and ^{90}Sr. For eating fish caught in the Clinch River near the confluence with White Oak Creek, ^{137}Cs contributes 60-90% of the effective total-body dose (varies with species), and ^{90}Sr contributes most of the remainder. Strontium-90 is the major contributor to the bone dose (the maximum organ dose) via either pathway. Cobalt-60 is a relatively minor contributor to the off-site dose.

A search for data concerning releases from the individual waste management sites included examining the files of the ORNL Operations Division and DEM, a literature survey, and discussions with ORNL staff members.

Monitoring for ^{90}Sr has been conducted routinely since 1979, using continuous flow-proportional samplers at several stations in the White Oak Creek watershed. A relatively extensive data base for ^{90}Sr is averaged over a time period long enough to give a representative picture, although the data are primarily by area rather than for individual sites. The major contributors of ^{90}Sr releases during the period 1979-84 were undefined (or uncontrolled) sources in the central ORNL site (Bethel Valley), 31%; solid waste storage area (SWSA) 4, 31%; and SWSA 5, 24%. A surface water diversion system was installed at SWSA 4 in late 1983. Monitoring studies in 1984 indicated that this system reduced the total flux from SWSA 4 by about 35%. If this trend continues, ^{90}Sr discharges from SWSA 4 would be a little lower than from SWSA 5. On an annual basis, the ^{90}Sr discharges from SWSA 4, SWSA 5, the pits area, and the branch draining the 7500 area (Homogeneous Reactor Test, etc.) were respectively 5.5, 4.4, 0.4, and 0.5 mCi/cm of precipitation for the period 1979-1984. In 1985 there were two ^{90}Sr spills, and releases from undefined (or uncontrolled) Bethel Valley sources were about four times the norm.

Source term data for ^{3}H, ^{137}Cs, and ^{60}Co by waste management area are limited. Some streams were analyzed in 1985, but the data packages are not complete, and, as noted previously, 1985 was not a typical year. Additional source term data are needed before the dose calculations by waste management site or area can be made. It is thought that most of the ^{3}H comes from SWSA 5. The major source of ^{137}Cs (of sources monitored) was the process waste treatment plant effluent. An estimated 60% of the ^{137}Cs inflow to White Oak Lake was retained in the settling basin. In the monitored streams, the process waste treatment plant effluent contributed about 60% and Melton Branch sources about 40% of the ^{60}Co.

A qualitative dose assessment was made based on the available information. Of the known discharges, the following waste areas are the largest active sources of the environmentally significant radionuclides:

1a. Central ORNL site in Bethel Valley (undefined or uncontrolled sources),

1b. SWSA 5,

2a. SWSA 4, and

2b. Process waste treatment plant effluent.

For the purpose of reducing the off-site dose to the general public via aquatic pathways, these are the priority areas for remedial investigation. The other waste management areas are small sources by comparison.

The report includes a brief description of the waste areas, the existing environment, and the surface water transport pathways (Sect. 2). The dose calculations for current releases from White Oak Creek to the Clinch River and identification of the environmentally significant radionuclides are discussed in Sect. 3. The survey and evaluation of radionuclide releases from various waste management areas to White Oak Creek is presented in Sect. 4. Much of the material in this section is based on data compiled from the DEM and Operations Division files. Comparisons with historical data are included for ^{90}Sr and ^{3}H. More detailed tables and figures with supporting data are given in the Appendix. The report provides a reference data base for evaluating the effectiveness of remedial measures that might be undertaken. The qualitative dose assessment and ranking of areas for remedial investigation are discussed in Sect. 5.

This study does not address decommissioning/closure of waste management areas, the intruder, or worker exposure to radiation.

2. BACKGROUND

The Oak Ridge National Laboratory (ORNL) is a national energy laboratory, with its major mission being the development of safe, economic, and environmentally acceptable technologies for efficient production and use of energy. Laboratory facilities consist of nuclear reactors, chemical pilot plants, research laboratories, radioisotope production laboratories, and support facilities. The central ORNL site and most satellite areas, including the burial grounds, lie in the watershed of White Oak Creek (WOC), a small tributary of the Clinch River. The WOC watershed has received treated and untreated effluents from Laboratory activities since 1943. Controlled releases include those from the process waste treatment plant (PWTP), the sewage treatment plant (STP), and a variety of process waste holdup ponds scattered throughout the ORNL complex. The WOC also receives discharges from nonpoint sources such as solid waste storage areas (SWSAs), the liquid waste seepage pits and trenches area (closed in the mid 60s), leaking ponds, leaking waste transfer pipes, contaminated pipe trenches, and other sources contaminated by leaks and spills over the years.

A brief description of the existing environment is presented here to enhance understanding of the surface water transport pathways.

2.1 SURFACE STREAM DESCRIPTION AND USE*

The WOC drains an area of 17 km^2 in Bethel and Melton Valleys (Fig. 2.1). The mouth is at Clinch River kilometer (CRK) 33.5. The Clinch is part of the Tennessee River watershed and is controlled by the operation of Tennessee Valley Authority dams.

The WOC originates from springs on the forested slopes of Chestnut Ridge and flows southwest through Bethel Valley. Knox dolomite and Chickamauga limestone (water bearing formations) underlie these two areas, respectively. Discharge from the Knox is the main source of the

*Much of the material contained in Sect. 2.1 (Surface Stream Description and Use) was abstracted from the environmental analysis by Boyle et al.[1] This report should be consulted for more detailed information and a complete listing of reference sources.

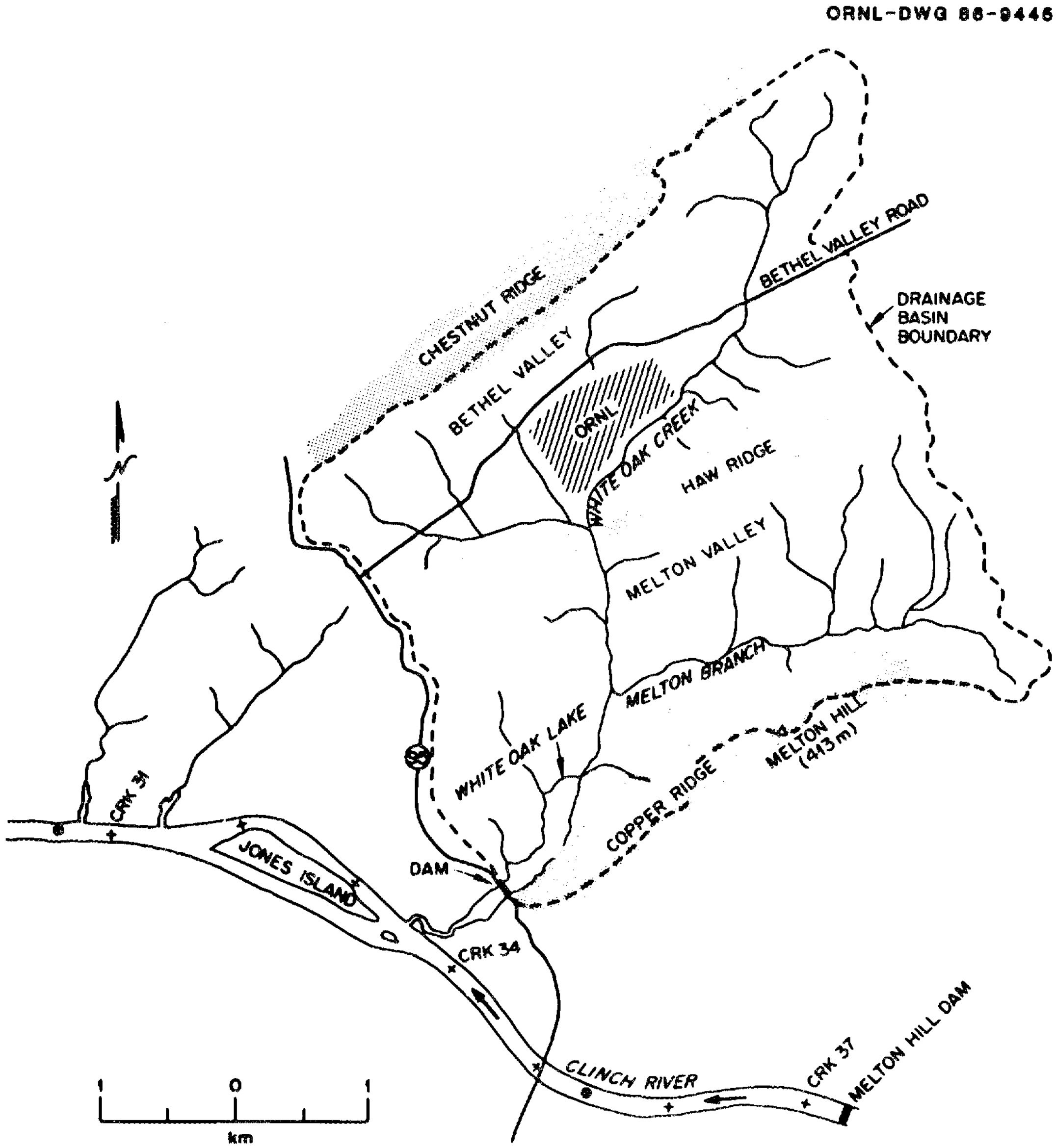

Fig. 2.1. White Oak Creek watershed.

base flow. After flowing through the central ORNL site, the creek passes through a gap in Haw Ridge (Rome formation) and enters Melton Valley, under which lies Conasauga shale. These formations contribute little to the creek's base flow. After passing Haw Ridge, WOC is joined by its major tributary, Melton Branch, which is the drainage basin of the ORNL facilities in Melton Valley. Flow rates of WOC just above the confluence with Melton Branch vary from a maximum of 18.2 m^3/s to a minimum of zero, the average being 0.27 m^3/s. The ORNL plant discharges substantially augment the dry weather flow. Flow rates of Melton Branch vary from a maximum of 6.85 m^3/s to zero, averaging 0.07 m^3/s.

The waters of WOC and its tributaries are impounded by a dam 1 km above the mouth of WOC. White Oak Lake is a small shallow impoundment that functions as the final settling basin for waste effluents. The normal lake level creates a pool surface area of approximately 9.8 ha (24 acres) with approximately a 2-d retention time. The structure has floodgates to allow temporary impoundment of flow in the event of an accidental spill. The discharge is monitored continuously for flow and water quality. The average flow in WOC at the dam is 0.38 m^3/s.

Water levels and flow in the WOC embayment below White Oak Dam are largely controlled by the operation of Melton Hill Dam, 3.7 km upstream on the Clinch River, and Watts Bar Dam, about 94 km downstream on the Tennessee River. During summer months (mid-April through October), Watts Bar Reservoir's pool creates a backwater that extends upstream to White Oak Dam. During the winter months the embayment resembles a large mudflat. Power is not generated continuously at Melton Hill Dam, so water flow in the Clinch is pulsed. As a result, daily fluctuations in water levels and flow (including reversals) occur in White Oak Embayment.

The average Clinch River flow at Melton Hill Dam between 1969 and 1979 was 150 m^3/s. The average summer (June-September) discharge was 134 m^3/s. Periods of no flow over the dam have lasted as long as 29 days; the average number of days per year of no flow is 13.

Major uses of surface water in the ORNL area include withdrawals for industrial and public supplies, navigation, and recreational activities such as fishing and swimming. There are several water withdrawals from surface sources for industrial and public water supplies within a 32.2-km radius of ORNL; the closest withdrawals downstream of the outfall of White Oak Dam are at the Oak Ridge Gaseous Diffusion Plant (CRK 23.3) and Kingston, located 10.4 river km and 34.1 river km, respectively, from ORNL. The intake to the Kingston water filtration plant is located on the Tennessee River about 0.6 river km upstream from the confluence of the Clinch and Tennessee Rivers. Normally, Tennessee

River water is used, but backflow can occur under certain conditions of power generation. 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.

Recreational surface water uses include boating, fishing, waterskiing, and swimming. Two public boat docks are located in the vicinity of Melton Hill Dam. Most swimming and waterskiing activity takes place above Melton Hill Dam at public facilities. These areas above the dam are not affected by discharges from WOC. No quantitative data are currently available on the number or amount of fish taken for human consumption from the Clinch River in the tailwater area below the dam.

2.2 GROUNDWATER DESCRIPTION AND USE*

The base flow of the surface water of the WOC watershed is maintained primarily by groundwater discharge and the discharge of process streams from ORNL facilities. The nature and extent of an aquifer are determined by the character, distribution, and structure of the bedrock and the overlying soil, as well as by the size, shape, and continuity of the interstices.

The four major geologic zones of the ORNL area mentioned earlier differ somewhat in their groundwater characteristics and capacity. Of the four groups, only the Knox dolomite has any extensive water storage capacity. This storage usually occurs in solution cavities that may be quite large in some instances and may frequently result in springs, as seen in the headwaters of WOC. The water storage capacity of the Rome formation, Conasauga shale, and Chickamauga limestone is small and occurs primarily along joints and bedding planes. Most wells in these formations typically have flows less than 0.04 m^3/min.

Groundwater flow in the weathered residual soil on the ORNL site basically follows water table conditions. Groundwater levels parallel

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*The material in Sect. 2.2 (Groundwater Description and Use) was abstracted from the environmental analysis by Boyle et al.,[1] the site data compilation by Fitzpatrick,[2] and the compilation by Nix et al.[3] These reports should be consulted for more detailed information and a complete listing of reference sources.

topographic contours, and the water movement is from areas of high elevation to areas of low elevation. However, the direction of movement in the underlying bedrock is influenced strongly by directional variations in permeability. In the Chickamauga limestone underlying Bethel Valley, groundwater moves through small solution channels and is essentially a subdued replica of the topography. The lay of the land is such that drainage at and below the surface of the Bethel Valley site apparently converges to feed WOC and White Oak Lake. An exception to this situation occurs in the western end of the Bethel Valley site where groundwater west of a groundwater divide flows west into the Raccoon Creek drainage basin rather than into WOC. Studies of groundwater movement in the Conasauga shale of Melton Valley have suggested that the primary direction of groundwater movement parallels the strike.

Groundwater discharge is through evapotranspiration, springs, and streams; it contributes to the base flow of surface streams that ultimately augment the Clinch River water supply. The bed of the Clinch River lies at the basal level of the zone of saturation, and groundwater from both sides of the channel enters the river. It is commonly believed that groundwater flow does not pass beneath the Clinch River except in cases where extensive well pumping may lower the water table.

Depth to the water table varies according to the location and the time of year. At a given location, the depth to the water is generally greatest during the October-December quarter and least during the January-March quarter, corresponding to periods of minimum and maximum precipitation. In Bethel Valley, the depth to the water table ranges from 0.3 to 11 m, whereas in Melton Valley the range is from 0.3 to 20 m.

Although the major portion of industrial and public drinking water supplies in the Oak Ridge area is taken from surface water sources, there are numerous single-family wells in adjacent rural areas. Of the domestic wells located within 16 km of ORNL (listed by the Tennessee Department of Conservation, Division of Water Resources), most are south of the Clinch River.[1] Those north of the Clinch River in the north central portion of Roane County are from 10 to 16 km from ORNL. Four industrial and three public groundwater supplies are located within 16 km of ORNL. The probability of groundwater migration from the reservation to offsite wells is thought to be low, particularly migration to wells south of the Clinch River and those upgradient from the site.

An extensive investigation of the groundwater characteristics involving drilling a number of additional monitoring wells is currently in progress.

2.3 CLIMATIC FACTORS

Precipitation, the driving mechanism of the hydrologic system, is plentiful on the Oak Ridge Reservation. Precipitation establishes the quantity and variation in runoff and stream flow and also replenishes the groundwater system. These factors affect the leaching of buried wastes and the transport of contaminants from nonpoint sources to the creek as well as the transport of contaminated sediments in the creek and White Oak Lake.

Long-term meteorological data (1948 to present) are available from the National Oceanic and Atmospheric Administration (NOAA) weather station in Oak Ridge townsite, about 11 km from the central ORNL site in Bethel Valley and about 13 km from the Melton Valley burial grounds. The record mean annual precipitation at townsite is 138.8 cm (54.7 in.) (Ref. 4). The winter months, the months of highest rainfall, are characterized by passing storm fronts. Winter storms are generally of low intensity and long duration. Another peak in rainfall occurs in July (or sometimes August), when short, heavy rains associated with thunderstorms are common. The annual precipitation for the period 1976-85 and the long-term monthly mean precipitation at the NOAA station are given in Tables 2.1 and 2.2. Monthly precipitation data at ORNL and NOAA townsite stations for the period 1972-86 are presented in the appendix (Tables A.1 and A.2).

Loss of water to the atmosphere by evapotranspiration is about 76 cm (30 in.) annually, or about 55% of the total annual precipitation.[5] Evapotranspiration is at a maximum from July to September, during the vegetation growing season. Seasonal relationships between evapotranspiration and precipitation are reflected in seasonal

Table 2.1. Annual precipitation at NOAA Oak Ridge townsite station, 1976-85[a]

Year	Precipitation (cm)
1976	135.5
1977	159.4
1978	123.0
1979	170.9
1980	101.9
1981	108.2
1982	152.5
1983	121.1
1984	143.6
1985	118.8
Record mean	138.8[b]

[a]B. Hicks (NOAA), personal communication to M. B. Sears, June 4, 1986.

[b]Period of record, January 1948-December 1984.

Table 2.2. Average monthly and total yearly precipitation at NOAA Oak Ridge townsite station[a,b]

Month	Precipitation (cm)
January	13.39
February	12.04
March	15.06
April	10.92
May	11.20
June	10.29
July	13.67
August	9.37
September	9.12
October	7.77
November	11.92
December	14.12
Total	138.84

[a]B. Hicks (NOAA), personal communication to M. B. Sears, June 4, 1986.

[b]Period of record, January 1948-December 1984.

patterns of runoff to streams. Runoff is greatest in winter, when evapotranspiration is low and precipitation is high. Precipitation not lost as evapotranspiration or quick runoff to streams percolates through the soil and eventually recharges the groundwater system.

2.4 RADIOACTIVE WASTE AREAS

Radioactive solid wastes have been buried in the vicinity of ORNL since 1943. Other sources of radioactive contamination include the settling basins, impoundments, and seepage pits and trenches of the liquid waste systems.

2.4.1 Solid Radioactive Wastes*

By 1983, an estimated 1.9 x 105 m^3 of solid radioactive waste had been placed in six burial areas. The largest volume consists of radioactive wastes or "laboratory trash" that is either known or suspected to be contaminated. Contaminated equipment, machinery, tools, tanks, and other items that cannot be economically decontaminated are disposed of as waste. Other potential high-volume sources of solid waste are soil, concrete, and various building materials that have become contaminated. Little is known about the radiological characteristics for much of the waste buried before 1971. During that period, from 1955-63, ORNL served as the Southern Regional Burial Ground for low-level waste (LLW).

The disposal methods that were used are similar to methods used in sanitary landfill operations; waste was placed in unlined trenches and covered with approximately 60 cm of soil. Current practice is to cover waste with about 90 cm of soil. In some areas, trenches containing alpha- contaminated materials were covered with concrete. Higher-activity solid wastes were disposed of in auger holes and covered with

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*The material in Sect. 2.4.1 (Solid Radioactive Wastes) was abstracted from the environmental analysis by Boyle et al.[1] and reviews of the solid radioactive waste areas by Oakes and Shank[6] and by Webster.[7] These reports should be consulted for more detailed information.

concrete. Current practice is to use box-like concrete culverts on concrete bases for LLW burial. Transuranic (TRU) waste was formerly buried in separate trenches and covered with concrete, but since 1970 it has been placed in metal or concrete containers in retrievable storage at SWSA 5.

