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Annual Environmental Monitoring Report: Calendar Year 1977

Billy M. Farmer and Daniel G. Carfagno

April 25, 1978

MOUND FACILITY
Miamisburg, Ohio

operated by
MONSANTO RESEARCH CORPORATION
a subsidiary of Monsanto Company

for the
U. S. DEPARTMENT OF ENERGY

Contract No. EY-76-C-04-0053

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Foreword

This report was prepared by the Environmental Assessment and Planning Section of the Safety and Environmental Technology Function in the Administrative Services Department at Mound Facility. Sample analyses and data reduction were performed by the Environmental Evaluation and Environmental Laboratory groups of the Environmental Assessment and Planning Section. Particulate samples offsite are collected by the Air Pollution Control Section of the Montgomery County Combined General Health District which acts as the Regional Air Pollution Control Agency in this area for the Ohio Environmental Protection Agency.

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Introduction

Mound Facility is situated on 180 acres of land in Miamisburg, Ohio. This location is approximately 16 km (10 mi) southwest of Dayton. The predominant geographical feature in the five-county region surrounding the Facility is the Great Miami River which flows from northeast to southwest through Miamisburg. This river valley area is generally highly industrialized. The remainder of the region is predominantly agricultural with some light industry and scattered residential communities. The location and population of these communities are shown in Figure 1. Figure 2 shows the population distribution around Mound Facility. Drinking water for the area is obtained from a buried valley aquifer which generally follows the Great Miami River. The primary agricultural activity in the area is raising field crops such as corn and soybeans. Approximately 10% of the land area in agricultural use is devoted to pasturing livestock [1]. Weather conditions in the area are moderate. The average annual precipitation is approximately 91 cm (36 in.) and is evenly distributed throughout the year. Winds are predominantly from the south or west except during the summer months when a higher frequency is recorded from out of the southwest. The wind speed averages about 16 km/hr (10 mi/hr) annually [2]. Figure 3 shows the wind rose compiled at Wright Patterson AFB which is located approximately 13 miles northeast from Mound.

Mound Facility began operations in 1949. Its mission currently includes research, development, engineering, production and surveillance of components for the Department of Energy (DOE) weapon programs; separation, purification, and sale of stable isotopes of the noble gases; the fabrication of radioisotopic heat sources fueled with plutonium-238 for thermoelectric generators. The radionuclides of primary concern currently being handled include plutonium-238 and tritium.

Radionuclides in particulate form are removed from process air effluents from nuclear operations facilities by high efficiency particulate air (HEPA) filters. The air effluents are filtered first at the points of origin, i.e., glove boxes, and just prior to the release point, i.e., the stack. The filtering system at the stack consists of two banks of HEPA filters in series, each bank with a collection efficiency of 99.9%. Radionuclides are removed from liquid effluents such as process waste liquids by chemical processing. Solid radioactive wastes are packaged and shipped offsite for burial at approved burial sites. Airborne and liquid wastes generated in the processing of explosive materials are collected and disposed of according to the Army Materiel Command Regulation 385-100.

An onsite sanitary waste treatment plant provides secondary treatment in accordance with U. S. Environmental Protection Agency (EPA) requirements [3] using an activated sludge process operating in the extended aeration mode. All domestic sewage generated onsite is treated in this facility. The influent and effluent at the sewage treatment plant are also monitored for radioactivity to ensure no undetected release can occur to the environment via the sanitary sewage plant. The digested sludge from the sewage plant is shipped offsite for burial at an approved burial site. Nonradioactive solid wastes are

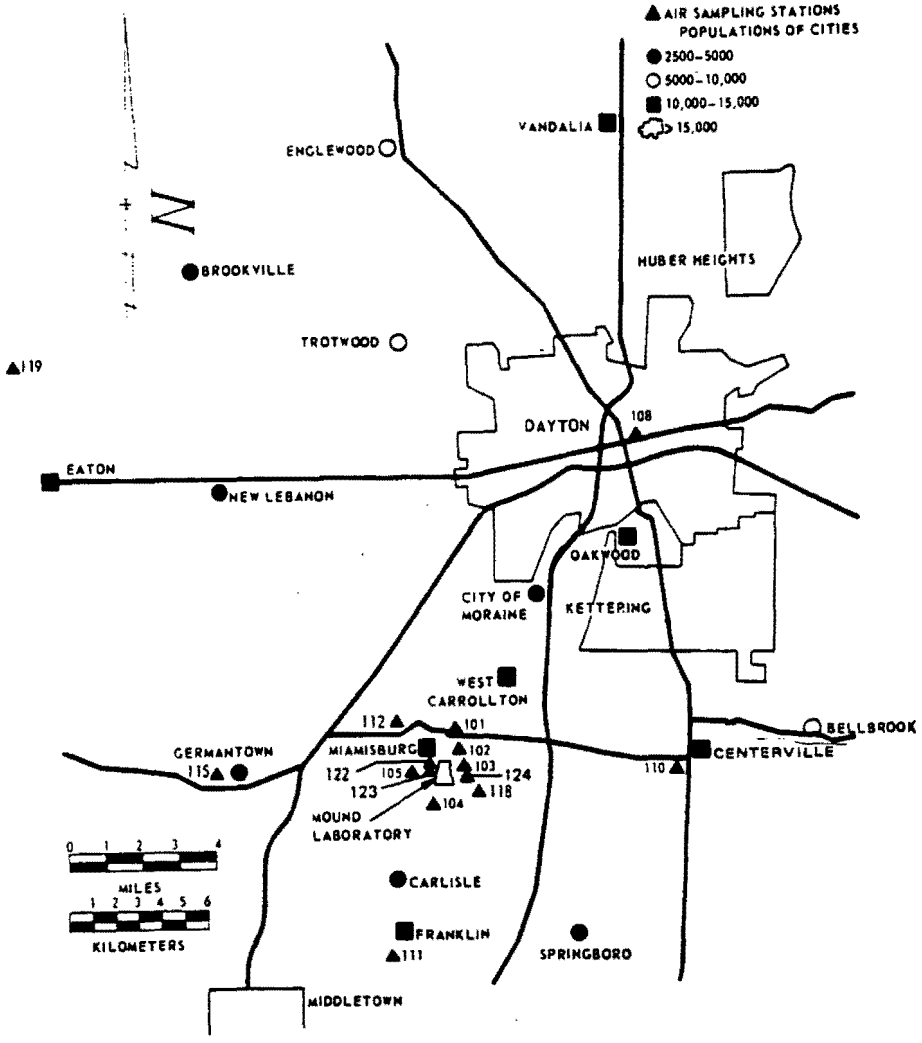

FIGURE 1 - Offsite air sampling locations.

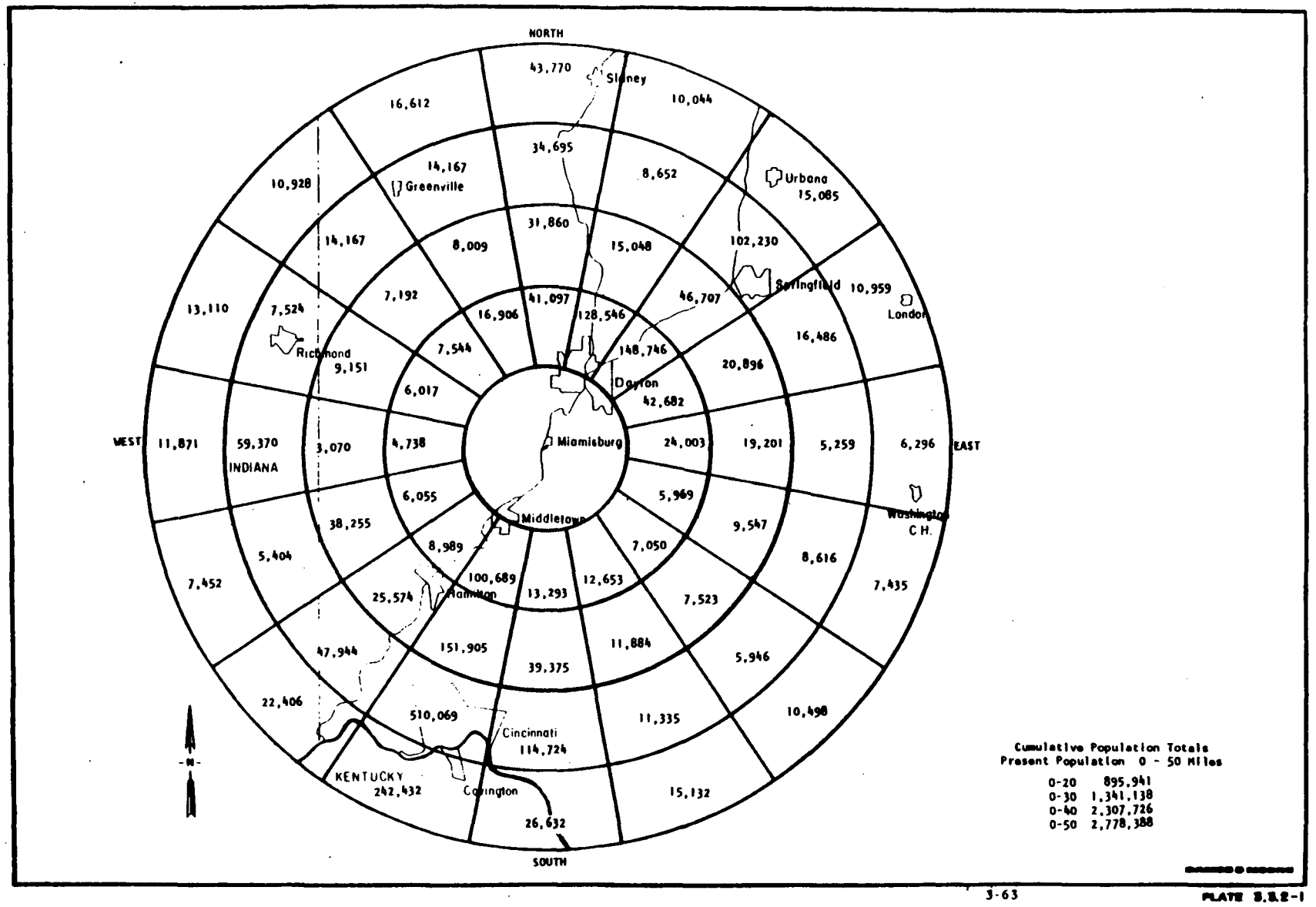

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PLATE 3.3.2-1

FIGURE 2 - 1970 population within 50 miles of Mound Facility.

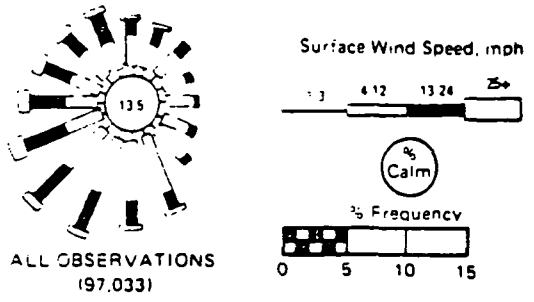

FIGURE 3 - The relative frequency and strength of winds from different directions for Wright-Patterson Air Force Base.

disposed of according to a recycling and reclamation program.

White paper, scrap metal and wood are sold for reclamation. General refuse was transported during 1977 to the Franklin Reclamation Center, Franklin, Ohio, for processing and eventual use in recycled products. Waste solvents and chemicals are removed offsite by a commercial industrial-waste-disposal firm.