The land use, service dates, and estimated radionuclide inventories of the SWSAs are summarized in Table A.3. (A location map, Fig. 4.1, is given in Sect. 4.) The sites for the first three SWSAs, selected primarily for convenience and ease of digging, were located in Bethel Valley. As the volume of waste grew, more attention was paid to site selection. SWSAs 3-6 were sited in Melton Valley, which is underlain by Conasauga shale (a material with desirable ion exchange properties). The use of the SWSA 2 site was later found to be incompatible with the long-range planning at ORNL. Most of the waste in SWSA 2 was removed and reburied in SWSA 3, but there is some question whether all of it was removed.

2.4.2 Liquid Radioactive Waste Systems and Areas

A variety of collection ponds, settling basins, impoundments, and seepage pits and trenches that are associated with past and present liquid waste systems are potential sources of contamination to WOC. The status (active or inactive), approximate capacities, and estimated radionuclide inventory of these facilities are summarized in Tables A.4-A.6. Most of the liquid waste basins are unlined. (The locations of some of these facilities are given in Figs. 4.1 and 4.2).

Low-level waste.[1,8] When ORNL was built an extensive underground piping system was installed to collect LLW (designated as intermediate-level waste in early Laboratory operations), and to transport it to large underground concrete ("gunite") tanks. The waste was treated with caustic to precipitate radionuclides, and the resulting sludges were stored in the tank. The supernatant liquid was decanted, and after dilution with the large volume of process wastewater, it was released to WOC. In June 1944 a settling basin (3513 pond, now inactive) was completed to allow additional time for gravity settling of radioactive solids before discharge of the supernate to WOC. The release of the supernate directly to WOC was discontinued in 1949.

From June 1949 to June 1954 the LLW was concentrated in an evaporator, with the condensate discharged to WOC. The concentrate was stored in the gunite tanks to allow solids to settle. The supernate from the tanks was disposed of in seepage pits and trenches in Melton Valley. The soils acted as an ion exchange medium, inhibiting the migration of soluble radionuclides. Concerns about groundwater contamination led to discontinuing seepage disposal in 1966.

A new waste evaporator went into service in 1965. The disposal of the LLW concentrate by the hydrofracturing process, in which a waste-cement grout mixture was injected into the shale at depths of 210-300 m, was inaugurated in 1966; it continued until 1985. Currently the concentrate is being stored pending review. The evaporator overheads are treated by the process waste treatment plant.

Process wastewater.[1] Process wastewater is water that is slightly or potentially contaminated (steam condensate from heating coils, process cooling water, leakage, and waste from building sinks, floor drains, etc.) In early Laboratory operations, the low-level process water was not chemically treated; it was released to WOC or Melton Branch through equalization basins or holding ponds. A soda-lime treatment plant was placed in operation in 1957. Other, more efficient treatment facilities were put into use in 1976 and again in late 1981. Sludges generated from these facilities were disposed of in the liquid waste seepage pits (1957-76) and in a polyvinyl-chloride-lined basin located at SWSA 5 (1976-81). The flowsheet was changed in 1981 to eliminate sludge formation.

Present wastewater discharges to the WOC watershed are shown schematically in Fig. 2.2. An extensive system (over 30 km) of underground piping is provided to transport process wastewater from the generators to open collection ponds. The flow rate and activity level are monitored at the major branches. The primary collection pond is the equalization basin, which acts as a surge volume to equalize flow to the process waste treatment plant. Currently the waste stream is clarified with anthracite filters and processed through an ion-exchange system for removal of ^{90}Sr and ^{137}Cs before release to WOC. The waste from the regeneration of the ion-exchange bed is sent to the LLW system. The

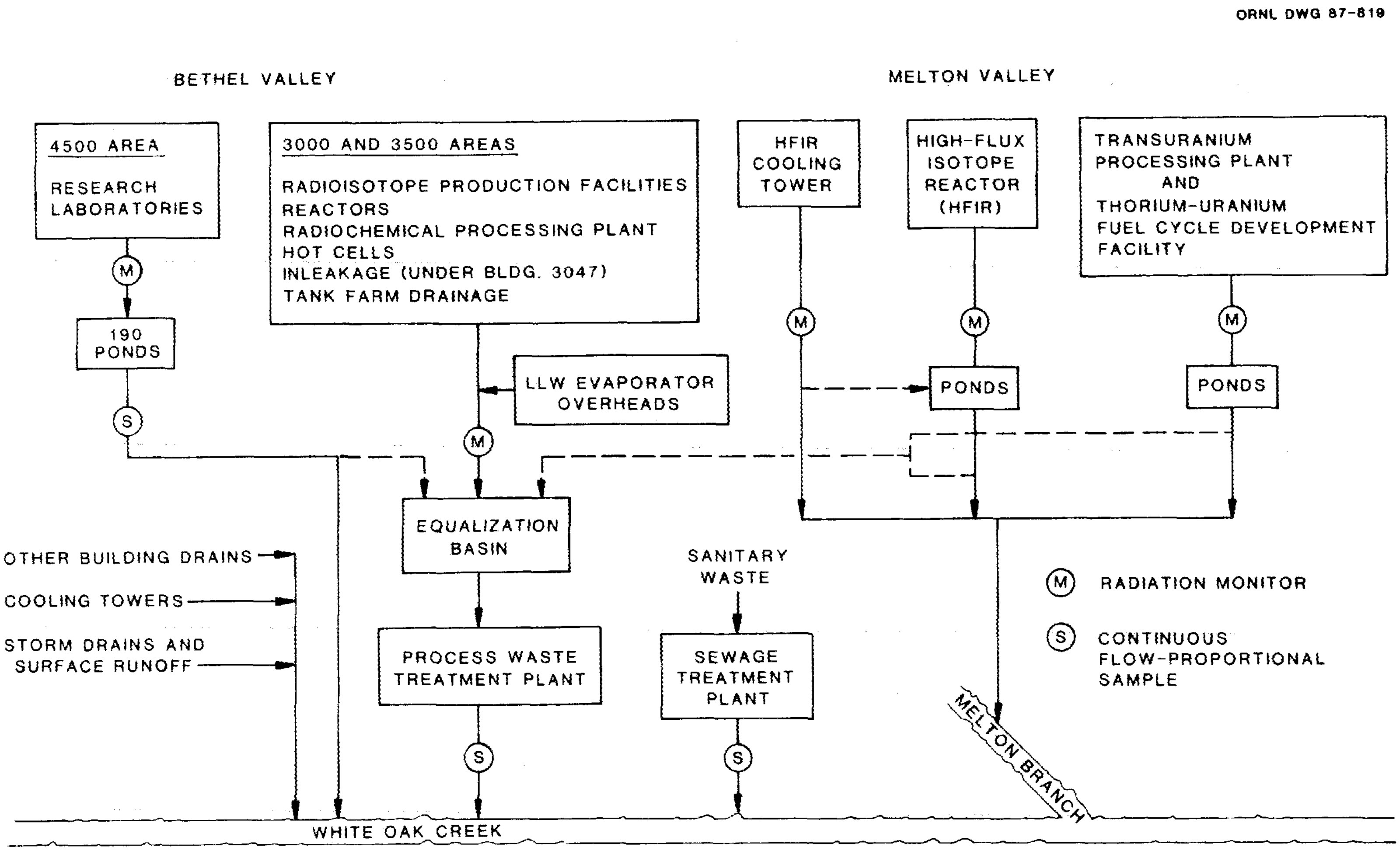

Fig. 2.2. Schematic of ORNL wastewater discharge to White Oak Creek watershed (present).

process wastewater from the 4500 area and the Melton Valley facilities is collected in ponds, monitored for radioactivity, and then discharged directly to the creek if appropriate. If appreciable activity levels are detected, the water is pumped to the process waste treatment plant.

"Intermediate" impoundment. In the spring of 1944 a dam was built across WOC about 2.7 km from the confluence with the Clinch River.[9] In September 1944 the dam was breached by high water, and the pond was greatly reduced in size. A residual pond existed behind the dam until the early 1950s. This contaminated floodplain is part of the SWSA 4 waste management area.

White Oak Lake. White Oak Lake is the final hold-up basin for liquid discharges from ORNL. Oakes et al. estimated that by 1981, 130,000 m^3 of sediment had collected behind the dam, accumulating about 644 Ci of radioactivity.[10] The principal sediment-borne radionuclides are ^{137}Cs (by far the greatest contributor of radioactivity in the lake sediments), ^{60}Co, and ^{90}Sr, with trace amounts of ^{152}Eu, ^{154}Eu, and various transuranics (mainly ^{244}Cm). Sediments now entering the lake are less radioactive than those in the 1940s and 1950s when LLW was discharged directly to WOC.

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10. T. W. Oakes et al., Technical Background Information for the Environmental and Safety Reports, Vol. 4, White Oak Lake and Dam, ORNL-5681, Oak Ridge National Laboratory, Oak Ridge, Tenn., March 1982, p. 2.

3. PRINCIPAL RADIONUCLIDES VIA WATER PATHWAY

Radionuclides were selected as source terms for this study based on the potential off-site doses from current releases at White Oak Dam. The annual radiological discharges to the Clinch River for the period 1976-85 are presented in Table 3.1. There is some variation from year to year due in part to differences in precipitation, affecting the seepage from the burial grounds.

Doses from drinking the water were estimated based on the measured radionuclide concentration in the water discharged at White Oak Dam in 1984 and 1985 (Table 3.2). White Oak Creek (WOC) is not a drinking water source. For the annual environmental monitoring reports, doses are calculated after dilution by the Clinch River.[1] After dilution (assuming complete mixing) the total body dose commitment for drinking Clinch River water at Clinch River kilometer (CRK) 33.3 (the confluence with WOC) was about 0.15 mrem in 1984 and 1985. The dilution varies from year to year (Table 3.3). In 1984 and 1985 the ratio of Clinch River flow to WOC flow was ~300. The long-term average dilution is ~390, based on data by Boyle et al.[2] However, Table 3.2 illustrates the types of doses that might be expected if the concentration factor were applied at White Oak Dam (i.e., at the site boundary). The analysis assumes an intake of 730 L/year (2 L/d) and the dose conversion factors given in Table 3.4.

The major contributors to the effective total body dose from drinking the water are ^{3}H (~70% and ~50% for 1984 and 1985, respectively), and ^{90}Sr (Table 3.2). Strontium-90 is the major contributor to the bone (endosteal cells) dose (the maximum organ dose). Precipitation in the year 1984 was the closest to the average of recent years, and operating releases were relatively stable. The 1985 releases were not typical because (1) the break in the low-level waste (LLW) line servicing Building 3074 and the spill from the ventilation filter pit at Building 3517 resulted in higher-than-normal ^{90}Sr releases from the central ORNL complex and (2) the precipitation was below normal, which reduced seepage from the burial grounds (see Sect. 4).

Table 3.1. Annual releases of radionuclides from White Oak Creek to the Clinch River

	Releases (Ci)						
Year	^{3}H	^{60}Co	^{90}Sr	^{106}Ru	^{131}I	^{137}Cs	TRU
1976[a]	7420	0.9	5[b]	0.2	0.03	0.2	0.01
1977[a]	6250	0.4	3	0.2	0.03	0.2	0.03
1978[a]	6290	0.4	2	0.02	0.04	0.07	0.03
1979[c]	7700	0.9	2.44	0.13	0.06	0.24	0.03
1980[d]	3400	1.4	1.4	<0.01	0.09	0.60	0.040
1981[d]	2900	0.66	1.5	0.1[e]	0.04	0.23	0.043
1982[d]	5400	0.96	2.7	0.2[e]	0.06	1.5	0.034
1983[d]	5600	0.29	2.1	0.18	0.004	1.2	0.048
1984[d]	6400	0.17	2.6	0.28	0.057	0.56	0.028
1985[f]	3700	0.62	3.0	0.01	NA[g]	0.42	0.008

[a]T. W. Oakes and K. E. Shank, Radioactive Waste Disposal Areas and Associated Environmental Surveillance Data at Oak Ridge National Laboratory, ORNL/TM-6893, December 1983, p. 14.

[b]New process waste treatment plant became operational in April 1976. (T. W. Oakes and K. E. Shank, Radioactive Waste Disposal Areas and Associated Environmental Surveillance Data at Oak Ridge National Laboratory, ORNL/TM-6893, December 1979, p. 25.)

[c]Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1979, Y/UB-13, June 2, 1980, p. 36.

[d]Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1984, ORNL-6209, August 1986, p. 26.

[e]W. F. Ohnesorge, Historical Releases of Radioactivity to the Environment from ORNL, ORNL/M-135, May 1986, p. 19.

[f]Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, p. XXIV.

[g]NA = not available.

Table 3.2. Doses from drinking water

Radionuclide	Average concentration in water at White Oak Dam[a,b] (μCi/mL)	Individual dose (mrem)[c] White Oak Dam[d] Effective total-body[f]	Individual dose (mrem)[c] White Oak Dam[d] Bone[g]	Individual dose (mrem)[c] Clinch River km 33.3[e] Effective total-body[f]	Individual dose (mrem)[c] Clinch River km 33.3[e] Bone[g]
		1984			
^{3}H	4.8 E-4	31.5 (70%)	23.0	0.10	0.07
^{60}Co	<1.08 E-8	0.1	0.03	<0.001	<0.001
^{90}Sr	1.7 E-7	10.9 (25%)	106.7 (81%)	0.035	0.34
^{106}Ru	1.8 E-8[h]	0.4	0.1	0.001	<0.001
^{131}I	3.7 E-9	0.2	<0.01	0.001	<0.001
^{137}Cs	2.9 E-8	1.7	1.7	0.005	0.005
	Total	44.8	132	0.14	0.42
		1985			
^{3}H	3.5 E-4	22.9 (51%)	16.8	0.079	0.06
^{60}Co	6.3 E-8	0.5	0.2	0.002	<0.001
^{90}Sr	3.0 E-7	19.2 (43%)	188.3 (91%)	0.066	0.65
^{106}Ru	1.0 E-9[h]	0.02	<0.01	<0.001	<0.001
^{137}Cs	4.2 E-8	2.5	2.5	0.009	0.009
	Total	45.1	208	0.16	0.72

[a]Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, p. 123.

[b]Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1984, ORNL-6209, August 1985, p. 23.

[c]Fifty-year dose commitment. Intake of water, 730 L/year.

[d]White Oak Creek is not a drinking water source.

[e]Calculated based on dilution factors given in Table 3.4 and assuming complete mixing.

[f]Weighted sum dose.

[g]Endosteal cells of the bone.

[h]Estimated from total releases.

Table 3.3. Dilution of White Oak Creek flow by the Clinch River

Year	Average dilution factor[a]
1979	511[b]
1980	1130[c]
1981	371[d]
1982	463[e]
1983	NA[f]
1984	310[g]
1985	290[h]

[a]Ratio of Clinch River to White Oak Creek flow.

[b]*Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities Calendar Year 1979*, Y/UB-13, June 1980, p. 10.

[c]*Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1980*, Y/UB-15, June 10, 1981, p. 9.

[d]*Environmental Monitoring Report, United States Department of Energy Oak Ridge Facilities, Calendar Year 1981*, Y/UB-16, May 1, 1982, p. 10.

[e]*Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1982*, Y/UB-18, May 1, 1983, p. 10.

[f]NA = not available.

[g]*Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1984*, ORNL-6209, August 1983, p. 100.

[h]Estimated from *Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985*, ORNL-6271, April 1986, p. 127.

Table 3.4. Fifty-year committed dose equivalent conversion factors used for drinking water calculations[a]

		Ingestion doses (rem/mCi)	
Nuclide	Fl	Effective dose commitment	Endosteal
^{3}H	9.50E-01	8.98E-05	6.56E-05
^{60}Co	5.00E-02	1.13E-02	3.99E-03
^{90}Sr	2.00E-01	8.75E-02	0.86
^{106}Ru	4.00E-02	2.88E-02	9.57E-03
^{131}I	9.5E-01	5.45E-02	3.32E-04
^{137}Cs	9.50E-01	8.19E-02	7.99E-02

[a]D. E. Dunning, Jr., G. G. Killough, S. R. Bernard, J. C. Pleasant, and P. J. Walsh, Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring in Routine Releases from Fuel Cycle Facilities, Vol. III, NUREG/CR-0150, Vol. 3, October 1981, pp. 59-62, 81.

The ORNL Department of Environmental Management collects and analyzes fish from the Clinch River. The calculated 1985 doses from eating fish (assuming the ingestion of 20 kg of fish flesh in a year) are given in Table 3.5. The highest doses (~1 mrem effective total-body) are for eating fish caught at CRK 33.3 (the confluence with WOC). Cesium-137 contributes 60-90% of the effective total-body dose (varying with the species) and ^{90}Sr most of the remainder. Strontium-90 is the major contributor to the bone dose. The dose conversion factors used for fish calculations are listed in Table 3.6.

Human consumption of 10 kg of carp patties containing the maximum amount of ^{90}Sr (carp caught near the confluence with White Oak Creek) would result in an effective total-body dose equivalent of 0.6 mrem and a dose to the bone (endosteal cells) of 6 mrem (Ref. 3). This is based on the assumption that 10% of the carp patty (prepared by grinding fish flesh and bone) is bone.[3] Strontium-90 is the major contributor to the doses from eating carp patties.

Table 3.5. Doses from consumption of Clinch River fish[a,b]

Location	Fish species	Radionuclide								
		^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu	Total
		Effective total-body dose[c] (mrem)								
Clinch River km 40.0[d]										
	Bass	0.0	0.0029	0.013	0.0035	0.00018	0.0021	0.000079	0.000079	0.022
	Bluegill	0.0	0.0037	0.022	0.011	0.0012	0.0049	0.00015	0.000097	0.043
	Carp	0.0	0.029	0.012	0.0091	0.0020	0.0041	0.000055	0.000018	0.056
Clinch River km 33.3[e]										
	Bass	<0.0053	0.13	1.2	0.0068	0.0012	0.0024	0.000095	0.000044	1.3
	Bluegill	0.0075	0.34	0.64	0.015	0.0019	0.0056	0.000095	0.00014	1.0
	Carp	<0.0033	0.13	0.22	0.005	0.00075	0.003	0.000071	0.00061	0.36
Clinch River km 19.2[f]										
	Bass	<0.0015	0.014	0.1	0.0056	0.00069	0.0034	<0.000063	<0.000062	0.13
	Bluegill	<0.0035	0.051	0.037	0.029	0.0026	0.014	<0.00017	0.00047	0.14
	Carp	<0.0017	0.037	0.029	0.018	0.0015	0.013	0.0001	0.00047	0.1
Clinch River km 16.0										
	Bass	<0.0011	0.013	0.13	0.0043	0.00051	0.0035	0.0021	0.00039	0.16
	Bluegill	0.0044	0.027	0.069	0.011	0.00064	0.0056	0.0011	0.00033	0.12
	Carp	0.017	0.063	0.019	0.0079	0.0008	0.0038	0.00034	0.00015	0.11
Clinch River km 8.0										
	Bass	<0.00086	0.013	0.099	0.0056	0.0011	0.0028	0.0017	0.00073	0.12
	Bluegill	<0.0025	0.068	0.042	0.0096	0.00069	0.0082	0.00013	0.00063	0.13
	Carp	<0.00075	0.077	0.047	0.0079	0.00085	0.0061	0.00037	0.000071	0.14
Clinch River km 3.2										
	Bass	<0.0010	0.00088	0.046	0.0036	0.00075	0.0019	0.000032	0.00078	0.055
	Bluegill	<0.0026	0.088	0.034	0.012	0.0020	0.0061	0.00020	0.000097	0.15
	Carp	<0.00097	0.0071	0.055	0.0056	0.00040	0.0033	0.00051	0.000062	0.073

[a] Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, pp. 62, 63.
[b] Fifty-year dose commitment; intake of fish, 20 kg/year.
[c] Weighted-sum dose.
[d] Melton Hill Lake (i.e. background).
[e] Confluence with White Oak Creek.
[f] Confluence with Poplar Creek.

Table 3.6. Fifty-year committed dose equivalent conversion factors used for fish calculations[a]

Nuclide	Effective dose commitment (mrem/pCi ingested)
^{60}Co	2.7E-5
^{90}Sr	1.4E-4
^{137}Cs	5.0E-5
^{234}U	2.8E-4
^{235}U	2.7E-4
^{238}U	2.5E-4
^{238}Pu	4.0E-3
^{239}Pu	4.4E-3

[a]G. G. Killough and K. F. Echerman, Radiological Assessment, NUREG/CR-3332, 1983.

At the present time, releases of TRU alpha emitters from ORNL are quite small. The plutonium content of Clinch River fish is highest near the confluence with Poplar Creek (Table 3.5), and the source is probably the Y-12 plant.

In summary, the radionuclides that are currently important as source terms via the water pathway for off-site dose calculations are ^{3}H, ^{90}Sr, and ^{137}Cs. The ^{60}Co is a relatively minor contributor to the off-site doses. However, the ^{60}Co in the creek sediments/gravels is of concern in on-site exposure because its high gamma makes it the major contributor to the ground surface exposure of personnel in the creek area.[1]

3.1 REFERENCES

1. K. L. Daniels, Oak Ridge National Laboratory, personal communication to M. B. Sears, June 23, 1986.

2. J. W. Boyle et al., Environmental Analysis of the Operation of Oak Ridge National Laboratory (X-10 Site), ORNL-5870, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 1982, pp. 3-19, 3-20.

3. Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, Oak Ridge National Laboratory, Oak Ridge, Tenn., April 1986, p. 63.

4. RADIONUCLIDE RELEASES FROM VARIOUS WASTE AREAS TO WHITE OAK CREEK

4.1. STRONTIUM-90

Monitoring for ^{90}Sr has been conducted routinely at several stations on White Oak Creek (WOC) and Melton Branch since 1979. The sampling stations are listed in Table 4.1, and the locations are shown in Fig. 4.1.

The average monthly ^{90}Sr releases (averaged over the year) from various waste areas to the WOC drainage are presented in Table 4.2 for the years 1979-85. Also included in Table 4.2 is the average for the period 1979-84. The average precipitation for this period at the NOAA Oak Ridge weather station was 133 cm/year compared with the record mean of 139 cm (Ref. 1). The 1985 releases were not typical because (1) the break in the low-level waste (LLW) line servicing Building 3074 and the spill from the ventilation filter pit at Building 3517 resulted in higher-than-normal releases from the central ORNL complex and (2) the precipitation (119 cm) was below normal, which reduced seepage from the burial grounds. Therefore, the 1985 releases were not included in the averages.

There is a chronic ^{90}Sr release at White Oak Dam of about 2.2 Ci/year averaged over the period 1979-84 (Table 4.3). The principal contributors are undefined Bethel Valley sources, 31%; solid waste storage area (SWSA) 4, 31%; and SWSA 5, 24%. No quantitative data were available for any groundwater pathways that bypass the stream monitoring stations.

More detailed discussion of the sources is presented in Sects. 4.1.1–4.1.6. Tables showing the monthly ^{90}Sr discharges are given in the Appendix, Tables A.7–A.20. The 1985 data are from the Department of Environmental Management (DEM) files, while the 1979-84 data are from Operations Division monthly reports. Monthly reports contain preliminary results, and there may be slight differences between the tables in the Appendix and the final results in Table 4.2. The creek monitoring stations have an accuracy of about ±20% (Ref. 2).

Table 4.1. Listing of surface water monitoring stations monitored routinely for ^{90}Sr, 1979–85

Location	Station code (see Fig. 4.1)
Flume on White Oak Creek near 190 Ponds	Flume
190 Ponds (also called 3539 and 3540 Ponds); holdup and monitoring ponds for 4500 area	190 Ponds
Process waste treatment plant	PWTP
Sewage treatment plant	STP
7500 bridge; the exit from Bethel Valley	7500B
White Oak Creek just above confluence with Melton Branch	WOC
Melton Branch just above confluence with White Oak Creek	MB1
Tributary to 7500 area [Homogeneous Reactor Test (HRT), Nuclear Safety Pilot Plant (NSPP), and Molten Salt Reactor Experiment (MSRE)]	HRT
Upper Melton Branch to 7900 area [High Flux Isotope Reactor (HFIR) and Transuranium Processing Plant (TPP)]	MB2
Liquid waste pits disposal area (closed)	
East weir	East weir
West weir	West weir
White Oak Dam	WOD

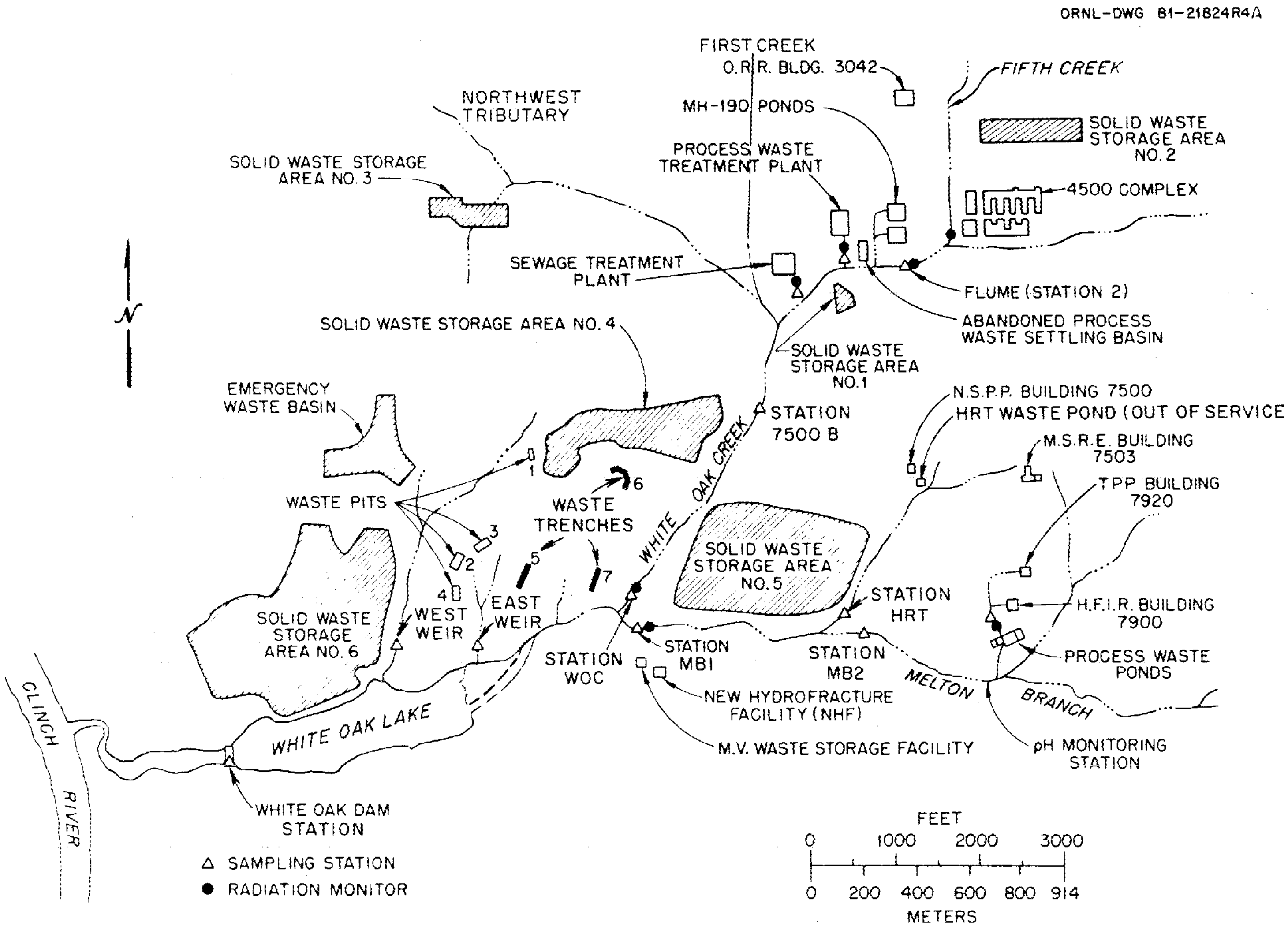

Fig. 4.1. Location map of ORNL waste facilities and sampling stations on White Oak Creek and Melton Branch.

Table 4.2. Average monthly contribution of ^{90}Sr from various ORNL Areas,[a,b] 1979-1985

Area	Discharge (mCi/month)							
	1979	1980	1981	1982	1983	1984	Chronic releases (average 1979-84)	1985[c]
			Measured contributors					
Measured flume	15	10	13	12	10	7.8	11	30
Bethel Valley plant operations	15	19	21	37	21	13	17	38
Measured 190 Ponds	1.0	2.4	0.40	0.20	0.20	0.40	0.8	1.1
Measured Process Waste Treatment Plant (PWTP)	2.9	1.9	2.7	0.50	0.30	0.40	1.4	2.8
Measured Sewage Treatment Plant (STP)	11	15	18	36	20	12	15[d]	34
Measured station 7500B	70	77	72	115	85	72	75[d]	253
Measured station WOC	170	110	100	180	170	110	132[d]	214
Melton Branch facilities	6.8	5.0	3.6	9.9	11	5.7	6.0	4.9
Measured HFIR/TPP	0.20	0.20	0.30	0.90	6.1	0.49	0.4[e]	0.24
Measured HRT/NSPP/MSRE	6.6	4.8	3.3	9.0	4.9	5.2	5.6	4.7
Measured station MB1	67	52	17	50	82	44	52	32
Total pits		6.2	2.0	3.2	3.7	5.2	4.1	2.2
Measured east weir	NA[f]	0.30	1.0	0.10	0.10	0.14	0.3	0.08
Measured west weir	NA	5.9	1.0	3.1	3.6	5.1	3.7	2.1
Total effluents[g] (sum of Station WOC, Station MB1, and pits)	240	170	120	230	260	160	NA	248
Measured White Oak Dam Station	200	125	123	225	208	216	183	250
			Inferred contributors					
Unidentified Bethel Valley sources [7500B minus (flume and plant operations)]	40	48	38	66	54	51	46[d]	185
SWSA 4 (WOC minus 7500B)	99	31	31	63	85	38	58	h
SWSA 5 [MB1 minus (HRT and HFIR/TPP)]	60	47	14	40	71	38	45	27

[a]Does not include underground pathways, if any, which might bypass the stream monitoring stations.
[b]Derived from data in Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, pp. 128-29.
[c]Based on unpublished data in Department of Environmental Management (DEM) files; K. L. Daniels (ORNL), personal communications to M. B. Sears, June 23 and 26, 1986. The 1985 data in ref. b apparently were preliminary results.
[d]Does not include 1982.
[e]Does not include 1983.
[f]NA = not applicable or not available.
[g]Does not include SWSA 6.
[h]In 1985 the input at the 7500 bridge station exceeded the outflow at the WOC station.

4.1.1 Construction Activities and Unplanned Events

In 1985 two incidents resulted in higher-than-normal ^{90}Sr releases from the main ORNL complex in Bethel Valley. On January 26, elevated levels of ^{90}Sr were detected at White Oak Dam.[3,4] Investigations indicated that a broken LLW transfer line near Building 3074 was a major source of the ^{90}Sr, which infiltrated the sanitary waste lines near Building 3019 and also migrated to WOC. Dye tests revealed that the dominant pathway for liquid movement from the leak site was to Building 3042, where contaminated groundwater is pumped to the process waste system for treatment.[5]

On November 29, a storm drain pipe broke during a heavy rain, flooding a construction pit project at Building 3517.[3,6-8] An ongoing upgrade to a hot-cell ventilation system had exposed a ventilation duct and filter pit and the storm sewer line. Large amounts of water infiltrated the ventilation duct, which was heavily contaminated with ^{90}Sr. Contaminated water overflowed the pit and percolated into the groundwater. Strontium-90 found its way into the storm and sanitary drainage systems in the area and into WOC.

In 1985 the total ^{90}Sr discharges from Bethel Valley as measured at the 7500 bridge station (the WOC exit from Bethel Valley) were 3.0 Ci compared with the norm of 0.9 Ci/year. The 1985 ^{90}Sr releases from undefined (or uncontrolled) Bethel Valley sources were about four times the norm, while the releases in the sewage treatment plant effluent were double the norm (Table 4.3). A more detailed table showing the discharges by month is given in the Appendix (Table A.7). In January and December 1985, the ^{90}Sr outflow at the WOC station was less than one-half the inflow at the 7500 bridge station (Table A.8 and Fig. 4.1). It is inferred that part of the ^{90}Sr released in the spills was in the creek sediments and that it takes time for the stream to cleanse itself.

In 1982, releases were also high for several months from undefined Bethel Valley sources and the sewage treatment plant (Table A.13). There were no known line breaks during this period.[7] It was a wetter season than some in recent years; but 1979 was also a wet year, and releases then were in the normal range (Table A.19). A number of construction projects were under way in the early 1980s in or near contaminated areas[7-9]; these activities might have loosened contaminated dirt or

Table 4.3. Annual contribution of ^{90}Sr from various waste areas to White Oak Creek drainage[a]

Area	^{90}Sr discharge (mCi/year)	
	Chronic releases[b] (average 1979-84)	1985[c]
Bethel Valley		
Process waste treatment plant	17	33
Sewage treatment plant	180[d] (8%)	400
190 Ponds	10	13
Undefined sources		
Upstream of flume	130 (6%)	360
Flume to 7500 bridge	550[e] (25%)	2230
Melton Valley		
HFIR/TPP	5[f]	3
HRT/NSPP/MSRE	70	56
SWSA 4	700 (31%)	NA[g,h]
SWSA 5	540 (24%)	320
Pits and trenches	50	26
SWSA 6	NA	3[i]
Total to White Oak Lake	2250	3000

[a]Does not include groundwater pathways, if any, that might bypass the stream monitoring stations.

[b]Derived from data in Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, pp. 128-129.

[c]Based on data in Department of Environmental Management files; personal communication from K. L. Daniels (ORNL) to M. B. Sears, June 23 and 26, 1986.

[d]Does not include 1982 release, which was 430 mCi.

[e]Does not include 1982 release, which was 790 mCi.

[f]Does not include 1983 release, which was 70 mCi.

[g]NA = not available.

[h]In 1985 the input at the 7500 bridge station exceeded the outflow at the White Oak Creek station. Therefore, it is not possible to estimate SWSA 4 by the difference between these stations.

[i]Estimated from grab samples (see Sect. 4.1.6).

allowed ingress of water into contaminated areas, followed by transport to the creeks.

There will continue to be ongoing construction projects. For example, construction of the piping system for the proposed nonradiological wastewater treatment project may open up contaminated pipe trenches. Also, the plant waste piping system is old, and leaks or breaks are to be expected with increasing frequency. Therefore, additional and unpredictable contributions from construction activities and waste line leaks/breaks or other unplanned events should be added to the chronic releases.

4.1.2 Bethel Valley Plant Operations (Controlled Discharges)

Controlled releases to WOC from Bethel Valley plant operations are the effluents from the process waste treatment plant, the 190 Ponds, and the sewage treatment plant. These facilities discharge to the section of WOC between the flume and the 7500 bridge monitoring stations (Fig. 4.1).

The sanitary sewer system theoretically is a nonradioactive system, but in practice it contributes about 8% of the chronic ^{90}Sr discharges. Potential sources of ^{90}Sr to the sanitary sewer system are water ingress from contaminated pipe trenches, leaking manholes, building floor or laboratory drains, and storm sewers carrying contaminated surface runoff.[7] Much of the sanitary sewer was relined in the summers of 1984 and 1985 in order to reduce the load to the new sewage treatment plant. However, 2000 ft of the sanitary waste line in the most highly contaminated pipe trenches were not relined. The corrective measures were beneficial in reducing the volume of water ingress but may not have much effect on the radioactive contamination.[7]

The process waste treatment plant and the 190 Ponds are relatively small ^{90}Sr sources, contributing about 0.8% and 0.4%, respectively, of the chronic discharges (Table 4.3).

4.1.3 Upstream of the Flume (Includes SWSA 2)

The monitoring station called the flume is located on WOC in the vicinity of the 190 Ponds. (The effluent from these ponds is discharged below the flume.) The chronic ^{90}Sr discharge at the flume is about 6% of the total (Table 4.3). Fifth Creek, the isotopes area, Oak Ridge

Research (ORR), the 4500 area, the transuranium research laboratory, and SWSA 2 lie upstream of the flume. Thirteen building drain pipes with a potential for contamination empty directly to the creek. The pipe trenches in the isotopes area are highly contaminated.[7] The LLW line servicing the isotopes area runs along the creek bank at a relatively short distance from the creek.[7] Storm sewer and building drain pipe trenches discharging to the creek potentially offer migration pathways from the LLW pipe trench to the creek.

The shallow groundwater drainage from SWSA 2 will drain to the flume. Most of the waste in SWSA 2 was exhumed and reburied in SWSA 3, but there is some question whether all the material was removed.[10,11]

4.1.4 Undefined Sources Between the Flume and 7500 Bridge Stations

It is inferred from the stream monitoring data that undefined (or uncontrolled) sources between the flume and the 7500 bridge station contributed about 25% of the total ^{90}Sr releases to the WOC drainage during 1979-84 (Table 4.3). The 7500 bridge station is the creek exit from Bethel Valley. The undefined sources as summarized in Tables 4.2 and 4.3 account for the difference between the measured outflow at the 7500 bridge and the measured inputs from the flume, the sewage treatment plant, the process waste treatment plant, and the 190 Ponds.

The liquid waste treatment facilities and associated collection basins and waste pipelines lie along this stretch of WOC (see Fig. 4.2). Potential sources include seepage from unlined ponds, leaking pipes and tanks, contaminated pipe trenches, potentially contaminated building drains, surface runoff, a contaminated flood plain along the creek, SWSA 1, and SWSA 3. (The locations of SWSAs 1 and 3 are shown on Fig. 4.1.) In Tables 4.2 and 4.3 the undefined sources include the Northwest Tributary (SWSA 3) and First Creek because long-term monitoring data were not available for them. Short-term monitoring data for SWSA 3 and First Creek are discussed in Section 4.1.5.