Conformance to regulations prescribed by DOE pertaining to the safety of employees and the public has been demonstrated during the history of Mound Facility. The fundamental objective of the Mound Facility Environmental Control Program, which has been in existence throughout the history of the Facility, is the containment of radioactive effluents to levels well within the existing standards. As part of this function, effluents are monitored and controlled at each operating step resulting in only low-level releases of airborne or liquid wastes to the environment. Because of early detection, control techniques can be taken thus ensuring that concentrations are well within existing standards.

As part of the Mound Environmental Program monitoring functions, air, water, foodstuff, and soil samples are collected from the environment at distances up to 45 km (28 mi) from the Facility boundaries. These samples are analyzed for the specific radionuclides handled at the Facility.

A quality control program for environmental analytical procedures has been in effect for several years. There are two parts to the program: internal and external. The internal portion consists of blank and duplicate analyses for each group of samples. The blank values have been consistently small in comparison with sample values indicating good control during analytical procedures. The duplicate results for 1977 were in the range expected. Chemical recoveries were greater than 50%. The external portion of the program consists of sending duplicate samples to an independent laboratory. These results for 1977 were also satisfactory. Mound Facility participated in DOE's Quality Assurance Program conducted by the Environmental Measurements Laboratory (EML) during CY-1977. Sample media such as air, water, soil, vegetation, and tissue were analyzed for various radionuclides such as plutonium-238, plutonium-239, uranium-234, uranium-235, uranium-238, and tritium. In this program, Mound along with other facilities received and analyzed samples of various media and submitted data for comparison with EML values. Overall, the ratio of Mound to EML values averaged 0.85 ± 0.24 with a range of 0.40 to 1.14 which indicates good agreement with the Environmental Measurements Laboratory.

The results of the environmental analyses for calendar year 1977 are provided in

this report. Error limits, when given, reflect standard deviations in the data from counting statistics at the 95% confidence level. A lower detection limit (LDL) is provided for each set of data. This LDL is composed of the average blank for the set of analyses plus 2σ of the average of the blanks for those analyses involving chemical processes. The LDL for data consisting of analyses by counting procedures only is equal to 2σ of the counting error of the blank. In some special instances, where an inadequate number of blanks exist, the average blank plus 2σ of the counting error is used for those analyses involving chemical procedures.

Summary

The local environment surrounding Mound Facility was monitored for tritium and plutonium-238. The results are reported for calendar year 1977. The environmental parameters analyzed included air, water, foodstuffs, soil and silt. The average concentrations of plutonium-238 and tritium were within the applicable stringent standards for radioactive species adopted by the U. S. DOE. Mound Facility drinking water has been brought into compliance with the new EPA standard for tritium in community drinking water systems, and Mound has undertaken a program to achieve compliance for nine private wells adjacent to the Facility site. The program has partially achieved its objective by bringing Mound wells and some of the nine affected private wells in the vicinity of Mound Facility into compliance with the U. S. EPA standard and significantly reducing tritium concentration in the remaining wells. Data concerning nonradioactive species in air and water are also presented and compared to federal, state, and local standards, where applicable.

The average concentrations of plutonium-238 and tritium oxide in air measured at all offsite locations during CY-1977 were $<0.75 \times 10^{-17}$ and $<0.63 \times 10^{-11}$ μCi/ml, respectively. These correspond to <0.037% and <0.009% of their respective Radioactivity Concentration Guides (RCG). Details of the applicable standards are given in the Appendix.

The average concentrations of plutonium-238 and tritium measured at all locations in the Great Miami River during CY-1977 were $<0.27 \times 10^{-10}$ and $<1.4 \times 10^{-6}$ μCi/ml, respectively. These correspond to <0.0014% and <0.14% of the respective RCG.

The average concentrations of plutonium-238 and tritium found during CY-1977 in surface water and the drinking water of the area municipalities were also a fraction of each respective DOE RCG and EPA standard.

Although there are no specific standards (RCG) for plutonium-238 and tritium in foodstuffs, the concentrations found, if compared to the water standard, are also a small fraction of the RCG. In addition, there is no evidence of other than minimal uptake of plutonium-238 from soil. [4]

Mound Facility has been granted a National Pollutant Discharge Elimination System permit. Analyses during 1977 indicate compliance with permit conditions except for two minor exceptions involving suspended solids during July. All results indicated that Mound effluent streams have no significant effect on the Great Miami River and certainly do not cause Ohio Stream Standards to be exceeded.

The effluent data are summarized in Table 1. In addition, the person-rem calculated out to 80 km for CY-1977 was 12.2 person-rem.

These data demonstrate the status of compliance with various current regulatory agency standards.

Table 1 - EFFLUENT DATA FOR CY-1977

Radionuclide	Media	Quantity	
Tritium	air	4896	Ci
Tritium	water	56.7	Ci
Plutonium-238	air	0.012	mCi
Plutonium-238	water	2.8	mCi
Uranium-233	water	3.3	mCi

Environmental surveillance

Air - radioactive

An offsite air sampling network consisting of 14 continuously operating air-sampling stations which are used for sampling both tritium oxide and plutonium and a fifteenth sampler used for sampling plutonium only were used during CY-1977. Ten sampling stations are located approximately within a 1.6 km (1 mi) radius of the Facility and four samplers are located in or near population centers. The remaining sampler (#119) is approximately 44.8 kg (28 mi) from the Facility in the least prevailing wind direction. This site receives no measurable contribution from Mound operations and serves as a baseline sample for comparison purposes. The samplers currently in operation are located at critical distances and directions based on a diffusion model developed for Mound Facility. The locations of the sampling stations are shown in Figure 1.

Two types of samples are collected at each sampling station. One is a particulate air sample for plutonium-238 analysis and the other is a bubbler type sample for tritium oxide analysis. The particulate sample is collected on a 200-mm diameter Microsorban disk by a continuously operating (24 hr/day, 7 days/week) high-volume air sampler. The air is sampled at an average rate of 1.3×10^6 cm^3/min (~45 ft^3/min). The Microsorban disk is changed weekly and represents a sample of approximately 13,000 m^3 of air. Plutonium-238 analyses were performed on a monthly composite for three sampling locations, 122, 123 and 124, and on quarterly composites for the other offsite locations.

The analytical scheme for plutonium-238 incorporates the following basic steps: addition of a known amount of plutonium-242 tracer, ignition to 600°C, dissolution with nitric acid, separation of plutonium with anion exchange resin, electrodeposition of plutonium, and finally alpha spectrometry. The results reported represent total concentrations of the analyzed radionuclides including contribution from atmospheric fallout.

The average offsite plutonium-238 air concentration for all locations was $<0.75 \times 10^{-17}$ µCi/ml which is <0.037% of the DOE RCG. The RCG used for comparison is the guide for the soluble form of the isotope and for the general population. This is the most restrictive RCG for plutonium-238 and is applied since the solubility of the measured particles in the human body is unknown. The analytical results are summarized in Table 2. Samples reported as less than (<) the Lower Detection Limit (LDL) are, for averaging purposes, considered to be the value of LDL. This provides a conservative approach to low level environmental data.

Also included in Table 2 are ratios of plutonium-238 to plutonium-239 for each sampling location.

Table 2 - CONCENTRATIONS OF PLUTONIUM IN AIR AT OFFSITE SAMPLING LOCATIONS IN 1977

Location	Number of Samples	^{238}Pu Range (10^{-17} µCi/ml)	^{238}Pu Average[a,d] (10^{-17} µCi/ml)	Percent of RCG[b]	^{239}Pu Average[c,d] (10^{-17} µCi/ml)	$^{238}Pu/^{239}Pu$
101	51	0.15 - 3.2	1.0 ± 0.05	0.05	2.4 ± 0.13	0.42
102	52	0.52 - 1.3	0.81 ± 0.08	0.04	2.2 ± 0.13	0.39
103	51	0.42 - 0.88	0.62 ± 0.07	0.03	2.1 ± 0.13	0.30
104	52	0.22 - 0.50	0.37 ± 0.06	0.02	2.2 ± 0.13	0.17
105	52	<0.076 - 0.23	<0.15 ± 0.04	<0.01	2.0 ± 0.12	<0.08
108	48	<0.076 - 0.29	<0.15 ± 0.04	<0.01	2.7 ± 0.14	<0.06
110	51	<0.076 - 0.15	<0.09 ± 0.04	<0.01	2.3 ± 0.13	<0.04
111	52	<0.076 - 0.32	<0.21 ± 0.05	<0.01	2.5 ± 0.14	<0.08
112	48	<0.076 - 0.21	<0.16 ± 0.04	<0.01	2.1 ± 0.13	<0.08
115	51	<0.076 - 0.21	<0.13 ± 0.04	<0.01	2.5 ± 0.14	<0.05
118	51	0.25 - 1.2	0.75 ± 0.08	0.04	2.5 ± 0.14	0.30
119	51	<0.076 - 0.11	<0.10 ± 0.04	<0.01	2.1 ± 0.13	<0.05
122	47	0.61 - 6.3	2.1 ± 0.22	0.11	1.6 ± 0.19	1.3
123	52	0.54 - 9.6	2.9 ± 0.26	0.15	2.1 ± 0.22	1.4
124	52	0.35 - 4.2	1.7 ± 0.20	0.09	2.4 ± 0.23	0.71

[a]Lower Detection Limit (LDL) for ^{238}Pu in air for samplers 101 through 119 is 0.076×10^{-17} µCi/ml and the LDL for samplers 122 through 124 is 0.258×10^{-17} µCi/ml. This is 0.004% and 0.013%, respectively of the RCG.

[b]Radioactivity Concentration Guide (RCG) = 2000×10^{-17} µCi/ml for the soluble form of ^{238}Pu for the general population.

[c]The LDL for ^{239}Pu in air for samplers 101 through 119 is 0.033×10^{-17} µCi/ml and the LDL for samplers 122 through 124 is 0.121×10^{-17} µCi/ml.

[d]Error limits include only counting statistics at 95% confidence level.

The gas bubbler sample is also collected on a continuous basis by bubbling air at approximately 3×10^3 cm^3/min through 200 ml of ethylene glycol. Ethylene glycol is used because this material eliminates evaporation and freezing problems associated with sample collection [5]. Any tritium (oxide) in the air is collected in the solution. Tritium oxide rather than elemental tritium is sampled and analyzed because the RCG for the oxide is 200 times more restrictive than it is for elemental tritium [6]. A sample representing ~30 m^3 of air is collected and an

aliquot representing 1.5 m^3 is counted in a liquid scintillation spectrometer. The average concentration of tritium oxide measured during CY-1977 for all offsite locations was <0.63 x 10^{-11} µCi/ml which is <0.009% of RCG. The RCG used for comparison is the most restrictive RCG for tritium for the general population. The results are summarized in Table 3. Table 4 shows background values for plutonium-238 and tritium in air and water.

An onsite perimeter network consisting of five continuous, high-volume air samplers is used to further assess the effectiveness of stack emission control systems. The onsite sampling locations are shown in Figure 4. Particulate samples are collected by the onsite samplers at approximately the same flow rate as the offsite samplers, i.e., 1.3 x 10^6 cm^3/min, and are analyzed in the same manner. The tritium samplers operate at slightly less air flow, i.e., approximately 2 x 10^3 cm^3/min, and are analyzed in the same manner as offsite samplers.