4.1.5 SWSA 3 and First Creek

Steuber et al. studied the radionuclide release from SWSA 3 through the analysis of surface and ground waters from local drainage areas.[12] The

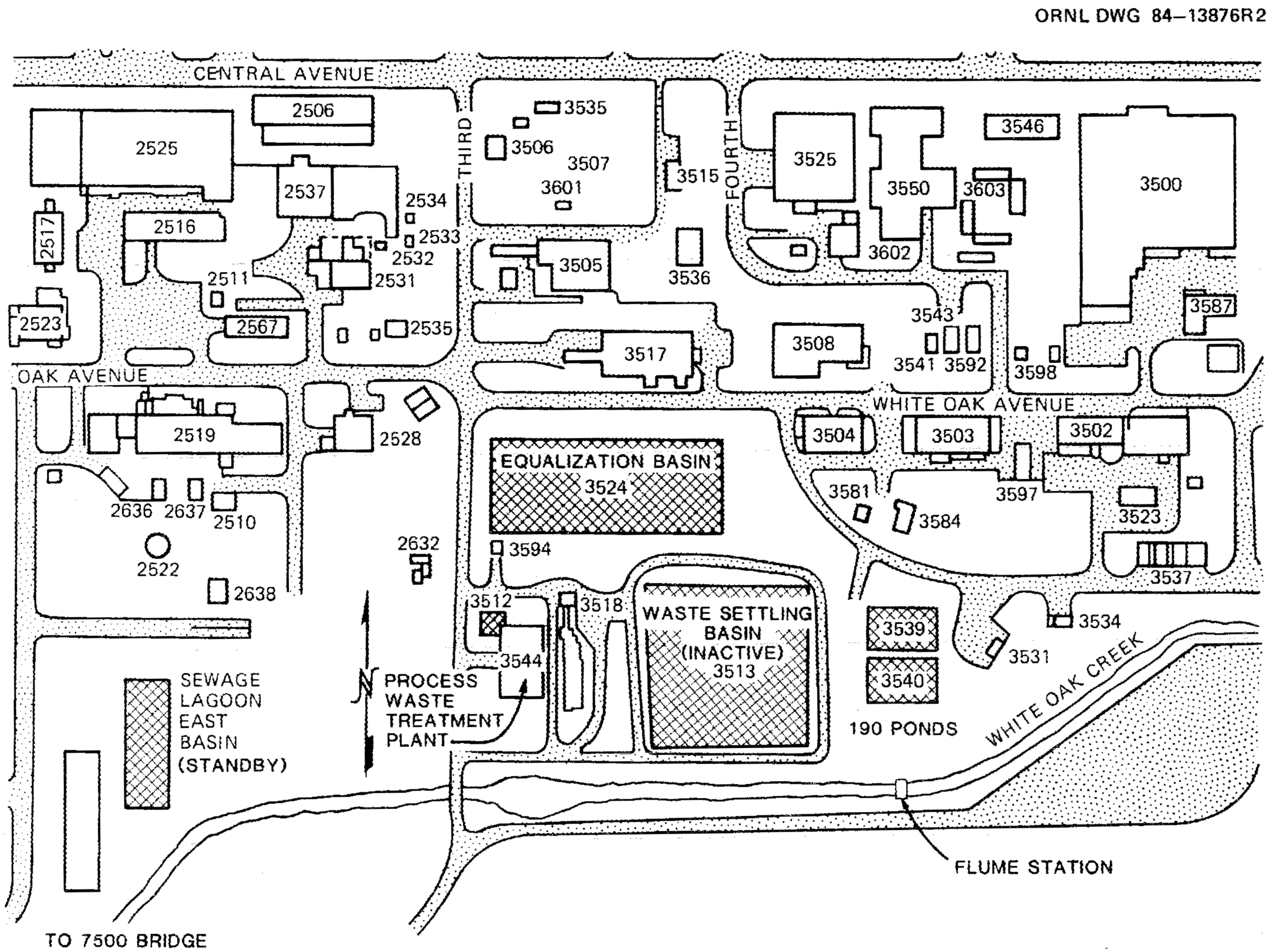

Fig. 4.2. Map showing process ponds in the central ORNL complex.

amount of ^{90}Sr discharged by the Northwest Tributary (including SWSA 3 and First Creek) averaged 6.4 mCi/month for the period September 1978-May 1979. The seepage entered the Northwest Tributary through base flow in a 30-m reach about 350 m from SWSA 3. Grab samples of water collected from First Creek (designated T-1 in the study) by Steuber et al.[12] and studies of stream bed gravels in First Creek in October 1978 and February 1979 by Cerling and Spalding[13] showed that First Creek was not a significant source at that time. The 1978-79 studies were conducted during a period of fairly typical precipitation (Table A.21) and included seasons of both high and low evapotranspiration. Lomenick et al. reported a mean value of 6.6 mCi/month for a five-month period in 1961.[14]

More recently the DEM monitored the Northwest Tributary (above the confluence with First Creek) and First Creek for the period July-November 1985 and found an average discharge of 0.32 and 0.0014 mCi of ^{90}Sr/month respectively (Table A.21).[2] During the July-November season burial ground seepage tends to be low because there is less precipitation and evapotranspiration is at a maximum, reducing the groundwater recharge. It was also preceded by a period of below-normal precipitation (Table 2.1). The discharges measured in the summer of 1985 may not be representative of long-term discharges because of the dry weather. Cerling analyzed gravel samples collected at the seep on the Northwest Tributary and found that the ^{90}Sr activity in the summer of 1985 was about 30% of the level in 1978.[15]

Conservatively assuming 6.4 mCi of ^{90}Sr/month (80 mCi/year), SWSA 3 would contribute 3.6% of the total chronic ^{90}Sr discharges.

The DEM monitored the Northwest Tributary and First Creek for concentration but not for flow during the first quarter of 1986 (Table A.21). The concentrations in First Creek were higher during the first quarter of 1986 than in the summer of 1985: 240-460 vs. 0.8-3 pCi/L (Ref. 2). The concentrations in the Northwest Tributary were about the same in the winter (40-60 pCi/L) as in the summer (20-50 pCi/L) (Ref. 2). Generally the ^{90}Sr concentration at particular stations is relatively constant (within a factor of 2 or 3) and independent of the season of the year and stream (volume) flow.[2] The large increase in the ^{90}Sr concentration in First Creek during early 1986 indicates that there might be a new source.

4.1.6 Melton Valley

4.1.6.1 Drainages from Melton Valley waste areas and locations of monitoring stations

The approximate locations of the waste areas and the permanent sampling stations are shown on Fig. 4.1. More detailed maps showing the topography and surface drainage of the burial grounds are presented in the Appendix (Figs. A.1-A.4). The groundwater drainage from SWSA 4 is into the WOC, which runs near the eastern edge of the burial ground (see Fig. A.1 for surface drainage).[16] The groundwater transport of radionuclides from SWSA 5 is primarily southward towards Melton Branch (see Fig. A.2 for surface drainage), while the drainages from the liquid waste disposal pits and trenches area are southward to White Oak Lake or WOC (see Fig. A.3).[16] There is no significant discharge of ^{90}Sr from the west side of SWSA 5 to WOC.[16,17] The ^{90}Sr (and ^{137}Cs) activity in the Homogeneous Reactor Test (HRT) tributary to the east of SWSA 5 has been traced upstream to the 7500 area.[13] The discharges from SWSA 6 are to the short, ephemeral streams tributary to White Oak Lake or directly to the lake.[16]

The discharges from SWSA 4 are estimated as the difference between the ^{90}Sr flows at the WOC and the 7500 bridge monitoring stations. The SWSA 4 area includes a contaminated flood plain (the old intermediate dam impoundment, Sect. 2.4.2) and the old WOC channel. SWSA 5 is monitored as the Melton Branch 1 (MB1) station minus the HRT and Melton Branch 2 (MB2) stations. The surface water discharges from the eastern and western drainages in the liquid waste pits area are monitored, but the drainage between the liquid waste trenches 5, 6, and 7 and the east side of trench 7 are not monitored. There are no sampling stations for SWSA 6, although some grab samples were taken in 1985.

4.1.6.2 Discharges from Melton Valley waste areas and facilities

SWSAs 4 and 5 are major sources of ^{90}Sr, contributing 31% and 24% of the releases for the period 1979-84 (Table 4.3). A surface water diversion system was constructed at SWSA 4 in late 1983.[17] Monitoring studies in 1984 indicated that the remedial action had reduced the ^{90}Sr flux from the surface tributaries by 47%, with the tributaries (after the diversion) contributing 58% of the total input from SWSA 4 to WOC.[17] This corresponds to a reduction of ~35% in the total flux from SWSA 4. If this trend continues, ^{90}Sr discharges from SWSA 4 would be slightly lower than those from SWSA 5.

The measured surface drainages from the pits area are relatively small contributors—2% of the chronic releases. The drainage between the liquid waste disposal trenches 5, 6, and 7 and the east side of trench 7 are not monitored. Cerling and Spalding estimated the relative importance of various subdrainages to the total discharge based on the ^{90}Sr concentration in the streambed gravels, the sorption characteristics of the gravels, and the area of the subdrainage.[13] They estimated the relative discharges from the trenches area as a factor of ~30 lower than the west seep from the pits area. This would be equivalent to ~0.1% of the total ^{90}Sr discharges at White Oak Dam.

The HRT waste pond (stabilized), the Nuclear Safety Pilot Plant (NSPP), and Molten Salt Reactor Experiment (MSRE) are small sources, collectively contributing 3% of the chronic ^{90}Sr releases. (These facilities are shut down and in the Surplus Facilities Management Program.[18] The HRT pond has been stabilized and capped with asphalt).[19]

The High Flux Isotope Reactor (HFIR) is a minor source of ^{90}Sr (0.2%). The Transuranium Processing Plant (TPP) releases only cooling water to the ponds (for subsequent discharge to Melton Branch).[20]

Flow proportional sampling data are not available for SWSA 6, although some grab samples were taken in 1985 (see Sect. 4.1.6.5).

4.1.6.3 Effect of precipitation on ^{90}Sr discharges

On an annual basis, the ^{90}Sr discharges from the Melton Valley waste areas are related to the precipitation as shown in Table 4.4. The average discharges from SWSA 4, SWSA 5, the pits area, and the HRT branch were respectively 5.5, 4.4, 0.4, and 0.5 mCi/cm of precipitation for the period 1979-84.

As noted earlier, a surface water diversion system was constructed at SWSA 4 in late 1983.[17] Preliminary results indicate that this system will reduce the flux from SWSA 4 by about 35%. If this trend continues, average SWSA 4 discharges would probably be ~3.6 mCi/cm.

Table 4.4. Strontium-90 discharges from Melton Valley waste areas as a function of precipitation

		^{90}Sr discharge							
		SWSA 4		SWSA 5		Pits		HRT/NSPP/MSRE[a]	
Year	Precipitation (cm)	Ci[b]	mCi/cm	Ci[b]	mCi/cm	Ci[b]	mCi/cm	Ci[b]	mCi/cm
1979	170.9[c]	1.19	7.0	0.72	4.2	NA	NA	0.079	0.46
1980	101.9[c]	0.37	3.7	0.56	5.5	0.074	0.73	0.058	0.56
1981	103.5[d]	0.37	3.6	0.17	1.6	0.024	0.23	0.040	0.38
1982	133.5[d]	0.76	5.7	0.48	3.6	0.038	0.29	0.108	0.81
1983	105.8[d]	1.02	9.6	0.85	8.0	0.044	0.42	0.059	0.56
1984	129.2[d]	0.46[e]	3.5[e]	0.46	3.5	0.062	0.48	0.062	0.48
Average	124.1	0.70	5.5 (±1.9)	0.54	4.4 (±1.6)	0.040	0.36 (±0.13)	0.067	0.54 (±0.10)

[a]HRT = Homogeneous Reactor Test, NSPP = Nuclear Safety Pilot Plant, and MSRE = Molten Salt Reactor Experiment.

[b]Derived from data in Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, pp. 128, 129.

[c]NOAA, Oak Ridge weather station; B. Hicks (NOAA), personal communication to M. B. Sears, June 4, 1986.

[d]Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

[e]Surface water diversion system installed in late 1983. (L. A. Melroy and D. D. Huff, Annual Reduction of ^{90}Sr Migration from Solid Waste Storage Area 4 to White Oak Creek by Flow Diversion, ORNL/TM-9620, May 1985, p. 2).

4.1.6.4 Comparison with 1982 environmental analysis

The ^{90}Sr discharges from SWSA 4 for the period 1979-84 were a factor of four lower than those reported in the environmental analysis by Boyle et al.[18] for the period 1962-75 (5.5 vs ~20 mCi/cm of precipitation). The SWSA 4 releases were overestimated in the study by Boyle et al. because some Bethel Valley sources (i.e., the undefined sources between the flume and the 7500 bridge plus the sanitary waste effluent) were not distinguished from SWSA 4. In addition, a surface water diversion system, completed at SWSA 4 in September 1975,[21] would have tended to reduce the ^{90}Sr discharges. The overestimate of SWSA 4 has been noted previously by Steuber et al.,[22] who reported an average of 5 mCi ^{90}Sr/cm precipitation for the five-month period September 1978-January 1979.

Corrective measures were applied at SWSA 5 in the summers of 1975 and 1977.[21,23] Discharges attributed to SWSA 5 (actually Melton Branch watershed) in the Boyle study averaged about 6.7 mCi/cm of precipitation for the water years 1967-76.* About 90% of the flow was estimated to come from SWSA 5 and 10% from the HRT tributary.[18] By comparison the 1979-84 discharges from SWSA 5 and the HRT tributary averaged 4.4 and 0.07 mCi/cm of precipitation, respectively. The 1975-77 remedial measures appear to have reduced the ^{90}Sr discharges from SWSA 5 by about 30%.

4.1.6.5 SWSA 6

The ^{90}Sr discharges from the small surface tributaries in SWSA 6 during 1985 are estimated to be about 3 mCi, or 0.1% of the discharges at White Oak Dam. This estimate is based on limited stream flow (volume) measurements and grab samples assuming that

(1) the discharges from SWSA 6 followed the same pattern as the discharges from the other Melton Valley burial grounds,

(2) the measured flows at SWSA 6 for the period June-October 1985 were 32% of the total flow for the year (by analogy to flows measured at other locations in Melton Valley), and

(3) the concentration was the average of grab samples collected in May 1985, October 1985, January 1986, and March 1986.

*The average does not include 1968, when there was a source other than buried waste.

The concentration and stream flow data for SWSA 6 were collected by E. J. Davis and are summarized in Tables A.22 and A.23.[24] Stream flows for other Melton Valley waste areas are also given in Table A.23 to illustrate the monthly variations throughout the year. In addition to the discharges to the surface drainages, there may be groundwater discharges directly to White Oak Lake that bypass the SWSA 6 gauging stations. Discharges would probably be higher under normal precipitation conditions. Because SWSA 6 is the most recent burial ground, releases may increase with time as the containers corrode, making the waste more accessible to leaching.

4.2 TRITIUM

The tritium (^{3}H) discharges have been monitored at White Oak Dam since 1964.[10] Information about the sources is sparse. It is thought that most of the tritium comes from SWSA 5. Historically, tritium releases were low until the mid 60s (Table 4.5). Starting in 1967, a dramatic increase in the quantity of tritium was observed in the creek. This increase was investigated, and the evidence indicated that the tritium originated in shipments of material received from Mound Laboratory before 1967.[18] The waste material was disposed of in SWSA 5.[18] Mound Laboratory did work on the hydrogen bomb and would have generated tritium-bearing wastes.[25] Two shipments were reportedly received from "Site M" in Dayton (Mound Laboratory is near Dayton) in 1945 for burial, followed by virtually weekly shipments from a source in that city during the late 1940s.[26] Thus, there is a possibility of tritium waste in SWSAs 3 and 4.

Tritium discharges at White Oak Dam remained high until 1976, when they decreased to about the levels observed today (still relatively high; see Table 4.5). For the period 1976-85 they have held constant at about 43 Ci/cm of precipitation.

The reduction (~40%) in the tritium discharges was probably the result of corrective measures at SWSA 5. In the summer of 1975 vertical dams were installed in two trenches, and a polyvinyl membrane was placed over four trenches.[21] Additional work was done at SWSA 5 in 1977.[23] A near-surface seal consisting of a bentonite-shale mixture was placed

Table 4.5. Tritium releases at White Oak Dam as a functions of precipitation, 1964-1975

Year	Precipitation (cm)	^3H release: Ci[a]	^3H release: Ci per cm precipitation	
1964	127[b]	1,930	15	
1965	122[b]	1,160	10	
1966	120[b]	3,090	26	
1967	175[b]	13,270	76	76 (±11), average (1967–1975)
1968	101[b]	9,680	96	
1969	126[b]	12,250	97	
1970	133[b]	9,470	71	
1971	135[b]	8,940	66	
1972	165[b]	10,600	64	
1973	183[c]	15,000	82	
1974	151[c]	8,630	57	
1975	151[c]	11,060	73	
	After corrective measures at SWSA 5			
1976	136[c]	7,420	54	43 (±7), average (1976–1985)
1977	154[c]	6,250	41	
1978	136[c]	6,290	46	
1979	171[b]	7,700[d]	45	
1980	102[b]	3,400[e]	33	
1981	104[f]	2,900[e]	28	
1982	134[f]	5,400[e]	44	
1983	106[f]	5,600[e]	53	
1984	129[f]	6,400[e]	50	
1985	101[f]	3,700[g]	37	

[a]T. W. Oakes and K. E. Shank, Radioactive Waste Disposal Areas and Associated Environmental Surveillance Data at Oak Ridge National Laboratory, ORNL/TM-6893, December 1983, p. 14.

[b]National Oceanic and Atmospheric Administration (NOAA), Oak Ridge weather station; B. Hicks, personal comunication to M. B. Sears, June 4, 1986.

[c]ORNL steam plant data; V. T. Carmony (ORNL), personal communication to M. B. Sears, July 1, 1986.

[d]Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1979, Y-UB-13, June 2, 1980, p. 36.

[e]Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1984, ORNL-6209, August 1985, p. 26.

[f]Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

[g]Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, p. XXIV.

over 14 trenches, and other corrective measures were taken (filling of collapsed trenches, installation of concrete drainage ditches, surface contouring for better drainage, etc.).[23] Remedial measures were also taken at SWSA 4 in 1975.[21]

Limited stream monitoring data exist for tritium at the WOC and Melton Branch 1 stations (Table 4.6). In 1972-73 (before corrective measures), 90-95% of the tritium was found in Melton Branch.[18] More recent monitoring by DEM revealed that Melton Branch contributed 60% of the tritium in 1985 and 91% in the first quarter of 1986 (Table 4.6).[2] There apparently was a Bethel Valley source (or sources) during the first half of 1985 that was not present the last half of the year or

Table 4.6. Tritium discharge to streams[a]

Period	^{3}H discharge (Ci)	
	Melton Branch (SWSA 5)	White Oak Creek (SWSA 4 plus Bethel Valley)
1972[b]	9,450 (90% of known discharge)	1,060
1973[b]	14,250 (95% of known discharge)	750
1985[c]	2,570 (62% of known discharge)	1,560[d]
January-March 1986[c]	1,400 (91% of known discharge)	120[e]

[a]No discharge data for SWSA 6 or pits and trenches.

[b]J. W. Boyle et al., <u>Environmental Analysis of the Operation of the Oak Ridge National Laboratory (X-10 Site)</u>, ORNL-5870, November 1982, p. 3-45.

[c]Based on data in DEM files; person communications from K. L. Daniels (ORNL) to M. B. Sears, June 23 and 26, 1986.

[d]Appears to have been Bethel Valley source(s) during first one-half of 1985; tritium releases during January-March 1985 were a factor of 10 higher than first-quarter 1986 discharges.

[e]SWSA 4 contributed 8–9%; Bethel Valley contributed 0–1%.

during early 1986 (Table A.24). Discharges at the WOC station for January-March 1985 were a factor of 10 higher than those during the first quarter of 1986, when the 7500 bridge station (the exit from Bethel Valley) was monitored for tritium and found to be near background.[2] In the first quarter of 1986, 91% of the tritium was from Melton Branch, 8-9% from SWSA 4, and 0-1% from Bethel Valley. (The 7500 bridge station was not monitored for tritium in 1985.)