Table 3 - CONCENTRATIONS OF TRITIUM OXIDE IN AIR AT OFFSITE SAMPLING LOCATIONS IN 1977

Location	Number of Samples	Tritium Oxide Range (10^{-11} µCi/ml)	Tritium Oxide Average[a,c] (10^{-11} µCi/ml)	Percent of RCG[b]
101	52	<0.29 - 2.16	<0.64 ± 0.43	<0.009
102	52	<0.29 - 9.73	<1.24 ± 0.44	<0.018
103	52	<0.29 - 2.77	<0.72 ± 0.43	<0.010
104	52	<0.29 - 1.27	<0.44 ± 0.42	<0.006
105	52	<0.29 - 1.45	<0.40 ± 0.42	<0.006
108	52	<0.29 - 0.94	<0.37 ± 0.42	<0.005
110	52	<0.29 - 1.22	<0.40 ± 0.42	<0.006
111	52	<0.29 - 7.53	<0.62 ± 0.43	<0.009
112	52	<0.29 - 2.10	<0.59 ± 0.43	<0.008
115	52	<0.29 - 2.66	<0.56 ± 0.42	<0.008
118	52	<0.29 - 2.37	<0.57 ± 0.42	<0.008
119	51	<0.29 - 2.33	<0.44 ± 0.42	<0.006
123	52	<0.29 - 4.36	<0.88 ± 0.43	<0.013
124	52	<0.29 - 5.98	<0.94 ± 0.43	<0.013

[a]Lower Detection Limit (LDL) for tritium oxide in air is 0.29 x 10^{-11} µCi/ml which is 0.004% of the RCG.

[b]Radioactivity Concentration Guide (RCG) = 7000 x 10^{-11} µCi/ml for the general population and for soluble form of tritium.

[c]Error limits include only counting statistics at 95% confidence level.

Table 4 - CONCENTRATIONS OF BACKGROUND LEVELS OF TRITIUM AND PLUTONIUM-238

Plutonium-238 in Air[a]	0.3 ± 0.1 x 10^{-17} µCi/ml
Plutonium-238 in Surface Water[b]	7 x 10^{-13} µCi/ml
Tritium Oxide in Air[c]	0.2 x 10^{-11} µCi/ml
Tritium in Surface and Ground Water[d]	0.9 x 10^{-6} µCi/ml

[a]References 7, 8
[b]Reference 9
[c]Reference 10
[d]Reference 11

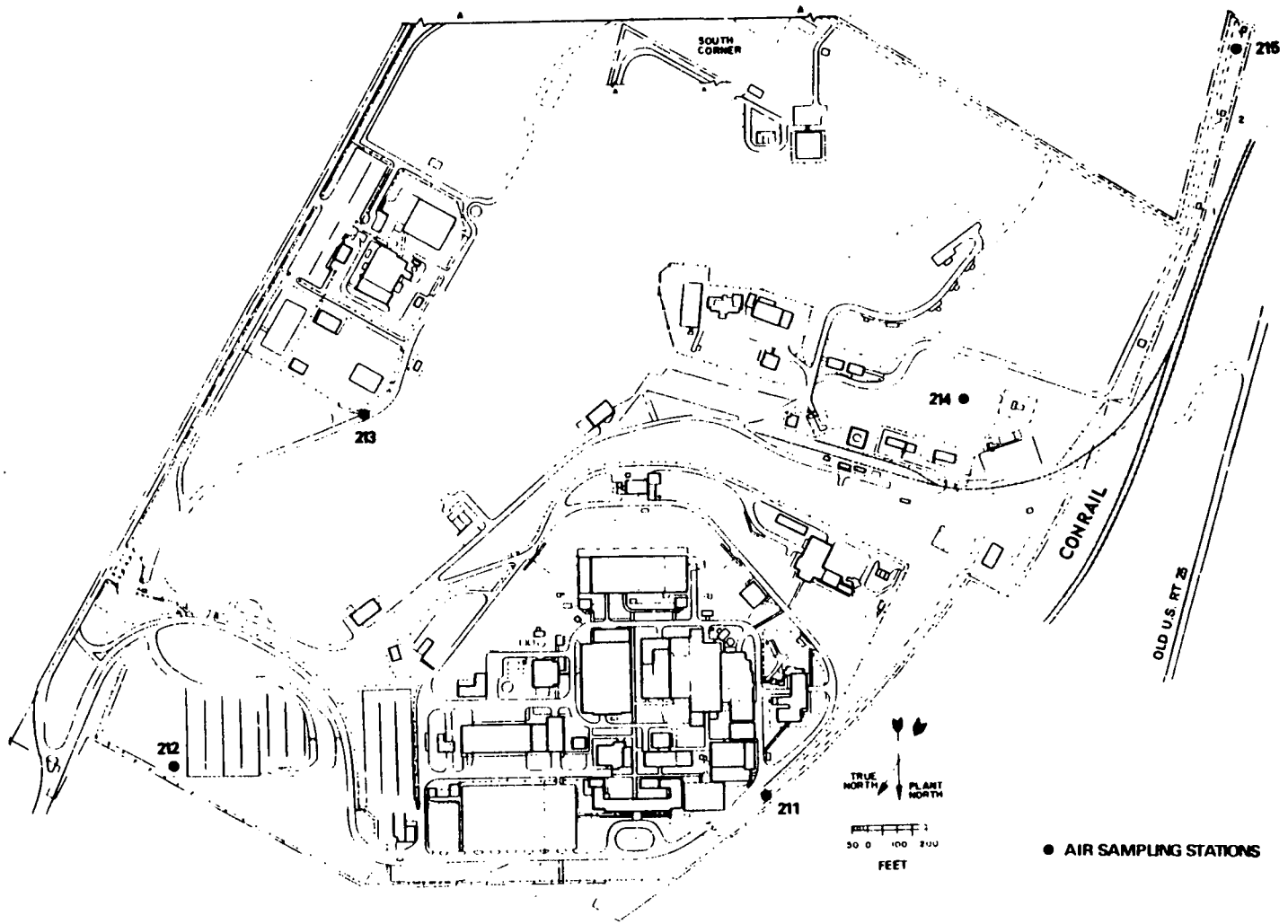

FIGURE 4 - Onsite air sampling locations.

The average plutonium-238 concentration measured for all locations onsite was 4.02×10^{-17} µCi/ml which is 0.057% of the RCG. The results are summarized in Table 5.

The average onsite tritium oxide concentration for all locations was $<2.0 \times 10^{-11}$ µCi/ml which is <0.01% of the RCG. The results are summarized in Table 6.

Table 5 - CONCENTRATION OF ^{238}Pu IN AIR AT ONSITE SAMPLING LOCATIONS IN 1977

Location	Number of Samples	^{238}Pu Range (10^{-17} µCi/ml)	^{238}Pu Average[a,d] (10^{-17} µCi/ml)	Percent of RCG[b]	^{239}Pu Average[c] (10^{-17} µCi/ml)
211	43	2.4 - 10.1	5.1 ± 0.34	0.07	2.0 ± 0.22
212	43	0.98 - 11.7	2.5 ± 0.24	0.04	1.9 ± 0.21
213	43	4.2 - 14.8	8.1 ± 0.42	0.12	3.1 ± 0.27
214	43	0.98 - 8.5	3.1 ± 0.27	0.04	1.9 ± 0.21
215	43	0.37 - 2.9	1.3 ± 0.18	0.02	<1.7 ± 0.20

[a]Lower Detection Limit (LDL) for ^{238}Pu in air is 0.258×10^{-17} µCi/ml which is 0.004% of the RCG.

[b]Radioactivity Concentration Guide (RCG) = 7000×10^{-17} µCi/ml for the soluble form of plutonium-238 for individuals in the population.

[c]Lower Detection Limit (LDL) for ^{239}Pu in air is 0.121×10^{-17} µCi/ml.

[d]Error limits include only counting statistics at 95% confidence level.

Table 6 - CONCENTRATION OF TRITIUM OXIDE IN AIR AT ONSITE SAMPLING LOCATIONS IN 1977

Location	Number of Samples	Tritium in Oxide Range (10^{-11} µCi/ml)	Tritium in Oxide Average[a,c] (10^{-11} µCi/ml)	Percent of RCG[b]
211	51	<0.73 - 27.8	<1.8 ± 1.1	<0.009
212	40	<0.73 - 14.3	<3.0 ± 1.1	<0.015
213	35	<0.73 - 6.7	<2.0 ± 1.1	<0.010
214	52	<0.73 - 6.8	<1.6 ± 1.1	<0.008
215	52	<0.73 - 6.4	<1.6 ± 1.1	<0.008

[a]Lower Detection Limit (LDL) for tritium oxide in air is 0.73×10^{-11} µCi/ml which is 0.004% of the RCG.

[b]Radioactivity Concentration Guide (RCG) = $20,000 \times 10^{-11}$ µCi/ml for individuals in the population and soluble form of tritium.

[c]Error limits include only counting statistics at 95% confidence level.

The RCGs used for onsite comparisons are those applicable for exposed individuals in the population. The total amounts of plutonium-238 and tritium discharged to the atmosphere were 0.012 mCi and 4896 Ci respectively. Comparison of these quantities to the RCG is not valid.

Air - nonradioactive

The Mound steam power supply has been converted from fuel oil to natural gas (on an interruptable basis). During unusually cold weather, natural gas supply to Mound is interrupted, and fuel oil with <1% sulfur content is burned. The average sulfur content of the fuel oil burned was approximately 0.4%. During 1977 Mound steam supply was fired almost equally by fuel oil and natural gas. Approximately 990,000 gal of No. 2 fuel oil were burned.

Additional sources of airborne emissions are as follows. A water-wash, paint spray booth is operated intermittently in the Mound paint shop. Wastes from operations involving explosives are disposed of by open burning. A shipping container fire test facility for testing shipping containers for radioactive wastes is used on the average of once per month. A maintenance grinding operation and a carpenter shop are also operated on an intermittent basis. Firefighter training excercises are held at an open outdoor facility.

Emissions from sources registered with the Regional Air Pollution Control Agency (RAPCA) and the Ohio EPA which have applicable emission standards are summarized in Table 7. The emissions were estimated from emission factors established by the USEPA or from material balances [12]. The emission from the shipping container fire test facility is controlled with a forced air supply and water spray nozzles at the fuel-flame interface to an average opacity of <20%. The particulates from the grinding and carpenter shop operations are captured by cyclone air cleaners rated at 95% efficiency. Nonradioactive airborne emissions at Mound Facility were all within applicable standards and had minimal impact on ambient air quality. This is further demonstrated by the particulate concentration data summarized in Table 8. The data presented are weekly particulate concentrations measured at Mound's offsite air sampling sites. The particulate concentration appears to be independent of distance from Mound which demonstrates no influence from Mound operations. For comparison purposes, the State of Ohio - Ambient Air Quality Standard for airborne particulates is 60 $\mu g/m^3$.

Water - Radioactive

Water sampling locations along the bank of the Great Miami River were selected according to guidelines recommended by the U. S. EPA [13]. The locations, shown in Figure 5, provide samples which are representative of river water after suitable mixing of the effluent from Mound has occurred. Water samples are normally collected at these locations five days per week and are subjected to specific analyses for plutonium-238 and tritium.