The estimated tritium discharge from HFIR to the ponds (which discharge to Melton Branch) is about 31 Ci/year based on the analysis of the pool water and estimated flows.[27*] This discharge is insignificant compared with the 2600 Ci discharged from Melton Branch in 1985. The TPP facility discharges only cooling tower water to the ponds.[20] TPP handles an estimated 12 Ci of tritium per year, with the waste discharged to either the process waste system or the stack.[20] No information on tritium is available for the HRT branch.

A summary of groundwater monitoring data for tritium around the SWSAs is presented in Tables 4.7 and 4.8 for 1984 and 1985. The groundwater monitoring data show that the tritium levels are much higher in SWSA 5 than in the other burial grounds and that there is a greater potential for tritium releases from SWSA 5. However, the discharge to the creek depends also upon the flow (volume) rate, which is unknown.

SWSAs 1, 2, and 3 are probably minor tritium sources, because tritium concentrations at the 7500 bridge station (exit from Bethel Valley) were only slightly above background during the period January-March 1986.[2] The Northwest Tributary (SWSA 3) and First Creek were monitored for tritium during the period July-November 1985 and found to be background.[2]

The tritium discharge from the small surface tributaries in SWSA 6 during 1985 is estimated as about 60 mCi, or 1.5% of the known input to the WOC watershed. The assumptions were given in Sect. 4.1.6.5 (see also Tables A.22 and A.23). This estimate does not include any groundwater discharges direct to White Oak Lake, bypassing the weirs. Discharges

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*Assumptions: Concentration of tritium in HFIR storage pool water, $2 \times 10^{+6}$ Bq/L (54 μCi/L); discharge 10,000 gal (38,000 L) per shutdown; 15 cycles per year.[27]

Table 4.7. 1984 groundwater monitoring of radionuclides around ORNL solid waste storage areas[a]

Analysis	No. of samples	Concentration (10^{-8} Ci/mL)[b] Max	Min	Av
		Solid Waste Storage Area 4		
^{60}Co	17	6.2	<0.22	<1.5
^{137}Cs	26	270	0.76	32
Gross alpha	10	68	0.27	15
^{3}H	24	170,000	590	28,000
^{90}Sr	27	4,100	12	1,100
		Solid Waste Storage Area 5		
^{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
^{3}H	49	34,000,000	1,800	4,700,000
^{90}Sr	50	220,000	0.49	5,500
		Solid Waste Storage Area 6		
^{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
^{3}H	11	3,900	<81	<1,300
^{90}Sr	12	470	1.9	140
		Pits and trenches		
^{60}Co	36	2,600	0.41	410
^{137}Cs	36	130	0.57	16
Gross alpha	15	410	0.27	62
^{3}H	34	25,000	570	10,000
^{90}Sr	35	230	0.43	29
		Reference wells		
^{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
^{3}H	10	360	<81	<220
^{90}Sr	10	35	1.0	13

[a] *Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1984*, ORNL-6209, August 1985, p. 71.

[b] To convert from 10^{-8} Ci/mL to 10^{-4} Bq/mL, multiply value in table by 3.7.

Table 4.8. 1985 groundwater monitoring of radionuclides around ORNL solid waste storage areas[a]

Analysis	No. of samples	Concentration (10^{-8} µCi/mL)[b] Max	Min	Av
		Solid Waste Storage Area 4		
^{60}Co	8	0.54	<0.27	<0.49
^{137}Cs	8	2.3	<0.27	<0.82
Gross alpha	8	170	2.7	32
^{3}H	8	200,000	1,100	34,000
^{90}Sr	8	2,500	30	660
		Solid Waste Storage Area 5		
^{60}Co	11	3.0	<0.27	<0.80
^{137}Cs	11	2.7	<0.27	<0.97
Gross alpha	11	95	<1.1	<21
^{3}H	11	7,300,000	2,000	2,000,000
^{90}Sr	11	1,400	1.8	480
		Solid Waste Storage Area 6		
^{60}Co	6	0.54	<0.27	<0.50
^{137}Cs	6	1.6	<0.27	<0.58
Gross alpha	6	5.4	<1.4	<3.7
^{3}H	6	6,200	190	2,100
^{90}Sr	6	8.4	0.35	2.3
		Pits and trenches		
^{60}Co	8	2,000	<0.54	<580
^{137}Cs	8	3.2	<0.27	<1.8
Gross alpha	8	130	0.54	33
^{3}H	8	14,000	2,200	8,600
^{90}Sr	8	12	0.22	3.2
		Reference wells		
^{60}Co	4	0.54	<0.54	<0.54
^{137}Cs	4	1.1	<0.27	<0.58
Gross alpha	4	6.2	1.6	3.5
^{3}H	4	250	120	170
^{90}Sr	4	3.2	0.19	1.4

[a]*Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985*, ORNL-6271, April 1986, p. 168.

[b]To convert from 10^{-8} µCi/mL to 10^{-4} Bq/mL, multiply value in table by 3.7.

would probably be higher under normal precipitation conditions. Because SWSA 6 is the most recent burial ground, releases might increase with time as containers corrode, making the waste more accessible to leaching.

No data are available on tritium discharges from the pits area. The groundwater monitoring data suggest that the pits and trenches are probably small contributors compared with SWSA 5, but stream data are needed for confirmation.

Tritium is the major contributor to the drinking water total-body dose. For planning purposes the conservative approach would be to assume 90% of the tritium from SWSA 5 and 10% from SWSA 4, and to watch the Bethel Valley sources, the pits and trenches, and SWSA 6. The HRT tributary should also be checked. It is recommended that additional monitoring data for tritium be acquired.

4.3 CESIUM-137 AND COBALT-60

Discharges of ^{137}Cs and ^{60}Co from several sources to the WOC drainage in 1985 are presented in Tables 4.9, A.25, and A.26. Quantitative data were not available for some of the waste areas. While the major sources are known, both longer term monitoring and more sampling points are needed to draw a material balance.

The major source of ^{137}Cs (of sources monitored) was the process waste treatment plant effluent. This finding is in agreement with conclusions in Cerling's studies of streambed gravels.[15] The Melton Branch facilities (SWSA 5, HFIR, HRT, etc.) collectively contributed less than 1% of the ^{137}Cs discharges. The Northwest Tributary (SWSA 3) and First Creek were monitored for ^{137}Cs in the creek water during the period July 1985-March 1986 and found to be below the analytical limit of detection.[2] Cerling found that the ^{137}Cs levels in streambed gravels upstream of the flume were essentially background in the summer of 1985.[15] The low levels of ^{137}Cs in the groundwater around the SWSAs and pits and trenches indicate that these are relatively small sources (Tables 4.7 and 4.8). Studies of the streambed gravels in 1978 also showed that the small subdrainages from the Melton Valley waste areas are of low concern for ^{137}Cs compared with the contamination from Bethel Valley sources.[13]

Table 4.9. Discharges of ^{137}Cs and ^{60}Co from various waste areas to White Oak Creek drainage in 1985[a]

Area	Discharge (mCi)	
	^{137}Cs[b]	^{60}Co[c]
Bethel Valley		
Process waste treatment plant	1090	240
Sewage treatment plant	4	2
190 Ponds	14	3
Undefined sources	NA[d]	NA
White Oak Creek (Bethel Valley and SWSA 4)	690	210
Melton Branch	5	140
Pits and trenches	NA	NA
SWSA 6	NA	NA
White Oak Dam	250	260[e]

[a]Based on data in Department of Environmental Management files; personal communications from K. L. Daniels (ORNL) to M. B. Sears, June 23 and 26, 1986.

[b]January-November 1985; data not available for December.

[c]January-December 1985.

[d]NA = not available.

[e]Does not include data for the ninth week of 1985 (last week of February), which are thought to be in error; reported value for the ninth week was 375 mCi.

Much of the ^{137}Cs is adsorbed by the stream sediments and moves with the sediments, in contrast to ^{90}Sr, which moves mainly in solution.[28] An estimated 60% of the ^{137}Cs inflow to White Oak Lake was retained in the settling basin during 1985. This is consistent with studies conducted by Struxness et al.[29] in the early 1960s, showing that 69% of the ^{137}Cs in the WOC system moved with the sediments (2% for ^{90}Sr and 19% for ^{60}Co). The ^{137}Cs discharges from the process waste treatment plant were unusually high during August and September 1985 (~50% of the total for the year), and the input to WOC exceeded the outflow at the WOC station during the period August-November (Table A.25). It is inferred that the ^{137}Cs is in the sediments and that it takes time for the stream to cleanse itself.

In the monitored streams, the process waste treatment plant effluent contributed about 60% and Melton Branch sources about 40% of the ^{60}Co (Tables 4.9 and A.26). These percentages differ from those in studies of the streambed gravels by Cerling and Spalding, who rated Melton Branch at 75% (with HFIR the major source) in 1978,[13] and qualitatively still the major source in 1985.[15] The ^{60}Co discharges from HFIR are probably in the form of insoluble fine particulates (i.e., corrosion products of neutron activated stainless steel), while the ^{60}Co in the process waste treatment plant effluent is probably in solution, since the plant has filters. Northwest Tributary (SWSA 3) and First Creek were monitored for ^{60}Co in the creek water during the period July 1985-March 1986 and found to be below the limit of detection.[2] In the summer of 1985, the ^{60}Co levels in streambed gravels upstream of the flume were essentially background.[15] Both the groundwater and the gravel monitoring data indicate that SWSAs 4 and 5 are relatively minor sources of ^{60}Co compared with other sources of contamination (Tables 4.7 and 4.8, and Refs. 13 and 15). However, there may be small discharges from the pits and trenches area.

During periods of heavy rain essentially all the ^{137}Cs and part of the ^{60}Co that moves out of the WOC-White Oak Lake system moves with the sediments.[28] There has been some question as to whether the accumulated sediments at the bottom of White Oak Lake might be an active source during high flow conditions. The heaviest 24-hour precipitation during 1985 occurred on August 16: 101 mm at the Engineered Test Facility station (SWSA 6), followed by 38 mm the following day. The known inputs to White Oak Lake exceeded the outflow at the dam; that is, White Oak Lake functioned as a settling basin (Table 4.10). For this particular storm White Oak Lake itself did not appear to be an active source when compared with the sources feeding into the lake. However, the 30-year accumulation of contaminated sediments in White Oak Lake is a potential source that should be addressed in the decommissioning plan.

Table 4.10. Discharge of ^{137}Cs and ^{60}Co during storm in August 1985[a]

	Discharge (mCi)			
	^{137}Cs		^{60}Co	
Area	Week 33[a]	Week 34[b]	Week 33	Week 34
White Oak Creek	10.8	70.5	3.0	8.5
Melton Branch	0.8	0.4	10.7	6.7
Sum (known input to White Oak Lake)	11.6	70.9	13.7	15.2
White Oak Dam	2.9	13.7	3.6	4.8

[a]Based on data in DEM files; personal communications from K. L. Daniels (ORNL) to M. B. Sears, June 23 and 26, 1986.

[b]Storm occurred during the 33rd week of 1985.

[c]Stream flow peaked at White Oak Dam during the 34th week of 1985.

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5. EVALUATION AND RECOMMENDATIONS

A search was made for information that could be used to develop source terms for the dose calculations by waste management sites or areas. A relatively extensive data base exists for ^{90}Sr, although data are given primarily by area rather than for individual sites. Source term data for ^{3}H, ^{137}Cs, and ^{60}Co by waste management area are limited. Additional source term data are needed before the dose calculations by individual sites can be made.

A qualitative assessment, based on the available information, was made for preliminary planning purposes. The waste management areas were evaluated in terms of currently active discharges of environmentally significant nuclides to surface streams. Of the known discharges, the undefined (uncontrolled) sources in the central Bethel Valley site, SWSA 5, SWSA 4, and the process waste treatment plant effluent are the major contributors to the off-site doses via aquatic pathways (Table 5.1). SWSA 6 bears watching. While SWSA 6 appeared to be a small source in 1985, discharges might be higher under normal precipitation conditions. Also, because it is the most recent burial ground, leaching might increase with time. SWSAs 2 and 3, the HRT ponds, the HFIR ponds and the TPP ponds are lower priority from the perspective of off-site dose to the general public. The limited data available indicate that the accumulated sediments at the bottom of White Oak Lake are probably not an active source when compared with the sources feeding into the lake. However, the accumulated sediments are a potential source that should be addressed in any decommissioning plan.

At the present time, releases of TRU alpha emitters from ORNL are quite small. The plutonium content of Clinch River fish is highest near the confluence with Poplar Creek (Table 3.5); the source is probably the Y-12 plant.

Additional monitoring data should be acquired for both surface water transport and ground water migration.

Table 5.1. Priority areas for remedial investigation

Ranking	Waste management area	Criteria[a]	Objective of remedial action
1a	Central Bethel Valley site, unidentified sources	Contribute ~27-31% of chronic ^{90}Sr discharges (~30-mrem bone dose from drinking water)	Reduce bone dose
	Construction activities, line breaks, etc.	In 1985, Bethel Valley site discharges increased by a factor of 3 and caused ORNL to be in non-compliance	Ensure regulatory compliance; and that doses are "as low as reasonably achievable" (ALARA)
1b	SWSA 5	Contributes ~60-90% of ^{3}H and ~24% of the ^{90}Sr (~22- to 31-mrem total body and ~39- to 46-mrem bone dose from drinking water)	Reduce total body dose from drinking water; reduce bone dose
2a	SWSA 4	Contributes ~31% of ^{90}Sr and ~10% of ^{3}H (~7-mrem total body and ~35-mrem bone dose from drinking water)	Reduce bone dose
2b	Process waste treatment plant	Contributes most of ^{137}Cs and about one-half the ^{60}Co	Reduce total body dose from eating Clinch River fish

[a]Dose estimates are for drinking the water at White Oak Dam; they assume the 1984 discharges and distribution factors defined above.

6. ACKNOWLEDGMENTS

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APPENDIX

DETAILED TABLES AND FIGURES

Table A.1. Monthly precipitation at ORNL and NOAA townsite stations, 1972-1979[a,b]

Station location	Precipitation (cm)												
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
						1972							
ORNL	c	c	19.71	6.83	11.00	10.39	15.39	10.41	10.57	13.41	9.17	26.82	c
NOAA	18.59	12.27	15.21	7.47	14.76	14.12	13.26	4.50	10.87	17.65	12.75	23.37	164.82
						1973							
ORNL	10.13	10.29	29.08	13.26	22.96	8.36	17.73	3.87	7.65	9.75	25.04	24.42	182.58
NOAA	10.69	8.69	29.03	14.38	26.49	17.63	14.07	5.72	8.66	8.53	27.38	22.61	193.88
						1974							
ORNL	24.18	13.61	18.26	10.49	16.92	11.76	2.31	14.48	6.93	4.70	12.93	14.25	150.82
NOAA	24.43	11.99	18.34	9.60	20.27	5.08	5.05	10.95	10.62	4.52	12.80	12.60	146.25
						1975							
ORNL	13.41	15.21	30.07	7.11	13.06	12.70	2.77	5.05	15.75	13.46	8.10	14.48	151.18
NOAA	14.94	15.01	31.09	5.99	10.21	14.22	7.32	6.78	14.71	14.10	8.69	11.07	154.13
						1976							
ORNL	16.28	9.12	15.90	2.46	18.19	11.91	12.47	6.91	10.36	14.12	7.21	11.33	136.27
NOAA	13.89	6.60	15.24	2.24	18.39	12.19	10.24	12.42	11.58	15.01	5.77	11.89	135.46
						1977							
ORNL	6.07	7.32	15.29	20.47	7.03	20.29	6.71	9.55	20.68	12.50	20.98	7.24	154.13
NOAA	6.40	4.80	13.77	21.59	4.24	16.97	10.44	11.17	22.02	12.62	23.16	12.24	159.44
						1978							
ORNL	16.43	3.84	11.76	7.06	12.27	11.76	16.71	20.55	5.56	1.14	13.92	14.71	135.69
NOAA	15.21	2.87	11.91	8.15	11.43	10.08	12.42	14.60	4.32	0.99	14.07	16.89	122.96
						1979							
ORNL	15.44	12.90	10.74	14.09	d	d	d	10.92	10.77	6.15	15.11	6.02	d
NOAA	19.30	10.92	12.73	13.33	23.67	9.47	32.82	13.94	9.50	4.90	14.66	5.69	170.94

[a]ORNL steam plant (Building 2519) station located at the central Bethel Valley site; data from V. T. Carmony (ORNL), personal communication to M. B. Sears, July 1, 1986.

[b]NOAA station located at Oak Ridge townsite; data from B. Hicks (NOAA), personal communication to M. B. Sears, June 4, 1986.

[c]Gauging station not in operation until March 1972.

[d]Records missing and presumed lost.

Table A.2. Monthly precipitation at ORNL and NOAA townsite stations, 1980–April 1986[a,c]

Station location	Precipitation (cm)												
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1980													
ORNL	9.50	4.42	19.86	10.54	8.81	1.07	2.29	2.79	6.32	2.72	5.44	4.32	78.08[d]
SWSA 6	e	e	e	e	e	e	e	3.25[e]	6.87	4.63	10.16	4.35	e
NOAA	15.85	3.84	23.37	9.89	7.64	2.16	6.07	5.26	8.41	2.74	11.56	5.13	101.90
1981													
ORNL	1.71	8.00	7.11	8.33	7.47	13.64	5.11	9.19	11.71	9.86	8.41	10.85	101.40
SWSA 6	2.21	11.93	7.34	9.37	10.85	12.23	7.40	7.55	7.10	9.35	7.92	10.24	103.49
NOAA	2.36	11.91	9.12	11.63	6.73	11.43	6.15	7.99	9.91	12.42	8.13	10.46	108.15
1982													
ORNL	12.93	13.74	16.18	6.93	6.68	10.59	16.31	13.03	4.50	6.45	23.65	20.37	151.36
SWSA 6	16.28	13.09	16.26	6.44	6.07	7.04	13.80	9.24	6.36	6.14	15.08	17.73	133.53
NOAA	17.07	13.77	15.75	7.09	7.32	5.46	17.80	11.71	13.59	4.95	19.84	18.34	152.53
1983													
ORNL	4.60	9.47	5.92	16.97	16.21	5.28	8.33	2.74	4.72	14.96	15.04	18.03	122.28
SWSA 6	3.93	10.33	5.41	11.43	13.21	5.39	4.80	2.92	4.48	11.64	13.73	18.48	105.75
NOAA	4.44	11.13	6.53	16.26	17.53	6.43	6.12	3.25	5.26	11.63	14.86	17.65	121.08
1984[f]													
SWSA 6	6.13	9.22	11.33	9.54	27.21	9.18	18.06	4.32	2.03	15.62	11.30	5.27	129.21
NOAA	6.65	9.96	12.22	10.57	27.18	11.94	22.15	4.75	4.75	15.72	11.10	6.58	143.56
1985													
ORNL	7.67	9.83	6.50	5.66	5.74	12.07	12.73	25.45	3.23	5.41	11.61	4.85	110.74
SWSA 6	5.65	7.94	3.68	4.32	5.97	13.27	10.09	23.05	4.25	7.56	10.16	5.27	101.21
NOAA	7.32	9.47	6.60	5.66	9.73	12.90	16.33	21.49	4.72	7.82	11.40	5.36	118.82
1986													
ORNL	3.38	14.58	6.76	4.55									
SWSA 6	3.11	10.35	7.17	5.14									

[a]ORNL steam plant (Building 2519) station located at the central Bethel Valley site; data from V. T. Carmony (ORNL), personal communication to M. B. Sears, July 1, 1986.