The plutonium-238 river water analyses have been improved by a procedure developed at Mound Facility to maximize the sensitivity in detection of plutonium-238 in water. Large volume water samples are analyzed by compositing daily samples for a semiannual

Table 7 - NONRADIOACTIVE AIRBORNE EMISSIONS 1977

Emission Source	Pollutant	Emission	Emission Standard[a]	% of Standard
Power House	Particulates	0.12 lb/10^6 Btu Input	0.25 lb/10^6 Btu Input	48
Power House	Sulfur Oxides	0.39 lb/10^6 Btu Input	1.6 lb/10^6 Btu Input	24
Paint Shop	Organics	0.32 lb/day	40 lb/day	0.8
Explosives Burning Area	Particulates	∿ 10 lb/yr	NA	NA
Firefighter Training	Particulates	∿ 330 lb	NA	NA

[a]Ohio EPA Air Pollution Regulations 3745-1701 through 3745-17-13 and 3745-21-01 through 3745-21-08.

NA - not applicable.

Table 8 - 1977 WEEKLY PARTICULATE CONCENTRATION DATA[a]

Location	Range (μg/m^3)	Average (μg/m^3)
101	13-189	72
102	19-123	56
103	16- 84	40
104	16-131	56
105	24- 91	45
108	16-143	72
110	15- 88	44
111	21-123	63
112	17- 98	45
115	22-110	50
118	13-113	52
119	2- 94	33
122	21-123	43
123	31-108	51
124	5-100	47

[a]Ohio Ambient Air Quality Standard = 60 μg/m^3

These data are obtained by Mound's air monitoring program and are indicative only of the particulate air loading in the Dayton metropolitan area. Mound's particulate discharges presented in Table 7 make a negligible contribution to the surrounding area.

analysis. The average concentration of plutonium-238 measured for all locations in the Great Miami River was <0.27 x 10^{-10} μCi/ml which is <0.0014% of the RCG for the general population and the most restrictive standard for plutonium-238. These results are summarized in Table 9.

Tritium analyses are performed on a weekly composite of daily samples. The average concentration of tritium measured at all locations in the Great Miami River was <1.4 x 10^{-6} μCi/ml which is <0.14% of the RCG for the general population and the most restrictive standard for tritium. These results are summarized in Table 10.

Results of plutonium-238 and tritium analysis for three offsite sampling locations on the abandoned Miami-Erie Canal and adjacent ponds shown in Figure 6 are reported in Tables 11 and 12, respectively. However, two of these locations, 6 and 7, went dry during the early part of the year which

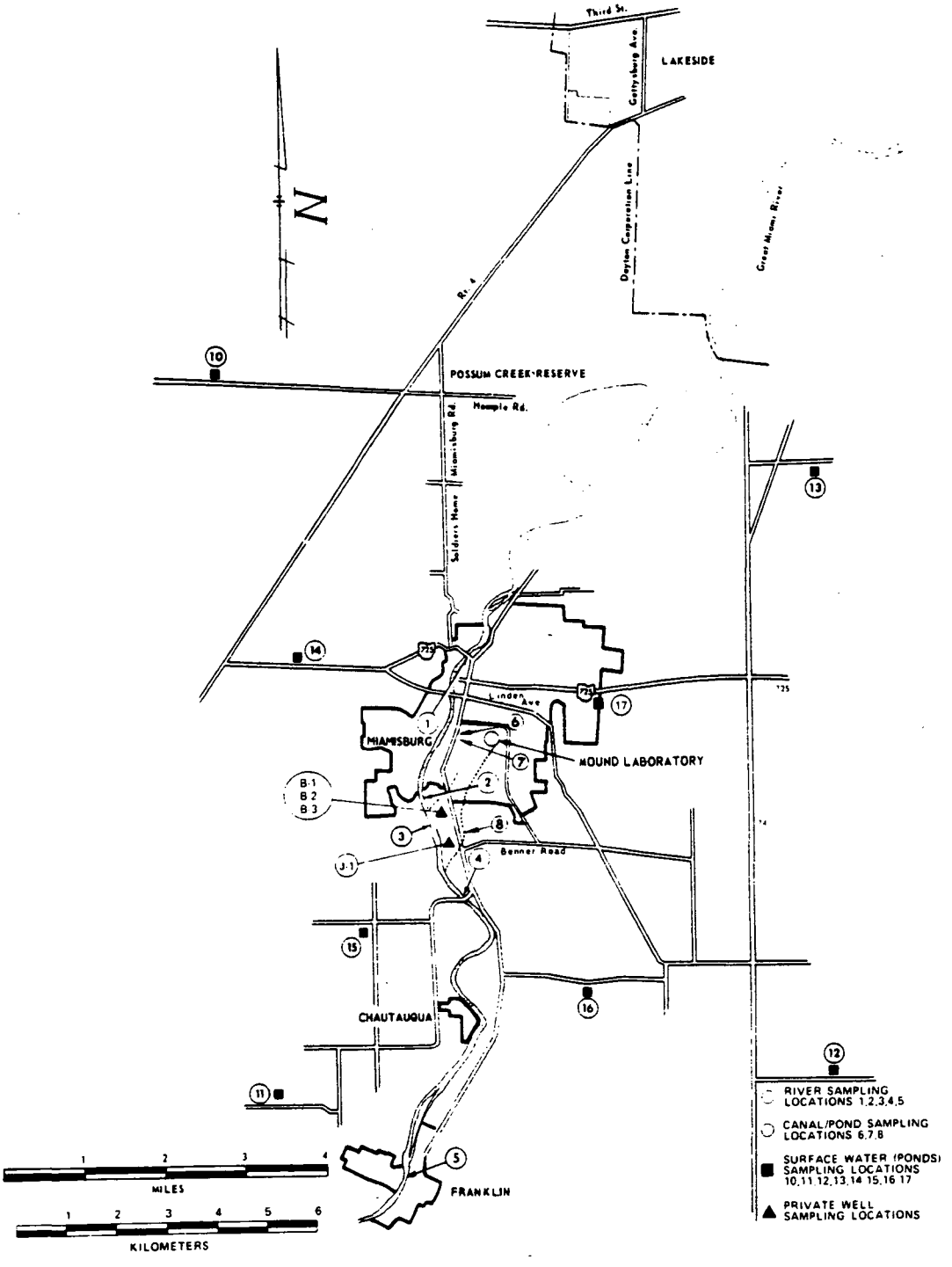

FIGURE 5 - Offsite water sampling locations.

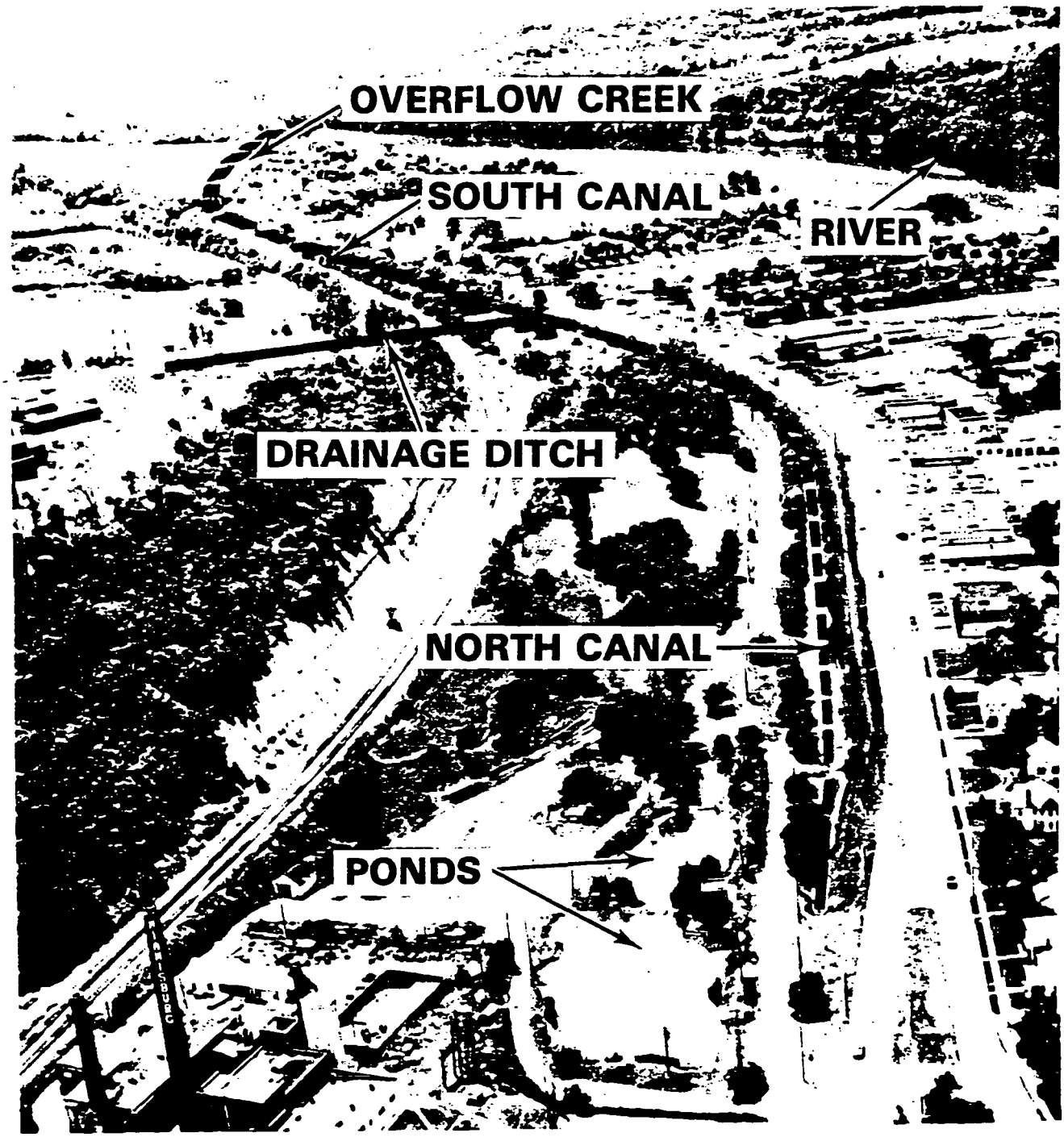

FIGURE 6 - Aerial view (from the north) of offsite abandoned canal and pond system.

Table 9 - CONCENTRATION OF ^{238}Pu IN THE GREAT MIAMI RIVER IN 1977

Location	Number of Samples[a]	^{238}Pu Range (10^{-10} µCi/ml)	^{238}Pu Average[b,d] (10^{-10} µCi/ml)	Percent of RCG[c]
1	210	-	<0.10 ± 0.01	<0.0005
2	210	<0.1 - 0.21	<0.16 ± 0.02	<0.0008
3	210	0.16 - 0.23	0.20 ± 0.01	0.0010
4	210	<0.1 - 1.5	<0.80 ± 0.05	<0.0040
5	210	-	<0.10 ± 0.03	<0.0005

[a]Two composite large volume water samples for each location from water collected during CY-1977.

[b]Lower Detedtion Limit (LDL) for ^{238}Pu in water is 0.1×10^{-10} µCi/ml which is 0.0005% of the RCG.

[c]Radioactivity Concentration Guide (RCG) = $20,000 \times 10^{-10}$ µCi/ml for the general population and the soluble form of plutonium-238.

[d]Error limits include only counting statistics at 95% confidence level.

Table 10 - CONCENTRATION OF TRITIUM IN THE GREAT MIAMI RIVER IN 1977

Location	Number of Samples	Tritium Range (10^{-6} µCi/ml)	Tritium Average[a,c] (10^{-6} µCi/ml)	Percent of RCG[b]
1	210	<0.20 - 4.3	<1.0 ± 0.35	<0.10
2	210	<0.20 - 16.8	<1.5 ± 0.36	<0.15
3	210	<0.20 - 8.3	<1.9 ± 0.36	<0.19
4	210	<0.20 - 23.4	<1.6 ± 0.36	<0.16
5	210	<0.20 - 4.5	<1.0 ± 0.35	<0.10

[a]Lower Detection Limit (LDL) for tritium in water is 0.20×10^{-6} µCi/ml which is 0.02% of the RCG.