[b]Engineered Test Facility station located in SWSA 6, Melton Valley; data from E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

[c]NOAA station located at Oak Ridge townsite; data from B. Hicks (NOAA), personal communication to M. B. Sears, June 4, 1986.

[d]Value appears low relative to NOAA data.

[e]Station at SWSA 6 was not in operation until Aug. 10, 1980.

[f]ORNL steam plant records for 1984 were not readily available at the time of this study.

Table A.3. Summary of solid waste storage areas[a]

Site	Location[b,c]	Type of waste or facility	Service dates	Approximate capacity (ha)	Estimated radionuclide inventory[c] (Ci)
SWSA 1	2624 (Bethel Valley)	Solid LLW	1943–44	0.6	4.3×10^3
SWSA 2	4003 (Bethel Valley)	Solid LLW	1944–46	Waste removed[d]	<10
SWSA 3	1001 (Bethel Valley)	Solid LLW	1946–51	2.8	5×10^4
SWSA 4	7800 (Melton Valley)	Solid LLW	1951–59	9.3	1.1×10^5
SWSA 5	7802 (Melton Valley)	Solid LLW Retrievable storage of transuranic waste	1959–73[e] 1970–present	14.2	2.1×10^5
SWSA 6	7822 (Melton Valley)	Solid LLW	1969–present	6.1	2.5×10^5

[a]Sources: T. W. Oakes and K. E. Shank, Radioactive Waste Disposal Areas and Associated Environmental Surveillance Data at Oak Ridge National Laboratory, ORNL/TM-6893, December 1979. J. O. Duguid, Status Report on Radioactivity Movement from Burial Grounds in Melton and Bethel Valleys, ORNL-5017, July 1955. C. E. Nix et al. (ORNL), personal communication, March 1986.

[b]Map showing locations given in Fig. 4.1.

[c]Numbers refer to designations in ORNL Building Directory, 1985.

[d]Waste was removed in 1946–1949 and reburied in SWSA 3, but there is some question whether all the waste was removed.

[e]Closed to trench burials in 1973.

Table A.4. Summary of liquid waste seepage pits and trenches[a]

Site	Location[b]	Type of waste or facility	Service dates	Quantity disposed (L)	Estimated radionuclide inventory
Waste pit 1	7805 (Melton Valley)	Liquid LLW Decontamination waste	1951 1962-64	4.5×10^4	600 Ci
Waste pits 2-4	7806-7808 (Melton Valley)	Liquid LLW	1952-76[c]	9.1×10^7	4.8×10^5 Ci
Waste trench 5	7809 (Melton Valley)	Liquid LLW	1960-66	3.6×10^7	3.1×10^5 Ci
Waste trench 6	7890 (Melton Valley)	Liquid LLW	1961	4.9×10^5	850 Ci
Waste trench 7	7818 (Melton Valley)	Liquid LLW	1962-66	3.2×10^7	2.7×10^5 Ci
Homogenous Reactor Experiment (HRE) fuel wells	7809 (Melton Valley)	Liquid sulfuric acid solution containing uranium		510	4652 g U; <20 Ci ^{90}Sr, ^{106}Ru

[a]Sources: B. P. Spalding and W. J. Boegly, Jr. (ORNL), personal communication, September 1985. J. O. Duguid, Status Report on Radioactivity Movement from Burial Grounds in Melton and Bethel Valleys, ORNL-5017, July 1955. C. E. Nix et al. (ORNL), personal communication, March 1986.

[b]Map showing locations given in Fig. 4.1.

[c]Taken out of service for disposal of LLW liquid in 1962, but Pit 4 used for disposal of sludge from the process waste treatment plant until 1976.

Table A.5. Summary of process ponds in Bethel Valley[a,b]

Site	Location	Status	Type of waste or facility	Service dates	Approximate capacity (L)	Estimated radionuclide inventory (Ci)
Equalization basin	3524	Active	Collection basin and surge volume for feed to process waste treatment plant	1945–present	3.8×10^6	150
190 Ponds (2)	3539,3540	Active	Collection of process wastewater from 4500 area	1964–present	5.7×10^6 each	<10
Sewage lagoon east basin	2521	Inactive/standby	Sanitary waste	1954–1985	3.8×10^6	<10
Waste basin	3512	Inactive/stabilized	Catch basin for liquid waste collected from tank farm	1944–1950	1.1×10^5	Unknown
Waste basin	3513	Inactive	Solids settling basin for LLW supernate from gunite tanks and process wastewater	1944–1976	7×10^6	150
Low-intensity test reactor pond	3075	Inactive/stabilized	Retention pond for process wastewater from the reactor	1951–1954	6.8×10^4	Unknown

[a]F. G. Taylor (ORNL), personal communication, March 1986.

[b]C. E. Nix et al. (ORNL), personal communication, March 1986.

Table A.6. Summary of process ponds and other impoundments in Melton Valley[a,b]

Site	Location	Status	Type of waste or facility	Service dates	Approximate capacity	Estimated radionuclide inventory (Ci)
High Flux Isotope Reactor (HFIR) pond	7905	Active	Collection of process wastewater from HFIR; standby for cooling tower blowdown	1965–present	9×10^5 L	<10[c]
HFIR pond	7906	Active	Collection of process wastewater from HFIR; backup for TPP ponds	1965–present	1.9×10^6 L	<10[c]
Transuranium Processing Facility (TPP) ponds (2)	7907,7908	Active	Collection of process wastewater from TPP	1965–present	1.9×10^6 L	<10[c]
Homogeneous Reactor Experiment (HRE) pond	7556	Inactive/ stabilized	Holdup basin for wastewater from chemical reprocessing system and tank shield water	1958–1961	1.1×10^6 L	91
Process waste sludge basin (SWSA 5)	7835	Inactive	Settling and storage basin for sludge from former process waste treatment plant	1976–1981	7.6×10^5 L	50
Old Hydrofracture Facility basin (SWSA 5)	7852	Inactive	Catchment for emergency backflow of LLW grout from hydrofracture operations and equipment washdown waste	1964–1980	3.8×10^5 L	85–400
"Intermediate" pond area (SWSA 4)		Inactive	Solids settling for White Oak Creek	1944–d		130
White Oak Lake		Active	Holdup for White Oak Creek	1943–present	9.7 ha	600–650

[a]F. G. Taylor (ORNL), personal communication, March 1986.

[b]C. E. Nix et al. (ORNL), personal communication, March 1986.

[c]Combined radioactivity in basins in TPP/HFIR area (7905, 7906, 7907, 7908).

[d]In September 1944, the dam was breached by high water and the pond was greatly reduced in size. Residual pond remained until early 1950s. (J. O. Duguid, Status Report on Radioactivity Movement from Burial Grounds in Melton and Bethel Valleys, ORNL-5017, July 1975, pp. 50–56.)

Table A.7. Monthly contribution of ^{90}Sr from various ORNL areas during 1985[a]

Month in 1985	Precipitation[b] (cm)	^{90}Sr discharge (mCi)								
		Flume	190 Ponds	PWTP	STP	PWTP + 190 Ponds + STP	7500 bridge[c]	WOC[c]	HRT	MB2
Jan.	5.65	14.1	2.5	0.1	90.1[d]	92.7[d]	645[d]	271	6.6	0.1
Feb.	7.94	7.2	1.7	0.5	70.1	72.2	213	312	8.2	0.1
March	3.68	5.8	1.8	0.1	15.4	17.4	78	84	4.5	0.3
April	4.32	4.7	1.2	0.2	9.0	10.3	80	78	6.5	0.2
May	5.97	5.5	0.3	0.1	7.7	8.1	82	62	3.5	0.1
June	13.27	4.6	0.4	0.2	7.6	8.3	71	53	2.4	<0.1
July	10.09	10.0	0.2	0.1	6.5	6.8	112	85	3.7	0.3
Aug.	23.05	7.4	0.3	0.5	9.1	10.0	189	223	7.3	0.4
Sept.	4.25	5.3	0.5	1.1	4.9	6.5	76	67	2.5	0.1
Oct.	7.56	6.7	0.2	21.0	5.8	27.0	230	214	3.4	0.2
Nov.	10.16	4.9	0.4	4.0	12.3	16.7	344[e]	730	3.2	0.3
Dec.	5.27	283.2[e]	3.6	5.2[f]	165.5[e]	174.3[e]	914[e]	393	4.5	0.8
Total	101.21	359.3[e]	13.2	33.2	403.9	450.3	3036	2571	56.2	2.9

[a]Based on data in DEM files; K. L. Daniels (ORNL), personal communications to M. B. Sears, June 23 and 26, 1986.

[b]Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

[c]In January and December 1985 the ^{90}Sr inflow at the 7500 bridge station exceeded the outflow at the WOC station, while in November 1985 the outflow at the WOC station exceeded the inflow at the 7500 bridge station. The inference is that part of the ^{90}Sr released during the LLW line break in late January and the filter pit spill on November 29 was in the creek sediments, and that it takes time for the creek to cleanse itself.

[d]Elevated ^{90}Sr levels detected at White Oak Dam, January 26, 1985, which were traced to break in the LLW line serving Building 3074.

[e]The ^{90}Sr spill from ventilation filter pit at Building 3517 occurred on November 29, 1985.

[f]K. Jeffries (ORNL), personal communication to M. B. Sears, June 20, 1986.

Table A.8. Monthly contribution of ^{90}Sr from various ORNL areas during 1985[a]

Month in 1985	Precipitation[b] (cm)	^{90}Sr discharge (mCi)								
			Pits					Inferred contributors		
		MBI	East seep	West seep	Sum pits	WOC + MBI + pits	WOD	Other sources between flume and 7500B	WOC-7500B[c]	SWSA 5
Jan.	5.65	41.2	0.02	4.3	4.3	317	405	539	(-374)	34
Feb.	7.94	53.1	0.02	2.3	2.3	367	239	133	99	45
March	3.68	37.6	0.03	0.8	0.8	122	144	55	5	33
April	4.32	35.2	0.12	0.8	0.9	114	123	65	(-2)	28
May	5.97	17.7	0.01	1.0	1.0	80	105	68	(-20)	14
June	13.27	7.2	<0.01	0.3	0.3	60	81	59	(-19)	5
July	10.09	9.6	<0.01	0.7	0.7	96	128	96	27	6
Aug.	23.05	76.9	0.08	3.5	3.6	304	336	172	34	69
Sept.	4.25	11.4	0.68	1.3	2.0	80	89	64	(-9)	9
Oct.	7.56	23.8	<0.01	2.1	2.1	240	249	197	(-17)	20
Nov.	10.16	32.7	<0.01	1.5	1.5	764[d]	309[d]	323	386	29
Dec.	5.27	32.8	0.03	6.8	6.9	432[d]	792[d]	457	(-522)	28
Total	101.21	379.0	1.01	25.4	26.4	2976	3001	2226	(-464)	320

[a]Based on data in DEM files; K. L. Daniels (ORNL), personal communications to M. B. Sears, June 23 and 26, 1986.

[b]Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

[c]It is not possible to estimate the SWSA 4 discharges in 1985 by the difference between the outflow at the WOC station and the inflow at the 7500 bridge station. In January and December 1985 the inflow at the 7500 bridge exceeded the outflow at the WOC station, while in November the outflow exceeded the inflow. The inference is that part of the ^{90}Sr released during the LLW line break in late January and the filter pit spill on November 29 was in the creek sediments and that it takes time for the creek to cleanse itself.

[d]The difference between the inflow to White Oak Lake (WOC + MBI + pits stations plus unmonitored sources) and the outflow at the WOD station in November and December 1985 reflects the holdup in White Oak Lake following the filter pit spill on November 29.

Table A.9. Monthly contribution of ^{90}Sr from various ORNL areas during 1984[a]

Month in 1984	Precipitation[b] (cm)	^{90}Sr discharge (mCi)								
		Flume	190 Ponds	PWTP	STP	PWTP + 190 Ponds + STP	7500 bridge	WOC	HRT	MB2
Jan.	6.13	8.6	0.8	0.6	11.9	13.3	62	103	4.0	0.4
Feb.	9.22	8.7	0.2	0.8	10.3	11.3	53	94	4.9	0.3
March	11.33	10.2	0.2	1.7	10.7	12.6	83	152	3.8	<0.4
April	9.54	7.0	0.4	0.2	12.9	13.5	66	104	4.3	0.4
May	27.21	5.4	0.9	0.2	22.6	23.7	182	280	6.5	0.8
June	9.18	7.3	0.5	0.2	11.1	11.8	44	36	5.5	<0.1
July	18.06	10.0	0.5	<0.1	13.0	13.5	90	93	5.8	NP[c]
Aug.	4.32	7.9	0.3	0.2	12.0	12.5	55	79	4.0	NP[c]
Sept.	2.03	4.4	0.2	0.1	6.5	6.8	d	36	2.1	NA[e]
Oct.	15.62	9.9	0.4	0.3	9.8	10.5	f	85	4.5	3.2
Nov.	11.30	8.1	0.4	0.2	8.6	9.2	53	120	3.6	0.2
Dec.	5.27	5.5	0.2	0.3	16.0	16.5	67	91	13.0	0.1

[a]Based on data in Operations Division files; L. C. Lasher (ORNL), personal communication, May 1984-March 1985.

[b]Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

[c]NP = not applicable.

[d]Not reported because indicated flows were in error.

[e]NA = not available.

[f]Measured value of 120 mCi is inconsistent with WOC station measurement of 85 mCi. Attributed, in part, to erroneous flow measurement; however, cross-contamination of samples may have occurred.

Table A.10. Monthly contribution of ^{90}Sr from various ORNL areas during 1984[a]

Month in 1984	Precipitation[b] (cm)	^{90}Sr discharge (mCi)						Inferred contributors		
		MBI	Pits: East seep	Pits: West seep	Pits: Sum pits	WOC + MBI + pits	WOD	Other sources between flume and 7500B	SWSA 4	SWSA 5
Jan.	6.13	51.7	<0.1	3.6	3.6	158	169	40	41	47
Feb.	9.22	51.6	0.1	4.4	4.5	150	141	33	41	46
March	11.33	63.3	<0.01	5.9	5.9	221	208	60	69	59
April	9.54	68.6	<0.01	2.9	2.9	175	189	45	38	64
May	27.21	67.4	0.2	10.4	10.6	358	360	153	98	60
June	9.18	37	<0.1	6.4	6.4	79	98	25	11	32
July	18.06	41	<0.3	1.2	1.5	136	170	66	3	35
Aug.	4.32	28	0.1	0.5	0.6	108	140	35	24	24
Sept.	2.03	8.7	0.1	4.8	4.9	50	46	NA[c]	NA	7
Oct.	15.62	30.0	0.1	2.9	3.0	118	180	NA	NA	22
Nov.	11.30	49	0.2	6.9	7.1	176	200	36	67	45
Dec.	5.27	33.0	0.4	11.0	11.4	135	160	45	24	20

[a] Based on data in Operations Division files; L. C. Lasher (ORNL), personal communications, May 1984–March 1985.

[b] Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

[c] NA = not available.

Table A.11. Monthly contribution of ^{90}Sr from various ORNL areas during 1983[a]

Month in 1983	Precipitation[b] (cm)	^{90}Sr discharge (mCi)								
		Flume	190 Ponds	PWTP	STP	PWTP + 190 Ponds + STP	7500 bridge	WOC	HRT	MB2
Jan.	3.93	16.5	0.2	0.5	19.7	20.4	93	181	3.9	0.7
Feb.	10.33	9.1	0.4	0.4	28.4	29.2	113	237	5.2	0.9
March	5.41	9.4	0.2	0.3	18.0	18.5	84	158	4.2	0.4
April	11.43	13.5	0.1	0.4	22.5	23.0	99	168	7.9	31.8
May	13.21	6.9	0.4	0.2	14.6	15.2	74	173	7.0	2.8
June	5.39	5.9	0.2	0.2	16.3	16.7	NA[c]	87	1.0	0.2
July	4.80	4.1	0.2	0.5	10.9	11.6	52	62	3.0	2.1
Aug.	2.92	3.8	0.3	0.2	17.5	18.0	98[d]	93[d]	3.4	0.2
Sept.	4.48	3.2	0.1	1.0	13.7	14.8	54[d]	50[d]	2.2	0.2
Oct.	11.64	9.6	0.3	0.6	10.7	11.6	73	94	4.0	0.2
Nov.	13.73	6.7	0.1	0.1	1.1	1.3	65	103	10.0	0.5
Dec.	18.48	2.0	0.2	0.3	15.9	16.4	121	298	7.6	<0.1

[a]Based on data in Operations Division files; L. C. Lasher and C. B. Scott (ORNL), personal communications, April 1983–March 1984.

[b]Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

[c]NA = not available.

[d]Discrepancy attributed to one or a combination, of the following sources of error: the inherent errors of the flow measuring system, sample collection and handling, cross-contamination, and analytical techniques.

Table A.12. Monthly contribution of ^{90}Sr from various ORNL areas during 1983[a]

Month in 1983	Precipitation[b] (cm)	^{90}Sr discharge[a] (mCi)								
			Pits					Inferred contributors		
		MBI	East seep	West seep	Sum pits	WOC + MBI + pits	WOD	Other sources between flume and 7500B	SWSA 4	SWSA 5
Jan.	3.93	52.8	0.1	1.3	1.4	235	267	56	88	48
Feb.	10.33	68.4	0.1	2.7	2.8	308	293	75	124	62
March	5.41	69.7	0.1	1.5	1.6	229	123	56	74	65
April	11.43	93.0	0.1	9.6	9.7	271	254	63	69	53
May	13.21	150.5	0.1	6.4	6.5	330	257	51	99	141
June	5.39	59.4	0.1	0.1	0.2	146	123	NA	NA	58
July	4.80	30.6	0.1	0.1	0.2	93	80	37	10	26
Aug.	2.92	14.7	0[c]	0[c]	0[c]	107	87	76	0[d]	11
Sept.	4.48	8.3	0[c]	0[c]	0[c]	58	76	36	0[d]	6
Oct.	11.64	9.0	0.1	0.2	0.3	103	76	52	21	5
Nov.	13.73	25.0	0.1	0.2	0.3	128	115	57	38	14
Dec.	18.48	43.0	<0.1	<0.1	<0.2	341	370	103	176	35

[a]Based on data in Operations Division files; L. C. Lasher and C. B. Scott (ORNL), personal communications, April 1983-March 1984.

[b]Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

[c]No flow during period.

[d]Discrepancy is attributed to one, or a combination of the following sources of error: the inherent errors of the flow measuring system, sample collection and handling, cross-contamination, and analytical techiques.

Table A.13. Monthly contribution of ^{90}Sr from various ORNL areas during 1982[a]

Month in 1982	Precipitation[b] (cm)	^{90}Sr discharge (mCi)								
		Flume	190 Ponds	PWTP	STP	PWTP + 190 Ponds + STP	7500 bridge	WOC	HRT	MB2
Jan.	16.28	13.5	0.2	1.2	76.7	78.1	186	278	11.2	0.7
Feb.	13.09	10.2	0.1	0.9	73.3	74.3	235	342	14.7	0.8
March	16.26	11.1	0.3	0.5	83.3	84.1	234	413	15.9	0.9
April	6.44	10.0	0.1	0.2	35.2	35.5	91	179	12.0	1.2
May	6.07	9.5	0.2	0.4	24.0	24.6	43	58	3.7	0.3
June	7.04	8.0	0.2	0.2	24.3	24.7	44	50	1.8	0.6
July	13.80	9.9	0.2	0.2	16.4	16.8	48	50	6.0	2.4
Aug.	9.24	11.9	0.2	0.2	19.0	19.4	108	144	14.0	0.5
Sept.	6.36	15.2	0.2	0.2	13.1	13.5	59	68	5.0	0.2
Oct.	6.14	13.5	0.2	0.5	8.2	8.9	42	54	4.9	0.1
Nov.	15.08	16.0	0.4	0.2	12.1	12.7	88	142	11.4	0.9
Dec.	17.73	20.7	0.2	1.1	49.6	50.9	204	359	7.1	2.3

[a]Based on data in Operations Division files; L. C. Lasher and C. B. Scott (ORNL), personal communications, May 1982–April 1983.

[b]Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

Table A.14. Monthly contribution of ^{90}Sr from various ORNL areas during 1982[a]

		^{90}Sr discharge (mCi)								
								Inferred contributors		
			Pits							
Month in 1982	Precipitation[b] (cm)	MBI	East seep	West seep	Sum pits	WOC + MBI + pits	WOD	Other sources between flume and 7500B	SWSA 4	SWSA 5
Jan.	16.28	60.6	0.1	5.8	5.9	344	391	95	91	49
Feb.	13.09	69.1	0.1	5.3	5.4	416	365	150	107	54
March	16.26	92.5	0.1	7.1	7.2	513	530	139	179	76
April	6.44	81.6	0.1	2.4	2.5	263	265	46	88	68
May	6.07	36.8	0.1	1.0	1.1	96	120	9	15	33
June	7.04	25.3	0.1	2.2	2.3	77	93	12	6	23
July	13.80	29.3	0.1	2.7	2.8	82	106	22	2	21
Aug.	9.24	23.0	0.1	2.2	2.3	169	76	77	35	8
Sept.	6.36	21.0	0.1	1.5	1.6	91	94	30	10	16
Oct.	6.14	22.6	0.1	1.3	1.4	78	70	20	12	18
Nov.	15.08	54.8	0.1	3.2	3.3	200	209	59	54	42
Dec.	17.73	80.1	0.1	2.5	2.6	442	468	132	155	71

[a]Based on data in Operations Division files; L. C. Lasher and C. B. Scott (ORNL), personal communications, May 1982–April 1983.

[b]Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

Table A.15. Monthly contribution of ^{90}Sr from various ORNL areas during 1981[a]

Month in 1981	Precipitation[b] (cm)	^{90}Sr discharge (mCi) Flume	190 Ponds	PWTP	STP	PWTP + 190 Ponds + STP	7500 bridge	WOC	HRT	MB2
Jan.	2.21	9.0	0.8	1.5	4.2	6.5	27	40	3.0	0.5
Feb.	11.93	14.4	0.4	1.3	14.9	16.6	59	122	6.3	0.2
March	7.34	11.1	0.4	14.2	7.7	22.3	47	82	4.5	0.1
April	9.37	14.3	1.0	2.4	11.1	14.5	52	108	4.3	1.1
May	10.85	12.7	0.5	2.3	11.4	14.2	48	67	4.3	0.8
June	12.23	7.1	0.2	0.7	32.1	33.0	106	163	4.6	0.2
July	7.40	9.7	0.2	1.6	13.6[c]	15.4	55	62	3.2	0.1
Aug.	7.55	16.3	0.2	2.2	11.3	13.7	67	77	1.8	0.1
Sept.	7.10	20.9	0.2	0.9	12.3	13.4	106	109	1.8	0.2
Oct.	9.35	13.4	0.3	0.8	16.0	17.1	85	97	0.3	0.1
Nov.	7.92	14.5	0.2	3.3	28.2	31.7	101	130	3.9	0.1
Dec.	10.24	10.9	0.7	0.8	54.4	55.9	110	175	1.4	0.2

[a]Based on data in Operations Division Files; L. C. Lasher and C. B. Scott (ORNL), personal communications, March 1981–March 1982.

[b]Engineered Test Facility (SWSA 6) data; E.J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

[c]Estimated value based upon the average release from the STP system during the first 6 months of 1981. The composite sample collected during the period was inadvertently discarded.

Table A.16. Monthly contribution of ^{90}Sr from various ORNL areas during 1981[a]

Month in 1981	Precipitation[b] (cm)	^{90}Sr discharge (mCi)								
			Pits					Inferred contributors		
		MBI	East seep	West seep	Sum pits	WOC + MBI + pits	WOD	Other sources between flume and 7500B	SWSA 4	SWSA 5
Jan.	2.21	10.6	3.6	0.5	4.1	54	54	11	13	7
Feb.	11.93	38.6	7.0	0.4	7.4	168	160	28	63	32
March	7.34	28.8	<0.1	3.0	3.0	133	71	13	35	24
April	9.37	36.7	0.3	2.3	2.3	148	214	23	57	31
May	10.85	21.1	<0.1	0.9	0.9	89	98	21	20	16
June	12.23	22.2	<0.1	0.8	0.8	186	239	66	57	17
July	7.40	10.5	<0.1	1.3	1.3	74	66	30[c]	7	7
Aug.	7.55	5.6	0.1	0.6	0.7	84	59	37	10	4
Sept.	7.10	3.7	0.1	0.6	0.7	113	87	72	3	2
Oct.	9.35	4.9	0.1	0.4	0.5	102	124	54	13	4
Nov.	7.92	8.9	0.1	0.4	0.5	139	118	55	29	5
Dec.	10.24	14.5	0.1	0.5	1.6	191	225	44	64	13

[a]Based on data in Operations Division files; L. C. Lasher and C. B. Scott (ORNL), personal communications, March 1981–March 1982.

[b]Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

[c]Estimated value based upon the averaged release from the STP system during the first 6 months of 1981.

Table A.17. Monthly contribution of ^{90}Sr from various ORNL areas during 1980[a]

Month in 1980	Precipitation[b] (cm)	^{90}Sr discharge (mCi)								
		Flume	190 Ponds	PWTP	STP	PWTP + 190 Ponds + STP	7500 bridge	WOC	HRT	MB2
Jan.	9.50[b]	21.0	2.5	4.6	33.6	40.7	95	39[c]	3.4	0.4
Feb.	4.42[b]	16.1	0.9	1.9	NA[d]	NA	204	205	6.8	0.4
March	19.86[b]	15.0	0.6	1.4	NA	NA	136	311	9.2	0.6
April	10.54[b]	6.3	0.4	0.7	31.3	32.4	114	195	8.3	0.1
May	8.81[b]	10.3	0.7	0.8	15.2	16.7	253[e]	163	7.2	0.4
June	1.07[b]	7.8	0.3	4.1	12.9	17.3	41	59	5.4	0.3
July	2.29[b]	4.3	0.3	1.5	11.5	13.3	29	35	3.7	0.1
Aug.	3.25[f]	5.5	1.0	1.3	12.9	15.2	34	35	2.7	0.2
Sept.	6.87[f]	5.3	0.9	0.7	8.2	9.8	29	32	2.6	0.2
Oct.	4.63[f]	8.7	15.4	3.4	4.7	23.5	50	70	1.7	<0.1
Nov.	10.16[f]	8.5	1.2	2.0	9.0	12.2	39	58	3.0	<0.1
Dec.	4.35[f]	10.0	2.0	2.4	9.5	13.9	40	47	4.5	<0.1

[a]Based on data in Operations Division files; L. C. Lasher and C. B. Scott (ORNL), personal communications, March 1980–February 1981.

[b]ORNL steam plant data (Bethel Valley); V. T. Carmony (ORNL), personal communication to M. B. Sears, July 1, 1986. Total precipitation in 1980 measured at steam plant appeared to be somewhat low compared with NOAA Oak Ridge Townsite station.

[c]Data are obviously in error because amount is less than sum of upstream monitoring stations.

[d]NA = not available.

[e]Data are believed to be in error.

[f]Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

Table A.18. Monthly contribution of ^{90}Sr from various ORNL areas during 1980 (contd.)[a]

Month in 1980	Precipitation[b] (cm)	^{90}Sr discharge (mCi)								
			Pits					Inferred contributors		
		MBI	East seep	West seep	Sum pits	WOC + MBI + pits	WOD	Other sources between flume and 7500B	SWSA 4	SWSA 5
Jan.	9.50[b]	88.9	NA[c]	NA	NA	NA	290	33	NA	85
Feb.	4.42[b]	99.4	1.4	37.2	38.6	343	210	NA	2[d]	92
March	19.86[b]	124.9	0.4	8.7	9.1	445	370	NA	176	115
April	10.54[b]	92.1	0.1	4.8	4.9	292	200	75	81	84
May	8.81[b]	94.2	0.4	6.8	7.2	265	100	NA	NA	87
June	1.07[b]	40.8	0.1	0.9	1.0	101	30	16	18	35
July	2.29[b]	11.0	<0.1	<0.1	<0.1	46	20	12	6	7
Aug.	3.25[e]	8.5	<0.1	<0.1	<0.1	44	30	13	1	6
Sept.	6.87[e]	5.6	<0.1	<0.1	<0.1	38	30	14	3	3
Oct.	4.63[e]	13.2	<0.1	<0.1	<0.1	84	20	18	20	12
Nov.	10.16[e]	16.2	<0.1	<0.1	<0.1	74	30	18	20	13
Dec.	4.35[e]	16.3	0.1	0.7	0.8	64	40	16	7	12

[a]Based on data in Operations Division files; L. C. Lasher and C. B. Scott (ORNL), personal communications, March 1980–February 1981.

[b]ORNL steam plant data (Bethel Valley); V. T. Carmony (ORNL), personal communication to M. B. Sears, July 1, 1986. Total precipitation in 1980 measured at steam plant appeared to be somewhat low compared with NOAA Oak Ridge townsite station.

[c]NA = not available.

[d]Value is low compared with previous data. Value for 7500 bridge station appears high, which would result in low estimate for SWSA 4.

[e]Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

Table A.19. Monthly contribution of ^{90}Sr from various ORNL areas during 1979[a]

		^{90}Sr discharge (mCi)								
Month in 1979	Precipitation[b] (cm)	Flume	190 Ponds	PWTP	STP	PWTP + 190 Ponds + STP	7500 bridge	WOC	HRT	MB2
Jan.	15.44	24.2	0.6	2.4	13.8	16.8	103	437	9.5	0.7
Feb.	12.90	11.1	0.8	1.5	10.4	12.7	53	151	8.7	0.2
March	10.74	10.5	0.9	0.7	14.5	16.1	47	139	6.6	0.3
April	14.09	18.4	0.6	0.8	14.0	15.4	58	187	4.1	0.2
May	NA[c]	12.8	0.7	1.2	12.3	14.2	58	188	6.8	0.2
June	NA	16.0	0.7	0.8	10.3	11.8	69	129	7.3	0.1
July	NA	26.9	0.8	3.5	16.6	20.9	128	276	10.0	0.2
Aug.	10.92	8.8	0.6	6.4	10.6	17.6	62	96	4.9	0.1
Sept.	10.77	8.6	0.3	4.0	5.1	9.4	65	62	5.1	0.1
Oct.	6.15	9.4	0.4	5.2	6.2	11.8	47	80	5.7	0.1
Nov.	15.11	18.9	5.4	3.8	14.7	23.9	107	193	6.9	0.2
Dec.	6.02	13.1	0.8	4.8	8.6	14.2	43	86	3.7	0.1

[a]Based on data in Operations Division files; L. C. Lasher and C. B. Scott (ORNL), personal communications, March 1979–February 1980.

[b]ORNL steam plant data (Bethel Valley); V. T. Carmony (ORNL), personal communication to M. B. Sears, July 1, 1986.

[c]NA = not available; records missing.

Table A.20. Monthly contribution of ^{90}Sr from various ORNL areas during 1979 (contd.)[a,b]

		^{90}Sr discharge (mCi)					
					Inferred contributors		
Month in 1979	Precipitation (cm)	MBI	WOC + MBI[b]	WOD	Other sources between flume and 7500 B	SWSA 4	SWSA 5
Jan.	15.44	42.1	479	150	62	334	32
Feb.	12.90	55.6	207	260	30	98	47
March	10.74	64.2	204	150	20	93	57
April	14.09	82.7	270	170	24	129	78
May	NA[d]	78.4	267	NA	31	131	71
June	NA	108.0	237	NA	41	60	101
July	NA	115.9	392	520	81	148	106
Aug.	10.92	45.6	141	140	36	34	41
Sept.	10.77	52.0	114	110	47	0[e]	47
Oct.	6.15	41.8	122	NA	26	33	36
Nov.	15.11	76.6	270	160	64	86	70
Dec.	6.02	45.3	132	160	16	43	42

[a]Based on data in Operations Division files; L. C. Lasher and C. B. Scott (ORNL), personal communications, March 1979–February 1980.

[b]Pits area was not monitored in 1979.

[c]ORNL steam plant data (Bethel Valley); V. T. Carmony (ORNL), personal communication to M. B. Sears, July 1, 1986.

[d]NA = not available; records lost.

[e]Value is low; attributed to inherent errors of flow measuring system or sampling errors.

Table A.21. Strontium-90 discharges from the Northwest Tributary (SWSA 3) and First Creek

Month	Average precipitation 1948–1984[a] (cm)	1978–1979 Precipitation[b] (cm)	1978–1979 Northwest Tributary (SWSA 3) ^{90}Sr flow[c,d] (mCi)	1985–1986 Precipitation[b] (cm)	1985–1986 ^{90}Sr[e] Northwest Tributary (SWSA 3)[f] Conc. (10^{-4} µCi/L)[g]	Northwest Tributary (SWSA 3)[f] Flow (mCi)	First Creek Conc. (10^{-4} µCi/L)	First Creek Flow (mCi)	WOC-CHW (background) conc. (10^{-4} µCi/L)
July	13.7			12.7	0.23	0.28	0.016	0.002	NA[h]
Aug.	9.4			25.4	0.35	0.52	0.011	0.001	NA
Sept.	9.1	5.6	3.2	3.2	0.30	0.22	0.008	0.001	NA
Oct.	7.8	1.1	2.1	5.4	0.32	0.24	0.032	0.003	NA
Nov.	11.9	13.9	4.0	11.6	0.54	0.36	0.008	<0.001	NA
Dec.	14.1	14.7	10.5	4.8	NA	NA	NA	NA	NA
Jan.	13.4	15.4	11.1	3.4	0.59	NA	4.6	NA	0.027
Feb.	12.0	12.9		14.6	0.40	NA	2.5	NA	0.005
March	15.1	10.7	5.7	6.8	0.46	NA	3.5	NA	0.008
April	10.9	14.1							
May	11.2	23.7[a]	8.2						

[a]NOAA station, Oak Ridge townsite; B. Hicks (NOAA), personal communication to M. B. Sears, June 4, 1986.

[b]ORNL steam plant data (Bethel Valley); V. T. Carmony (ORNL), personal communication to M. B. Sears, July 1, 1986.

[c]A. M. Stueber et al., An Investigation of Radionuclide Release from Solid Waste Disposal Area 3, Oak Ridge National Laboratory, ORNL/TM-7323, August 1981.

[d]Includes First Creek.

[e]Based on data in DEM files; K. L. Daniels (ORNL), personal communication to M. B. Sears, June 23, 1986.

[f]Does not include First Creek.

[g]To convert from 10^{-4} µCi/L to Bq/L, multiply value in table by 3.7.

[h]NA = not available.

Table A.22. Tritium and ^{90}Sr concentrations in tributaries draining SWSA 6[a,b]

Date	^{3}H concentration (10^{-4} µCi/L)[c]	^{90}Sr concentration (10^{-4} µCi/L)
	Station 1	
5-17-85	2,970 ± 270	0.054 ± 0.046
10-25-85	2,220 ± 50	0.057 ± 0.041
1-14-86	5,135 ± 270	0.054 ± 0.037
3-21-86	2,400 ± 80	0.165 ± 0.057
	Station 2	
5-17-85	20,540 ± 270	0.062 ± 0.051
10-25-85	17,840 ± 270	0.030 ± 0.038
1-14-86	19,730 ± 270	0.208 ± 0.068
3-21-86	20,810 ± 270	0.138 ± 0.062
	Station 3	
5-17-85	20,270 ± 270	1.35 ± 0.16
10-25-85	12,430 ± 270	1.30 ± 0.16
1-14-86	37,840 ± 2700	2.24 ± 0.19
3-21-86	15,680 ± 270	1.54 ± 0.19

[a]E. J. Davis (ORNL), personal communication to M. B. Sears, June 17, 1986.

[b]For location of gauging stations, see Fig. A.4.

[c]To convert from 10^{-4} µCi/L to Bq/L, multiply value in table by 3.7.

Table A.23. Monthly stream flow at various gauging stations in Melton Valley during 1985[a]

Month in 1985	Stream flow (10^4 m^3)								
				Pits		SWSA 6[b,c]			
	HRT	MB2	MBI	East seep	West seep	Station 1	Station 2	Station 3	WOD
Jan.	2.74	10.94	25.51	0.142	4.79				111.7
Feb.	3.42	26.43	20.67	0.213	3.51				108.2
March	1.66	10.61	11.40	0.427	0.92				70.4
April	1.71	11.74	12.11	1.726	1.07				78.2
May	1.00	8.68	6.52	0.111	1.04				72.2
June	0.75	4.89	3.75	0.020	0.37	0.0220	0.0421	0.0569	61.1
July	1.25	6.25	6.35	0.042	0.93	0.0154	0.0557	0.1053	97.7
Aug.	2.26	20.65	35.02	1.404	4.33	0.0580	0.0871	0.2333	166.3
Sept.	0.99	5.48	3.88	8.179	1.22	0.0071	0.0243	0.0472	57.8
Oct.	1.44	7.23	7.70	0.048	2.34	0.0251	0.0391	0.1963	89.9
Nov.	1.28	8.46	13.96	0.086	1.26				95.8
Dec.	1.88	15.91	13.82	0.380	5.07				56.2
Total	20.38	137.3	160.7	12.78	26.80				1065.6

[a]Based on data in DEM files; K. L. Daniels (ORNL), personal communications to M. B. Sears, June 23 and 26, 1986.

[b]E. J. Davis (ORNL), personal communcation to M. B. Sears, June 17, 1986.

[c]Location of monitoring stations shown on Fig. A.4.

Table A.24. Monthly contribution of ^3H from various ORNL areas, January 1985 - March 1986

Month	Precipitation[a] (cm)	^3H discharge (mCi)					MBI÷(MBI+WOC) (%)
		STP	WOC	MBI	WOC + MBI	WOD	
				1985[b]			
Jan.	5.65	1,460	241,300	432,500	673,800	707,200	64
Feb.	7.94	5,970	566,400	483,900	1,050,300	602,700	46
March	3.68	740	43,600	277,100	320,800	416,200	86
April	4.32	400	61,700	305,500	367,200	295,800	83
May	5.97	230	343,400	98,700	442,200	230,500	22
June	13.27	230	143,400	34,500	177,900	109,000	19
July	10.09	280	28,500	59,800	88,300	133,400	68
Aug.	23.05	240	43,800	123,200	167,000	314,000	74
Sept.	4.25	160	10,200	72,900	83,100	121,400	88
Oct.	7.56	180	21,900	165,000	186,900	204,000	88
Nov.	10.16	130	32,400	219,000	251,900	335,400	87
Dec.	5.27	140	24,300	296,400	320,700	196,400	92
Total	101.21	10,150	1,561,100	2,568,900	4,123,000	3,666,000	62
				1986[c]			
Jan.	3.11	NA[d]	23,000	360,000	383,000	310,000	94
Feb.	10.35	NA	65,000	680,000	745,000	440,000	91
March	7.17	NA	33,000	390,000	423,000	410,000	92

[a]Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

[b]Based on data in DEM files; K. L. Daniels (ORNL), personal communication to M. B. Sears, June 26, 1986.