[b]DOE Radioactivity Concentration Guide (RCG) which is compared to tritium concentration in water not used for drinking purposes = 1000×10^{-6} µCi/ml for the general population and the soluble form of tritium.

[c]Error limits include only counting statistics at 95% confidence level.

Table 11 - CONCENTRATION OF ^{238}Pu IN WATER FROM CANAL/POND AREA IN 1977

Location[a]	Number of Samples[b]	^{238}Pu Range (10^{-10} µCi/ml)	^{238}Pu Average[c,e] (10^{-10} µCi/ml)	Percent of RCG[d]
8 (South Canal)	210	26.0 - 45.0	35.5 ± 0.20	0.18

[a]Locations are shown in Figure 5.

[b]Two composite large volume water sample for each location from water collected during CY-1977.

[c]Lower Detection Limit (LDL) for ^{238}Pu in Water is 0.1×10^{-10} µCi/ml which is 0.0005% of the RCG.

[d]Radioactivity Concentration Guide (RCG) = $20,000 \times 10^{-10}$ µCi/ml for the general population and soluble form of plutonium-238.

[e]Error limits include only counting statistics at 95% confidence level.

Table 12 - CONCENTRATION OF TRITIUM IN WATER FROM CANAL/POND AREA IN 1977

Location[a]	Number of Samples	Tritium Range (10^{-6} µCi/ml)	Tritium Average[b,d] (10^{-6} µCi/ml)	Percent of RCG[c]
6 (North Pond)	20	6.8 - 11	8.9 ± 0.46	0.89
7 (North Canal)	12	0.6 - 7.7	5.2 ± 0.41	0.52
8 (South Canal)	200	4.7 - 44	24 ± 0.63	2.4

[a]Locations are shown in Figure 5.

[b]Lower Detection Limit (LDL) for tritium in water is 0.2×10^{-6} µCi/ml which is 0.02% of the RCG.

[c]DOE Radioactivity Concentration Guide (RCG) which is compared to tritium concentration in water not used for drinking purposes = 1000×10^{-6} µCi/ml for the general population and soluble form of tritium.

[d]Error limits include only counting statistics at 95% confidence level.

prevented samples from being taken. Total annual data on sample location 8, however, is shown. These values represent levels from the site drainage ditch which discharges into the offsite canal-pond system prior to mixing with the Great Miami River. These values, as expected, are higher than those concentrations found in the Great Miami River where mixing and dilution occur. The total amounts of plutonium-238, tritium and uranium-233 discharged to the Great Miami River were 2.8 mCi, 56.7 Ci, and 3.3 mCi, respectively. The concentrations were 0.09%, 2.3%, and 0.01% of the most restrictive RCG for individuals in the population. From the uranium-233 concentrations found in the effluent streams, estimated concentrations offsite from Mound operations would be undistinguishable from any background. This can be readily seen by comparing plutonium-238 quantities found in the effluent streams with concentrations found offsite.

Eight additional surface water locations such as ponds in all quadrants surrounding Mound Facility are sampled annually. These samples, used for plutonium-238 determination, are large volume water samples of approximately 40 liters each. The large volume of sample increases the sensitivity of the analysis. A smaller aliquot (10 ml) was taken for the tritium analysis. The average concentrations of plutonium-238 and tritium for all locations were $<0.1 \times 10^{-10}$ and $<1.01 \times 10^{-6}$ µCi/ml, respectively, which are <0.0005% and <0.10% of the respective RCG for the general population. The results of the surface water samples are summarized in Tables 13 and 14. Background levels of plutonium-238 and tritium for the surface water are shown in Table 5.

Drinking water from communities in the surrounding area is sampled and analyzed annually for tritium with the exception of drinking water from Miamisburg which is sampled and analyzed quarterly. These communities and their relative locations are shown in Figure 1. The average concentration of tritium for all locations was 1.1×10^{-6} µCi/ml which is 5.5% of the new standard which was adopted by the U. S. EPA in 1977 for community drinking water systems. Data from the analyses of community drinking water samples are summarized in Table 15.

Several private wells in the vicinity of Mound Facility were analyzed semi-monthly for for tritium. The average concentration in these wells was 35.3×10^{-6} µCi/ml. Although these wells were always well within the prevailing AEC and ERDA standard for tritium effluent and drinking water, the U. S. EPA's new drinking water standards for radiological, biological, and chemical elements in water, which became effective in June 1977, placed some of the wells in a noncompliance status because the new standard for radioactivity is 50 times less than the old standard. The average concentration for 1977 exceeds the new standard by a factor of 1.8.

Private well analyses results are summarized in Table 16. As shown by the data, concentrations in these wells are higher than in municipal wells in the area. This situation resulted from Mound Facility releasing tritiated waste water to the Great Miami River via the site drainage ditch and Miami-Erie Canal over a period of years prior to 1970. Some of the water migrated into the aquifer adjacent to Mound Facility and increased the concentration of tritium in the aquifer.

Table 13 - SUMMARY OF SURFACE WATER MONITORING FOR PLUTONIUM-238 in 1977

Location	Number of Samples[a]	^{238}Pu Range (10^{-10} µCi/ml)	^{238}Pu Average[b,d] (10^{-10} µCi/ml)	Percent of RCG[c]
10	210	<0.1 - 0.13	<0.12 ± 0.02	<0.0006
11	210	-	<0.1 ± 0.01	<0.0005
12	210	-	<0.1 ± 0.01	<0.0005
13	210	-	<0.1 ± 0.01	<0.0005
14	210	-	<0.1 ± 0.01	<0.0005
15	210	-	<0.1 ± 0.01	<0.0005
16	210	-	<0.1 ± 0.01	<0.0005
17	210	-	<0.1 ± 0.01	<0.0005

[a]Two composite large volume water samples were used for each location.

[b]Lower Detection Limit (LDL) for ^{238}Pu in water is 0.1 x 10^{-10} µCi/ml which is 0.0005% of the RCG.

[c]Radioactivity Concentration Guide (RCG) for ^{238}Pu in water = 20,000 x 10^{-10} µCi/ml for the general population and soluble form of plutonium-238.

[d]Error limits include only counting statistics at 95% confidence level.

Table 14 - SUMMARY OF SURFACE WATER MONITORING FOR TRITIUM IN 1977

Location	Number of Samples	Tritium Range (10^{-6} µCi/ml)	Tritium Average[a,c] (10^{-6} µCi/ml)	Percent of RCG[b]
10	3	<0.4 - 1.4	<0.8 ± 0.6	<0.08
11	4	<0.4 - 0.9	<0.6 ± 0.6	<0.06
12	4	<0.4 - 0.7	<0.5 ± 0.6	<0.05
13	4	1.0 - 1.3	1.1 ± 0.6	0.11
14	4	<0.4 - 1.4	<1.1 ± 0.6	<0.11
15	4	0.8 - 1.5	1.3 ± 0.6	0.13
16	4	0.6 - 1.0	0.8 ± 0.6	0.08
17	3	1.5 - 2.3	1.9 ± 0.6	0.19

[a]Lower Detection Limit (LDL) for tritium in water is 0.4 x 10^{-6} µCi/ml which is 0.04% of the RCG.

[b]DOE Radioactivity Concentration Guide (RCG) which is compared to tritium concentration in water not used for drinking purposes = 1000 x 10^{-6} µCi/ml for the general population and soluble form of tritium.

[c]Error limits include only counting statistics at 95% confidence level.

Table 15 - SUMMARY OF TRITIUM LEVELS IN COMMUNITY DRINKING WATER IN 1977

Location	Number of Samples	Tritium Range (10^{-6} µCi/ml)	Tritium Average[a,c] (10^{-6} µCi/ml)	Percent of RCG[b]
Bellbrook	1	-	0.5 ± 0.4	2.5
Centerville	1	-	1.1 ± 0.4	5.5
Dayton	1	-	0.5 ± 0.4	2.5
Franklin	1	-	1.3 ± 0.4	6.5
Germantown	1	-	0.8 ± 0.4	4.0
Kettering	1	-	0.8 ± 0.4	4.0
Miamisburg	3	1.9 - 4.6	2.8 ± 0.6	14.0
Middletown	1	-	0.9 ± 0.4	4.5
Moraine	1	-	0.7 ± 0.4	3.5
Springboro	1	-	1.3 ± 0.4	6.5
Waynesville	1	-	0.6 ± 0.4	3.0
West Carrollton	1	-	2.0 ± 0.4	10.0

[a]Lower Detection Limit (LDL) for tritium oxide is 0.25 x 10^{-6} µCi/ml which is 1.2% of the EPA Standard for community drinking water.

[b]EPA Drinking Water Standard for tritium = 20 x 10^{-6} µCi/ml for community drinking water systems.

[c]Error limits include only counting statistics at 95% confidence level.

Table 16 - TRITIUM IN PRIVATE WELLS IN 1977

Location	Number of Samples	Tritium Range (10^{-6} µCi/ml)	Tritium Average[a,b,d] (10^{-6} µCi/ml)	Percent Standard[c]
B-1	25	33.0 - 59.0	46.7 ± 1.4	233
B-2	25	23.6 - 35.7	29.9 ± 1.1	149
B-3	25	22.4 - 37.3	31.1 ± 1.2	155
J-1	24	19.4 - 49.3	33.3 ± 1.2	165

[a]These concentrations are the average levels for 1977. The latest data obtained in March 1978 show that these levels have been reduced considerably as follows: B-1 = 22.6, B-2 = 22.3, B-3 = 20.9, and J-1 = 27.4 (x 10^{-6} µCi/ml). All wells are approaching compliance with the new EPA standard of 20 x 10^{-6} µCi/ml.

[b]Lower Detection Limit (LDL) for tritium in water is 0.4 x 10^{-6} µCi/ml which is 0.04% of the EPA Standard.

[c]EPA Standard for tritium in community drinking water systems = 20 x 10^{-6} µCi/ml. Mound is using the EPA Standard as a guide for the private water supplies.

[d]Error limits include only counting statistics at 95% confidence level.

There is no health problem associated with the levels of tritium in local water supplies although they exceed the new EPA standard. The EPA's very conservative regulations for tritium are essentially a nondegradation standard and are not based on new toxicological or epidemiological evidence of deleterious health effects and do not condemn water supplies that exceed the new standards.

Since 1970, changes in operating procedures reduced the Mound Facility tritium effluent concentration by a factor of almost 50 and resulted in a continuing decrease of tritium in the private wells. In order to accelerate the rate at which tritium was being dissipated from the aquifer and to achieve compliance of the private wells with the new EPA standard at the earliest possible time, Mound initiated a forced water-turnover program for the aquifer using a high-capacity well at the Mound site and an old well no longer used by the City of Miamisburg. These wells pumped continuously from spring of 1977 for the remainder of the year. Increased water infiltration to and discharge from the aquifer have brought some of the wells into compliance with the EPA standard. It is anticipated that the pumping program will result in all private wells achieving compliance during 1978. This program has been approved by the Ohio EPA and U. S. EPA. Mound has a continuing commitment to keep these agencies appraised of the program progress to achieve compliance by the affected wells.

A study to determine the impact of rainout of tritium from airborne emissions of tritium was conducted during 1977. Precipitation samples were collected at various locations around Mound Facility and analyzed for tritium. In addition, on several occasions, rainwater runoff was collected and analyzed.

The total 1977 rainfall was 34.88 in., with an average tritium concentration of 4 nCi/liter. A calculated total of 10.94 Ci of tritium was in the rainfall over an area of 1-km radius around Mound Facility during the year, of which an estimated 2.3 Ci infiltrated the aquifer. This represents less than 0.1% of the total tritium released to the atmosphere from Mound Facility and only 7% of the total amount withdrawn from the aquifer during the aquifer pumping program. Because a large portion of the total collected tritium fell during periods of heavy rain, with a resultant increased runoff, the total contribution to the aquifer could be much lower than 2.8 Ci.

Runoff water exhibited an average tritium concentration of 5 nCi/liter and never exceeded 10 nCi/liter. This concentration is well within the U. S. EPA standard for drinking water and is similar to the measured average tritium concentration in rain water.

Two private wells and Miamisburg city water were sampled and analyzed monthly for plutonium-238. These samples were large volume water samples averaging 40 liters. The average plutonium-238 concentration for these locations was $<0.46 \times 10^{-10}$ µCi/ml which is <0.002% of the applicable DOE RCG for the general population. These results are shown in Table 17.

Water - Nonradioactive

Mound Facility has a discharge permit under the National Pollutant Discharge Elimination System (NPDES) issued by Region V of the U. S. EPA. The permit specifies

Table 17 - PLUTONIUM-238 IN PRIVATE WELLS AND MIAMISBURG MUNICIPAL DRINKING WATER IN 1977

Location	Number of Samples[a]	^{238}Pu Range (10^{-10} µCi/ml)	^{238}Pu Average[b,d] (10^{-10} µCi/ml)	Percent of RCG[c]
Miamisburg	2	-	<0.1 ± 0.01	<0.0005
B-1	2	-	<0.1 ± 0.01	<0.0005
B-2	2	-	<0.1 ± 0.01	<0.0005
B-3	2	0.21 - 2.8	1.5 ± 0.08	0.0075
J-1	2	<0.1 - 0.9	<0.5 ± 0.02	<0.0025

[a]Two composite large volume water samples were analyzed from each location from water collected during CY-1977.

[b]Lower Detection Limit (LDL) for ^{238}Pu is 0.1 x 10^{-10} µCi/ml which is 0.0005% of the RCG.

[c]Applicable DOE Radioactivity Concentration Guide (RCG) for ^{238}Pu in water = 20,000 x 10^{-10} µCi/ml for the general population and soluble form of ^{238}Pu.

[d]Error limits include only counting statistics at 95% confidence level.

limitations for pollutants in the two effluent streams from Mound that discharge to the Great Miami River. The discharge from outfall number 001 includes the discharge from the sanitary waste treatment plant, radioactive waste disposal facility, single-pass cooling water, zeolite softener backwash, and some storm water runoff. The discharge from outfall number 002 consists of single-pass cooling water, cooling-tower blowdown, boiler-plant blowdown, zeolite softener backwash, and most of the storm water runoff. A 24-hr composite sample of each effluent stream is collected automatically. The volume of samples collected is proportional to the flow in the stream. The composite effluent water samples are analyzed for water quality parameters according to standard methods [14]. The results of effluent stream analyses for 1977 are summarized in Tables 18 and 19. Only two exceptions occurred during 1977. The exceptions were slightly elevated suspended solids discharged from outfall 001 during July. These waterborne effluents had no significant effect on the River since the river flow, even under low flow conditions, was approximately 350 times the maximum flow discharge from Mound during 1977. These data show that the Mound releases to the Miami River did not cause the Ohio Stream Standards to be exceeded.

Foodstuffs and vegetation - radioactive

Various locally grown foodstuffs and vegetation samples are collected from the surrounding area. The intent of this portion of the Environmental Monitoring Program is to determine whether there is any uptake and concentration of radionuclides by plant or animal life. Where possible, sampling sites are chosen at maximum deposition locations predicted on the basis of the diffusion model developed for Mound Facility [15]. Field crops and vegetables are collected on the basis of this diffusion model. Milk is collected from individual farms closest to the Facility. Aquatic life is trapped from the Miami River generally

Table 18 - 1977 NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM PERMIT DATA FOR STATION 001[a]

Parameter		No. Samples	Minimum	Maximum	Average
Flow, MGD	Reported	Cont.	0.07	0.34	0.18
	Permit			0.92	0.53
BOD_5	Reported	88	0.3	7.3	2.2
	Permit			45	30.0
Fecal Coliform	Reported	12	ND	52	15
	Permit			400	200
Suspended Solids	Reported	104	1.2	32.5	12
	Permit			45	30
Dissolved Oxygen	Reported	240	5.2	10.9	8.4
	Permit				5
Residual Chlorine	Reported	52	ND	0.6	0.1
	Permit			0.8	
Oil and Grease	Reported	52	ND	8.1	1.3
	Permit			10	
pH	Reported	240	6.2	9.0	
	Permit		6.0	9.0	
Organic Carbon	Reported	52	1	86	30
Ammonia	Reported	20	0.1	0.1	0.1

[a]ND - none detectable.

MGD - million gallons per day.

Values for fecal coliform are number of coliform per 100 ml of water and pH is reported in pH units.

All other values are in milligrams per liter.

Standards are those in effect through June 30, 1977. More restrictive standards went into effect on July 1. These are given in the Appendix.

Table 19 - 1977 NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM PERMIT DATA FOR STATION 002[a]

Parameter		No. Samples	Minimum	Maximum	Average
Flow, MGD	Reported	Cont.	0.18	0.90	0.38
	Permit				0.53
Suspended Solids	Reported	68	3.0	24.6	10.6
	Permit			25.0	20.0
Dissolved Oxygen	Reported	22	5.1	12.0	9.2
	Permit				>5.0
Residual Chlorine	Reported	38	<0.05	0.05	<0.05
	Permit			0.10	
Oil and Grease	Reported	40	ND	7.0	0.8
	Permit			10.0	
pH	Reported	180	6.0	9.0	
	Permit		6.0	9.0	
Dissolved Solids	Reported	65	242	2918	913
	Permit			3000	2000

[a]ND - none detectable.

MGD - million gallons per day.

All other values are in milligrams per liter, except pH.

Standards are those in effect through June 30, 1977. More restrictive standards went into effect on July 1. These are given in the Appendix.

downstream of Miamisburg and from adjacent waterways, depending upon availability of fish. Grass samples are collected in the vicinity of the surface water locations shown in Figure 5. The plutonium-238 content of the foodstuff and vegetation samples including milk is determined by ashing the samples and then proceeding with the same techniques used for plutonium-238 analyses of air samples (see section on Air - Radioactive). Milk samples are analyzed for tritium oxide by distilling the water fraction from an aliquot. The distillate is then analyzed for tritium by liquid scintillation spectrometry in the same manner as the water samples (see section on Water - Radioactive). The results of the foodstuff and vegetation analyses are summarized in Tables 20 and 21. The concentration is given in terms of the sample weight (wet weight) before ashing. The vegetables analyzed were turnips and potatoes. The sample of aquatic life analyzed included only the edible fleshy portions of fish. No evidence has been found that there is any significant uptake or concentration by plant or animal

Table 20 - PLUTONIUM-238 IN FOODSTUFFS AND VEGETATION IN 1977

Type of Sample	Number of Samples	^{238}Pu Range (10^{-10} µCi/g)	Average[a,b,c,d] (10^{-10} µCi/g)
Milk	3	<2.0 - 2.1	<2.0 ± 0.8
Vegetables	4	<7.5 - 11.0	<8.4 ± 2.8
Grass	25	<6.6 - 44.6	13.1 ± 6.2
Aquatic Life	4	<5.3 - 9.6	<6.7 ± 1.4

[a]Lower Detection Limit (LDL) for ^{238}Pu in milk is 2.0×10^{-10} µCi/g

[b]Lower Detection Limit (LDL) for ^{238}Pu in vegetables is 7.5×10^{-10} µCi/g

[c]Lower Detection Limit (LDL) for ^{238}Pu in grass is 6.6×10^{-10} µCi/g

[d]Lower Detection Limit (LDL) for ^{238}Pu in aquatic life is 5.3×10^{-10} µCi/g

[e]Error limits include only counting statistics at 95% confidence level.

Table 21 - TRITIUM IN FOODSTUFFS AND VEGETATION IN 1977

Type of Sample	Number of Samples	Tritium Range (10^{-6} µCi/g)	Average[a,b] (10^{-6} µCi/g)
Milk	4	0.27 - 0.45	0.38 ± 0.23

[a]LDL for tritium in milk = 0.16×10^{-6} µCi/g.

[b]Error limits include only counting statistics at 95% confidence level.

life of the radionuclides handled at Mound Facility.

Silt - radioactive

Silt samples were collected from the surface water sample locations shown in Figure 5. These samples were obtained by filtration of sediment (silt) from the water that was collected from these locations.

The results of the silt sample analyses are found in Tables 22, 23, and 24.

Soil - radioactive

During CY-1977, emphasis was placed on completing Mound's Soil Inventory for plutonium-238. Essentially all the soil samples taken and analyzed during CY-1977 were related to the Soil Inventory Program.

Table 22 - PLUTONIUM-238 IN SILT FROM RIVER MONITORING LOCATIONS IN 1977

Location	Number of Samples	^{238}Pu Range (10^{-6} µCi/g)	^{238}Pu Average[a,b] (10^{-6} µCi/g)
1	2	0.51 - 1.1	0.8 ± 0.05
2	2	0.48 - 14.4	7.4 ± 0.07
3	2	2.6 - 2.8	2.7 ± 0.12
4	2	4.4 - 5.1	4.7 ± 0.15
5	2	<0.3 - 1.6	<0.9 ± 0.04

[a]Lower Detection Limit (LDL) for ^{238}Pu in silt is 0.3 x 10^{-6} µCi/g.

[b]Error limits include only counting statistics at 95% confidence level.

Table 23 - PLUTONIUM-238 IN SILT FROM SURFACE WATER MONITORING LOCATIONS IN 1977

Location	Number of Samples	^{238}Pu Range (10^{-6} µCi/g)	^{238}Pu Average[a,b] (10^{-6} µCi/g)
10	2	-[a]	<0.3 ± 0.02
11	2	-[a]	<0.3 ± 0.01
12	2	-[a]	<0.3 ± 0.01
13	2	-[a]	<0.3 ± 0.03
14	2	-[a]	<0.3 ± 0.02
15	2	-[a]	<0.3 ± 0.001
16	2	-[a]	<0.3 ± 0.05
17	2	<0.3 - 0.55	<0.4 ± 0.05

[a]Lower Detection Limit (LDL) for ^{238}Pu is 0.3 x 10^{-6} µCi/g.

[b]Error limits include only counting statistics at 95% confidence level.

Table 24 - PLUTONIUM-238 IN SILT FROM CANAL/POND AREA SILT IN 1977

Location[a]	Number of Samples	^{238}Pu Range (10^{-6} µCi/g)	^{238}Pu Average[b,c] (10^{-6} µCi/g)
8 (South Canal)	2	61.1 - 263.9	162.5 ± 0.63

[a]Locations are shown in Figure 5.

[b]Lower Detection Limit (LDL) for ^{238}Pu in silt is 0.3 x 10^{-6} µCi/g.

[c]Error limits include only counting statistics at 95% confidence level.