[c]Based on data in DEM files; W. F. Ohnesorge, Jr., personal communication to M. B. Sears, May 8, 1986.

[d]NA = not available.

Table A.25. Monthly contribution of ^{137}Cs from various ORNL areas during 1985[a]

Month in 1985	^{137}Cs discharge (mCi)							
	190 Ponds	PWTP	STP	PWTP + 190 ponds + STP	WOC	MBI	WOC + MBI[b]	WOD[b]
Jan.	3.1	90	0.4	94	130	0.5	130	57
Feb.	0.2	154	1.0	155	162	0.4	163	46
March	6.3	27	0.3	34	26	1.0	27	20
April	0.4	67	0.2	68	23	0.2	24	16
May	0.1	66	0.4	67	58	0.2	59	15
June	0.2	32	0.6	33	33	0.1	33	9
July	0.3	60	0.5	60	29	0.2	29	22
Aug.	0.4	336	0.3	337	132	1.4	133	29
Sept.	0.3	164	0.1	165	26	0.1	27	6
Oct.	1.3	36	0.1	38	21	0.3	21	10
Nov.	1.6	60	0.1	62	51	0.7	52	24
Dec.	NA[c]	NA	0.9	NA	416	0.5	417	167
Subtotal Jan.-Nov.	14.0	1093	4.1	1111	692	5.3	698	254
Total Jan.-Dec.	NA	NA	5.0	NA	1109	5.8	1115	420

[a]Based on data in DEM files; K. L. Daniels (ORNL), personal communications to M. B. Sears, June 23 and 26, 1986.

[b]The difference between the measured inflow to White Oak Lake (WOC + MBI station) and the measured outflow at WOD station reflects solids settling (i.e., accumulation) in White Oak Lake.

[c]NA = not available.

Table A.26. Monthly contributions of ^{60}Co from various ORNL areas during 1985[a]

Month in 1985	190 Ponds	PWTP	STP	PWTP + 190 Ponds + STP	WOC	MBI	WOC + MBI	WOD
Jan.	0.3	44	0.7	45	60	25.3	86	48
Feb.	0.1	21	0.5	22	31	3.8	35	14[b]
March	0.1	16	0.1	16	11	6.2	17	16
April	0.2	12	0.1	12	7	2.0	9	9
May	0.1	8	0.1	9	8	1.3	9	8
June	<0.1	23	0.1	23	24	1.9	26	17
July	<0.1	21	0.1	21	15	2.6	17	20
Aug.	<0.1	37	0.1	37	17	19.5	36	14
Sept.	0.1	9	0.1	10	3	1.1	4	4
Oct.	0.9	20	0.1	22	17	1.7	19	19
Nov.	0.6	15	0.1	15	10	74.7	85	73
Dec.	0.1	19	<0.1	19	8	4.1	12	15
Total	2.6	245	2.0	250	210	144	354	257[b]

[a]Based on data in DEM files; K. L. Daniels (ORNL) personal communications to M. B. Sears, June 23 and 26, 1986.

[b]Does not include the ninth week of 1985 (last week of February) which is thought to be in error; reported value for the ninth week was 375 mCi.

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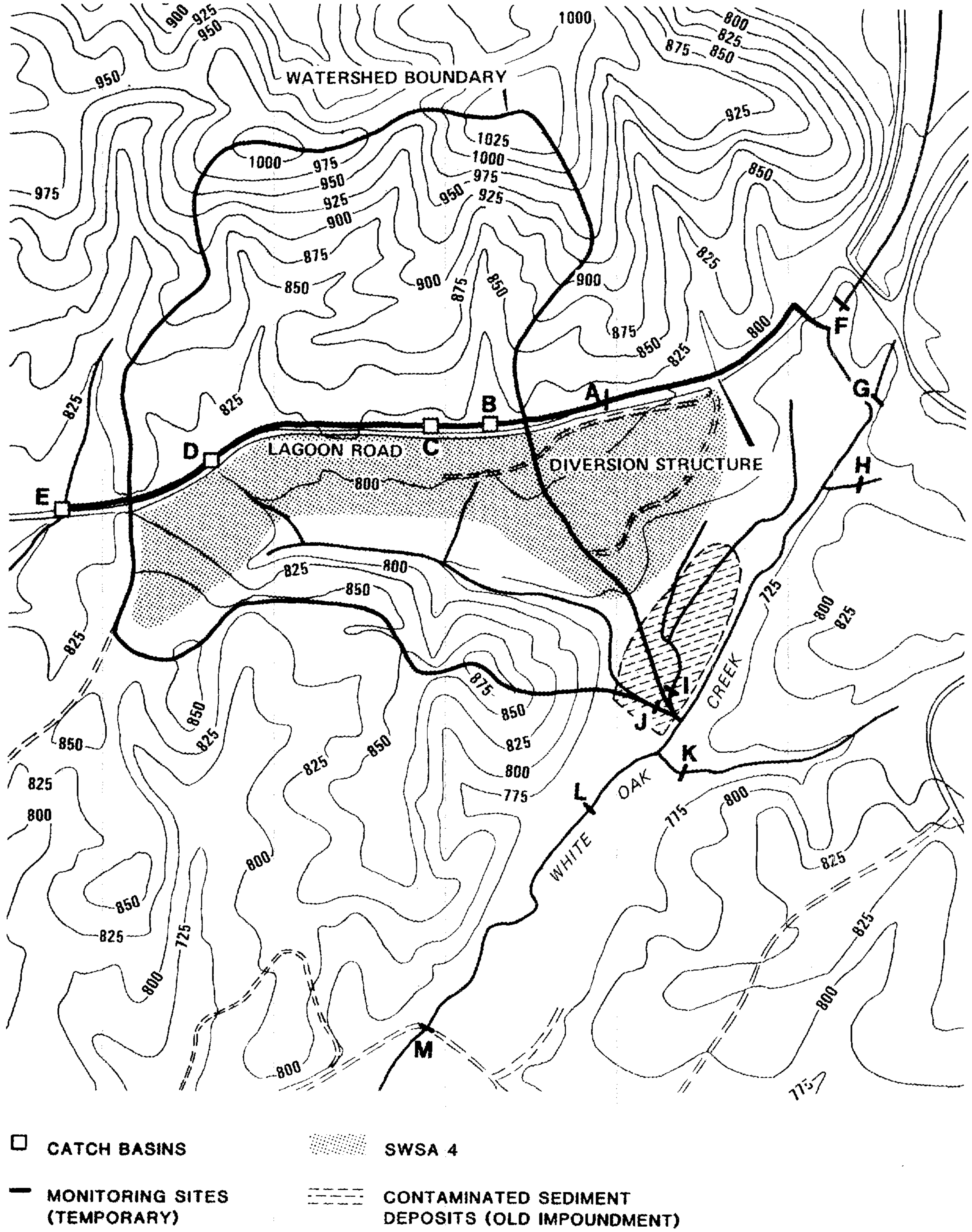

Fig. A.1. Map of SWSA 4 site. (Source: L. A. Melroy and D. D. Huff, Annual Reduction of ^{90}Sr Migration from Solid Waste Storage Area 4 to White Oak Creek by Flow Diversion, ORNL/TM-9620, May 1985, p. 5.)

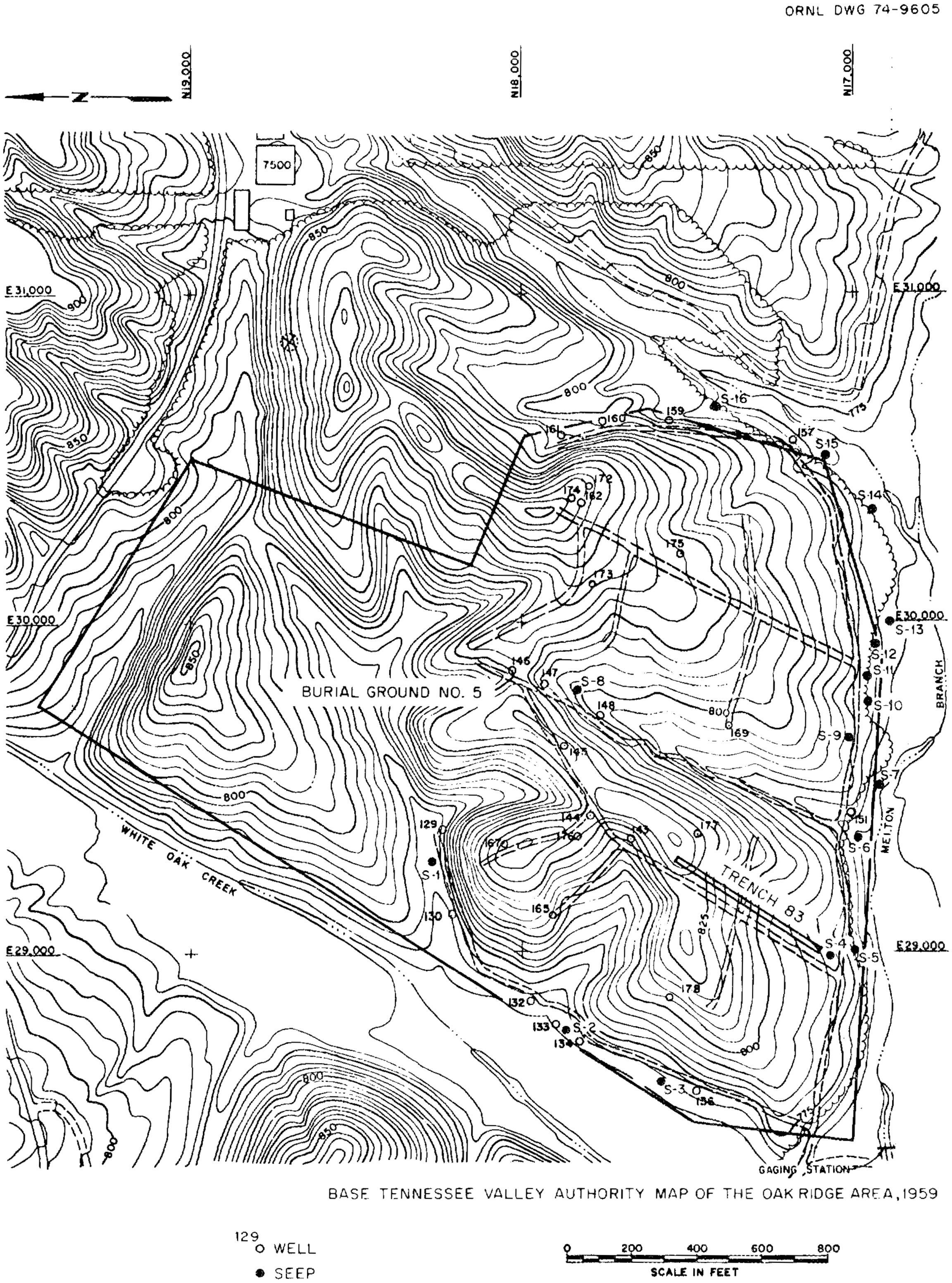

Fig. A.2. Map of SWSA 5 site. (Source: J. O. Duguid, Annual Progress Report of Burial Ground Studies at Oak Ridge National Laboratory: Period Ending September 30, 1975, ORNL-5141, September 1975, p. 29.)

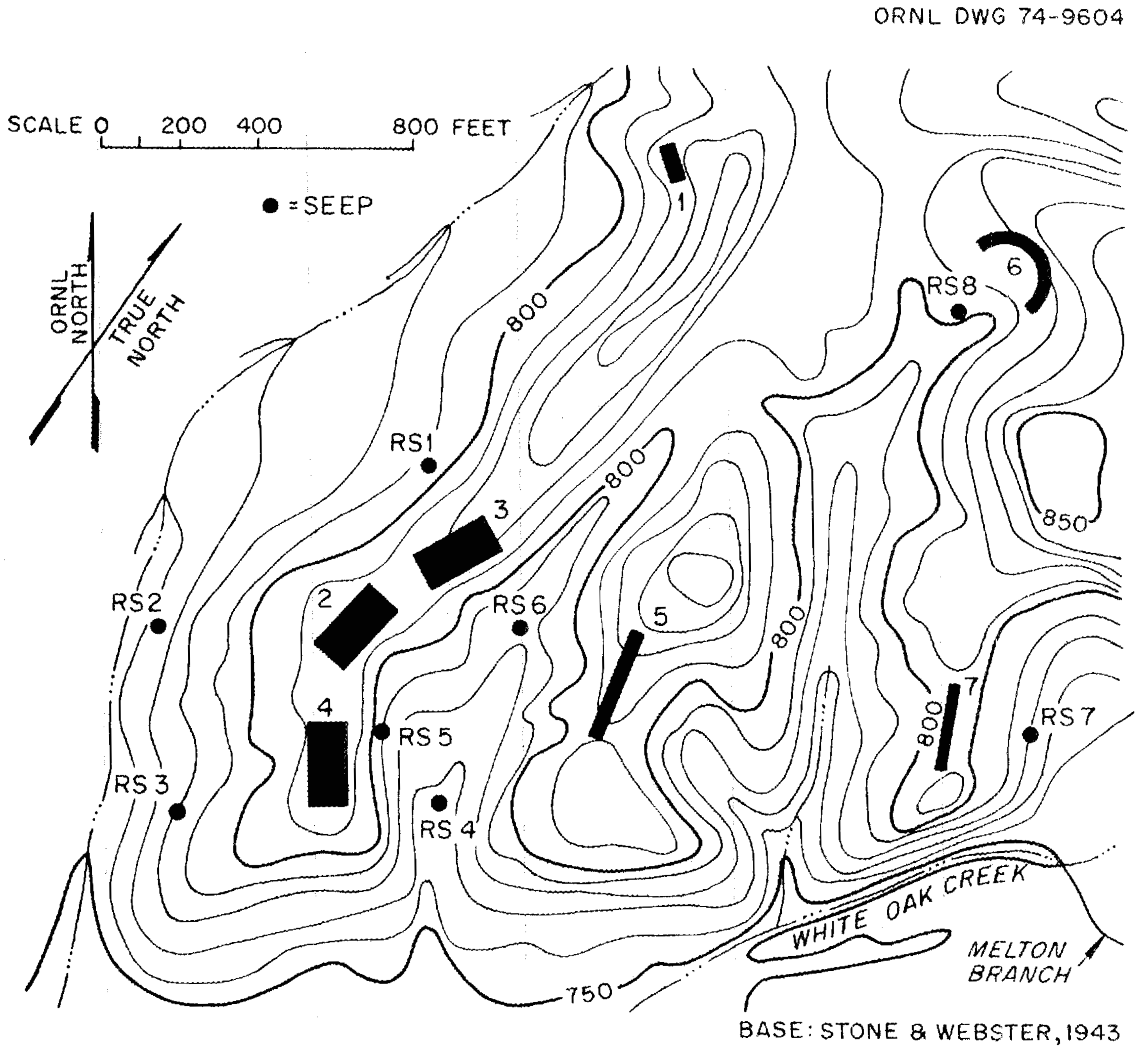

Fig. A.3. Map of liquid waste seepage pits and trenches area. (Source: J. O. Duguid, Status Report on Radioactivity Movement from Burial Grounds in Melton and Bethel Valleys, ORNL-5017, July 1975, p. 7).

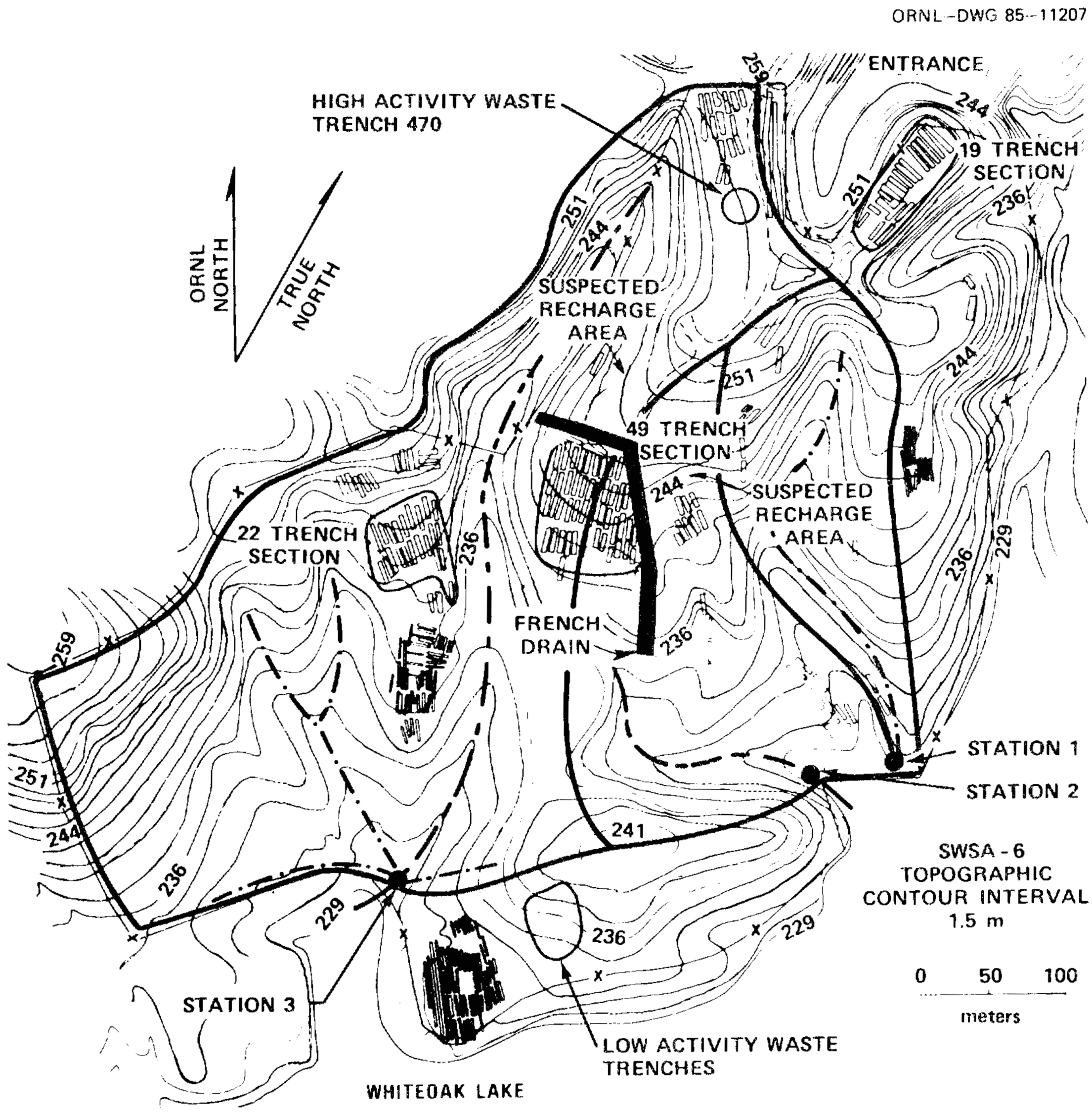

Fig. A.4. Map of SWSA 6 site. (Source: E. J. Davis, personal communication to M. B. Sears, June 17, 1986.)

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