The purpose of the soil inventory was to establish the quantity of plutonium-238 which was deposited in the environment from Mound Facility stack emissions. A preliminary soil inventory was performed in 1975; however, soil sampling was not completed, and additional samples were taken in 1977, to extend the soil isopleths to background concentrations.

Soil core sample values around and within the Facility site boundary were used to arrive at an estimate of deposition of airborne plutonium-238 from Facility operations. The core sample depths in most cases were 30 cm with a core diameter of ~8 cm. Ten cores were collected at each sampling location. The ten cores were composited, dried, crushed, and passed through a quarter-inch mesh screen. The sample was then riffled down to approximately 3 kg and pulverized to pass a 60-mesh sieve. Aliquots of 500 g or 1000 g, depending on soil location, were then taken from this homogenized sample for analysis. The analytical scheme used for these analyses was essentially the HASL (now EML) Procedure No. E-Pu-06 using plutonium-242 as the internal tracer.

A series of soil sampling locations sampled earlier were reinforced by 31 additional locations in 16 different directions and distances from the Facility. A total of 79 soil sampling locations were used in the inventory.

Soil background levels were obtained by collecting four additional samples at 0°, 90°, 180° and 270° at distance ranging from 34 to 51 km (21 to 32 mi). The ratio of plutonium-239 to plutonium-238 ranged from 22 to 27 for these samples which is in good agreement with accepted values for fallout or background plutonium [23]. The plutonium-238 values in these samples averaged 0.1 mCi/km^2 and any value exceeding that level was assumed to be the result of past emissions from Mound facilities.

The soil sampling values along each of 16 equally spaced radials originating in the center of Mound Facility were fit to power function curves by a least squares program. The concentration along each of the 16 radials is represented by the equation:

$$y = ax^b$$

where y = concentration, mCi/km^2
a = constant
x = distance, km
b = exponent, <0

Table 25 shows the values a, b, and the correlation coefficient for each of the 16 radials. The distances between each radial were obtained by a data smoothing technique. The isopleths were then completed and the area between isopleths was measured by planimetry. The concentration calculated at the midpoint distance between each isopleth was used as the average concentration for the area between the isopleths. The isopleth plot is shown in Figure 7.

The total quantity of plutonium-238 in the offsite environment due to airborne emissions from Mound operations is estimated by this technique to be 360 mCi. The error associated with this value is estimated to be ±35% which includes errors due to chemical analysis, counting, area measurement, and sampling. Radiation dose to the public due to resuspended plutonium, even from the areas of maximum concentration, is well within the proposed EPA standard for transuranium elements in soil.

Table 25 - CONSTANTS FOR THE EQUATION: $y = ax^b$ AND CORRELATION COEFFICIENTS SHOWING GOODNESS OF FIT

Direction Radial (degrees)	Constant a	Exponent b	Correlation Coefficient
0	10.59	-1.96	-0.98
22.5	16.33	-1.98	-0.98
45	6.57	-1.65	-0.98
67.5	11.08	-1.93	-0.97
90	14.16	-1.97	-0.97
112.5	6.41	-1.89	-0.99
135	4.07	-1.55	-0.98
157.5	1.32	-1.49	-0.99
180	0.83	-0.90	-0.98
202.5	1.11	-1.03	-0.99
225	3.30	-1.58	-0.93
247.5	13.53	-2.06	-0.91
270	5.30	-1.66	-0.96
292.5	6.67	-2.24	-0.99
315	6.08	-2.43	-0.99
337.5	2.02	-1.92	-0.99

Evaluation of potential dose to the public

A dose assessment was performed for radionuclides in the environment from Mound Facility operations. These radionuclides are plutonium-238 and tritium. Tritium (oxide) is the only radionuclide at Mound Facility for which the critical organ is the whole body. The critical organs for plutonium-238 are asssumed to be the lung for insoluble material and the bone for soluble material. The solubility of plutonium-238 in the receptor is unknown; therefore each dose evaluation for both lung and bone were based on total concentration of plutonium-238 found in the environment. This approach gives a very conservative estimate of dose equivalents.

Plutonium-238 assumptions and methodology

The dose equivalent estimates for plutonium-238 were based on environmental monitoring data for CY-1977. The estimates for maximum dose equivalent to the lung at the site boundary and maximum dose equivalent to the lung in individuals were based on the maximum onsite average concentration of plutonium-238 in air from onsite samplers (sampler 213) since the samplers are in close proximity to the site boundary. The maximum dose equivalent to the lung in population group(s) was based on the maximum offsite average concentration of plutonium-238 in air (sampler 123).

The estimates for maximum dose equivalent to the bone at the site boundary and in

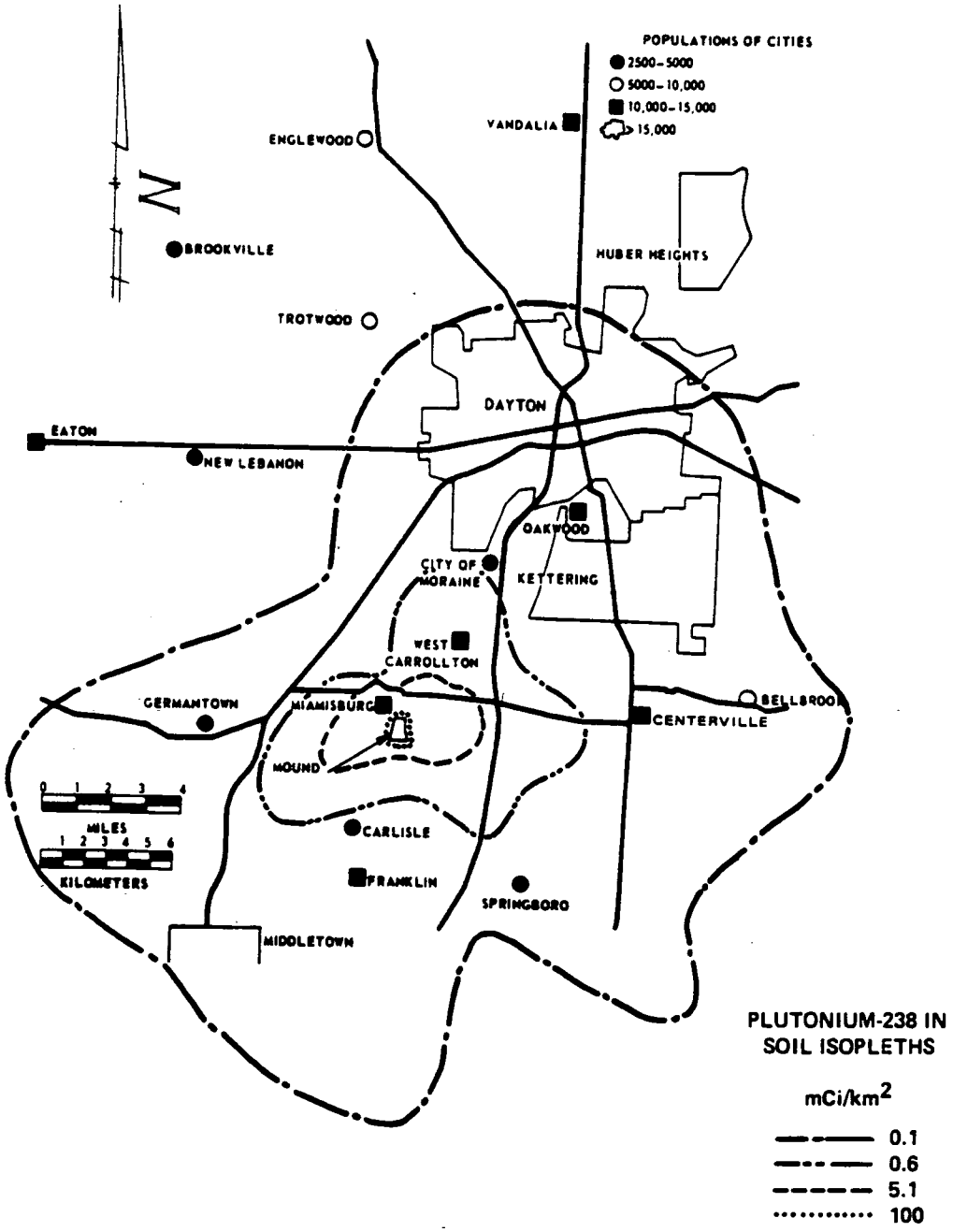

FIGURE 7 - Plutonium-238 in soil isopleths (mCi/km^2).

individuals were also based on the maximum onsite average concentration of plutonium-238 in air and the maximum offsite average concentration of plutonium-238 in drinking water (average of B-1, B-2, B-3). The maximum dose equivalent to the bone for individuals in population group(s) was based on the maximum offsite average concentrations of plutonium-238 in air and water (Miamisburg drinking water). The total dose equivalent for bone was obtained by the addition of the dose equivalent of plutonium in air and the dose equivalent of plutonium in water.

The term "maximum dose equivalent at the site boundary" and "maximum dose equivalent to individuals" refer to the maximum dose equivalent possible for individuals to receive assuming they remain at the site boundary 24 hr/day and 365 days/yr. The term "maximum dose equivalent for individuals in population group(s)," refer to those individuals who reside in a location adjacent to Mound Facility who receives the maximum dose equivalent values found in the offsite environment.

The calculational methods can be found in the Appendix.

Tritium (oxide) assumptions and methodology

The dose equivalent estimates for tritium (oxide) were also based on environmental monitoring data for CY-1977. The concentrations used for dose equivalent estimates for tritium (oxide) were arrived at by the same method as that used for plutonium. The maximum average onsite air concentration was measured at sampler 212, and the maximum drinking water concentration was the average of B-1, B-2, and B-3. The maximum average offsite air concentration was measured at sampler 102, and the maximum concentration of drinking water for individuals in a population group was Miamisburg drinking water. The total dose equivalent for the whole body was obtained by addition of the dose equivalent of tritium (oxide) in air and the dose equivalent of tritium (oxide) in water. The calculational methods can be found in the Appendix. The results of the dose estimate calculations are shown in Table 26.

The 80-km (50-mi) person-rem (whole body) dose equivalent estimates were based on average tritium (oxide) data from environmental air sampling stations, average tritium (oxide) data in community drinking water, and atmospheric dispersion estimates.

Two ranges of dose equivalent estimates based on distance from Mound Facility, were considered to obtain the 80-km (50-mi) person-rem dose estimate. The first range was from 0 to 3.2 km (2 mi). The second range was from 3.2 to 80 km (50 mi).

The 0 to 3.2 km (2 mi) range dose estimate for airborne tritium oxide was obtained from the average concentration (less background) of nine offsite tritium (oxide) samplers with a 3.2 km (2 mi) radius of Mound Facility. The dose in this distance range from tritium (oxide) in water was obtained from a weighted average of drinking water concentrations. These dose equivalents from tritium (oxide) in air and in water were summed.

The 3.2 to 80 km (50 mi) range dose estimate was obtained by finding the midpoint distance where the average tritium (oxide) concentration of the remaining offsite samplers would be located. This value is

Table 26 - DOSE EQUIVALENT ESTIMATES

	Plutonium-238 (mrem/yr)		Tritium Oxide (mrem/yr)
	Lung	Bone	Whole Body
Maximum dose equivalent at the site boundary	0.11	0.047	3.47
Maximum dose equivalent to an individual	0.11	0.047	3.47
Maximum dose equivalent to an individual in the population group(s)	0.036	0.016	0.21

estimated at 6.3 km (4 mi) [21]. From this distance and average concentrations of tritium (oxide) at sampling locations from 3.2 to 32 km (20 mi), it was determined that the maximum distance of influence from Mound Facility is ~32 km. Beyond 32 km the levels are calculated to be background concentrations.

The dose equivalent for tritium (oxide) from 3.2 to 32 km (20 mi) was based on the average of the remaining tritium (oxide) air sample concentrations and the average of the remaining community drinking water concentrations. The calculations are shown in the Appendix.

These calculated doses were then weighted by the population in each range. The total person-rem from 0 to 32 km is equal to 12.2 person-rem in addition to background. Based on diffusion model calculations, the remaining population from 32 to 80 km (50 mi) is not receiving dose from tritium (oxide) emissions from Mound Facility; therefore, the total person-rem from 0 to 80 km from tritium (oxide) emissions from Mound Facility is equal to 12.2 person-rem.

For comparison, the person-rem values from natural radiation, including cosmic rays and terrestrial radiation, would be approximately 320,000 person-rem for the 0 to 80 km (50 mi) range [22]. The dose commitment due to natural background tritium alone is 80 person-rem for the 0 to 80 km range.

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Appendix

Applicable standards

RADIOACTIVE STANDARDS

In conformance with DOE Manual Chapter 0524, "Standards for Radiation Protection," offsite sample results are compared with RCG's established for the general population. These RCG's are derived by dividing the RCG's for an uncontrolled area by three.

Onsite sample results are compared with the uncontrolled area RCG's which are applicable for individuals in the population.

The RCG values (in microcuries per milliliter - μCi/ml) used for comparison purposes for the various types of samples in this report are listed below. In all cases, these are the most restrictive RCG's

Plutonium-238 (Soluble Form)

Air

General Population	2×10^{-14} μCi/ml
Uncontrolled Area (Individuals in the Population)	7×10^{-14} μCi/ml

Water

General Population	2×10^{-6} μCi/ml
Uncontrolled Area (Individuals in the Population)	5×10^{-6} μCi/ml

Tritium (Soluble Form)

Air

General Population	7×10^{-8} μCi/ml
Uncontrolled Area (Individuals in the Population)	2×10^{-7} μCi/ml

Water (DOE RCG is compared to water not used for drinking purposes)

General Population	1×10^{-3} μCi/ml
Uncontrolled Area (Individuals in the Population)	3×10^{-3} μCi/ml

As of June 24, 1977, community drinking water quality is regulated by the EPA National Interim Primary Drinking Water Regulations for Radionuclides. The new standard = 20×10^{-6} μCi/ml (20,000 pCi/l).

Foodstuffs

There are no RCG values specified for foodstuffs.

Soil

There are no guidelines established for radioactive species in soil. (The U. S. EPA has guidelines under consideration.)

NONRADIOACTIVE STANDARDS

Water

Region V of the USEPA has issued a discharge permit under NPDES regulations covering both Mound Facility liquid effluent streams. The discharge limitations for each effluent stream through June 30, 1977, are as follows:

Outfall Number 001	Daily Average	Daily Maximum
Flow (10^6 gal/day)	0.53	0.92
BOD-5 Day (mg/liter)	30	45
Suspended Solids (mg/liter)	30	45
Dissolved Oxygen (mg/liter)	5	-
Residual Chlorine (mg/liter)		0.8
Oil and Grease (mg/liter)		10
Fecal Coliform (No./100 ml)	200	400
pH	6-9	

Outfall Number 002	Daily Average	Daily Maximum
Flow (10^6 gal/day)	0.53	-
Suspended Solids (mg/liter)	20	25
Dissolved Oxygen October-April (mg/liter)	>8	-
May-September (mg/liter)	>5	-
Residual Chlorine (mg/liter)		0.1
Dissolved Solids (mg/liter)	2000	3000
Oil and Grease (mg/liter)		10
pH	6-9	

The discharge limitations for each effluent stream as of July 1, 1977, became more restrictive and are as follows:

Outfall Number 001		
Flow (10^6 gal/day)	0.53	0.92
BOD-5 Day (mg/liter)	10	15
Suspended Solids (mg/liter)	10	15
Dissolved Oxygen (mg/liter)	5	-
Residual Chlorine (mg/liter)	-	0.5
Oil and Grease (mg/liter)	-	10
pH	6-9	-

Outfall Number 002	Daily Average	Daily Maximum
Flow (10^6 gal/day)	0.53	-
Suspended Solids (mg/liter)	15	20
Dissolved Oxygen (mg/liter October-April (mg/liter)	8	-
May-September (mg/liter)	5	-
Residual Chlorine (mg/liter)	-	0.05
Oil and Grease (mg/liter)		10
Dissolved Solids (mg/liter)	1500	2000
pH	6-9	

The Ohio EPA has established Water Quality Standards (3745-1-01-3745-1-09). The standards listed below are excerpted from these regulations. These standards are stream standards and apply to a stream beyond a suitable mixing zone permitted for discharges. They should not be compared with effluent concentrations.

Constituent	Average Concentration (mg/liter)
Dissolved Oxygen	5.0
pH	6-9
Fecal Coliform	200 per 100 ml
Dissolved Solids	1500
Ammonia	1.5
Arsenic	0.05
Barium	0.8
Cadmium	0.005
Chloride	250
Chromium (Hexavalent)	0.05
Cyanide (Free)	0.005
Fluoride	1.3
Foaming Agents (MBAS)	0.5
Iron	1
Lead	0.04
Manganese	1
Mercury	0.0005
Oil & Grease	5
Phenols	0.01
Selenium	0.005
Silver	0.001
Copper	0.005 - 0.075*
Zinc	0.075 - 0.5*

*Dependent on $CaCo_3$ hardness

Dose equivalent calculations

PLUTONIUM-238 CALCULATIONAL METHODS

The dose equivalent to the lung resulting from continuous inhalation of airborne plutonium-238 was calculated by:

$$D(t) = \frac{51.1CI_a t f_a f_r \ \Sigma EF(RBE)\eta}{\lambda m}\left(1-\frac{1-e^{-\lambda t}}{\lambda t}\right)$$

where D(t) = dose equivalent delivered to the lung in 365 days of continuous exposure to plutonium-238 in air, rem/yr.

C = average airborne concentration, μCi/ml

I_a = average air intake = 2×10^7 ml/day (Ref. 16)

t = time exposed, 365 days

f_a = fraction of inhaled material reaching organ of interest = 0.7 (max.) for the pulmonary region (Ref. 17)

f_r = fraction of pulmonary deposition undergoing long-term retention = 0.6 for actinide (class Y) (Ref. 17)

$\Sigma EF(RBE)\eta$ = effective energy deposition per disintegration = 57 (Ref. 16)

λ = effective decay rate, 0.0014 day^{-1} for actinides (class Y) from the pulmonary region (Ref. 18)

m = lung mass, 1000 g (Ref. 16)

The dose equivalent to bone resulting from continuous inhalation of airborne plutonium-238 was calculated by:

$$\dot{D}(t) = \frac{51.1CI_a f_a t \ \Sigma EF(RBE)\eta}{\lambda m}\left(1-\frac{1-e^{-\lambda t}}{\lambda t}\right)$$

where f_a = 0.2 (Ref. 16)

$\Sigma EF(RBE)\eta$ = 284 (Ref. 16)

m = 7×10^3 g (Ref. 16)

λ = 3×10^{-5} day^{-1} (Ref. 16)

The dose equivalent to bone resulting from continuous ingestion of plutonium-238 in water was calculated by:

$$D(t) = \frac{51.1CI_w f_a t \ \Sigma EF(RBE)}{\lambda m}\left(1-\frac{1-e^{-\lambda t}}{\lambda t}\right)$$

where I_w = average quantity of water intake, 2200 cm^3 (Ref. 16)

f_a = 2.4×10^{-5} (Ref. 16)

TRITIUM OXIDE CALCULATIONAL METHODS

The dose equivalent to the whole body resulting from continuous exposures to tritium (oxide) in air was calculated by:

$$D(t)a = \frac{\bar{C}a}{Ra} \times S$$

where D(t)a = dose equivalent, mrem/yr

$\bar{C}a$ = average concentration of tritium (oxide) in air

Ra = RCG for tritium (oxide) in air (Ref. 6)

S = Radiation protection standard in mrem/yr (Ref. 6)

The dose equivalent to the whole body resulting from continuous uptake of tritium (oxide) in water was calculated by:

$$D(t)w = \frac{\bar{C}w}{Rw} \times S$$

where D(t)w = dose equivalent in mrem/yr

$\bar{C}w$ = average concentration

Rw = RCG for tritium (oxide) in water (Ref. 6)

S = radiation protection standard in mrem/yr (Ref. 6)

Those dose equivalent values were divided by 1.7 in order to reflect the quality factor of one as recommended by the International Commission on Radiological Protection [19] and the National Council on Radiation Protection and Measurements [20].

Person-rem calculations

The equations used for this calculation in the 0-3.2 km range were:

$$\bar{D}(t)a_{0-3.2} = \frac{\bar{C}a}{Ra} \times S$$

where $\bar{D}(t)a_{0-3.2}$ = dose equivalent from 0 to 3.2 km from tritium (oxide) in air

Ca = average tritium (oxide) concentration in air from 0 to 3.2 km

Ra = RCG for tritium (oxide) in air (Ref. 6)

S = radiation protection standard for tritium (oxide) in air in mrem/yr (Ref. 6)

$$\bar{D}(t)w_{0-3.2} = \frac{\bar{C}w}{Rw} \times S$$

where $\bar{D}(t)w_{0-3.2}$ = dose equivalent from 0 to 3.2 km from tritium (oxide) in water

$\bar{C}w$ = average tritium (oxide) concentration in water from 0 to 3.2 km

Rw = RCG for tritium (oxide) in water (Ref. 6)

S = radiation protection standard for tritium (oxide) in water, mrem/yr (Ref. 6)

The equations for these calculations in the 3.2 to 32 km range are:

$$\bar{D}(t)a_{3.2-32} = \frac{\bar{C}a}{Ra} \times S$$

where $\bar{D}(t)a_{3.2-32}$ = dose equivalent from 3.2 to 32 km from tritium (oxide) in air

$\bar{C}a$ = average tritium (oxide) concentrations in air from 3.2 to 32 km

Ra = RCG for tritium (oxide) in air (Ref. 6)

S = Radiation Protection Standard for tritium (oxide) in air, mrem/yr (Ref. 6)

$$\bar{D}(t)w_{3.2-32} = \frac{\bar{C}w}{Rw} \times S$$

where $\bar{D}(t)w_{3.2-32}$ = dose equivalent from 3.2 to 32 km from tritium (oxide) in water

$\bar{C}w$ = average tritium (oxide) concentration in water from 3.2 to 32 km

Rw = RCG for tritium (oxide) in water (Ref. 6)

S = Radiation Protection Standard for tritium (oxide) in water, mrem/yr (Ref. 6)

The total person-rem from 0 to 32 km is obtained by:

$$\sum_{0}^{32} R = \left(\bar{D}(t)a_{0-3.2} + \bar{D}(t)w_{0-3.2}\right) \sum_{0}^{3.2} P + \left(\bar{D}(t)a_{3.2-32} + \bar{D}(t)w_{3.2-32}\right) \sum_{3.2}^{32} P$$

where $\sum_{0}^{32} R$ = person-rem within 32 km

$\sum_{0}^{3.2} P$ = population from 0 to 3.2 km = 14,700

$\sum_{3.2}^{32} P$ = population from 3.2 to 32 km = 881,241

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