Radiological Dose Assessment

During 1999, potential radiological doses to members of the public from ambient air, liquid, and gaseous effluents from Brookhaven National Laboratory sources were evaluated to determine compliance with regulations and limits. The potential doses were based on calculations using 1999 emission data, fauna sampling data, and conservative intake and exposure assumptions. All doses resulting from the internal deposition of radionuclides are expressed as 50-year committed effective dose equivalents.

In 1999, there was minimal radiological dose impact above natural background levels to members of the public and the environment from BNL operations. The ambient external radiation measured in the surrounding area with BNL's offsite thermoluminescent dosimeter network was 71 mrem (0.71 mSv) per year, which is within the natural background exposure range observed throughout New York State. The effective dose equivalent to the maximally exposed individual from BNL air emission sources was calculated to be 0.13 mrem (1.3 μSv). The U.S. Environmental Protection Agency air emission pathway dose limit is 10 mrem, and therefore, by comparison, demonstrating that BNL sources contributed an insignificant dose. The effective dose equivalent from consumption of fish taken exclusively from the Peconic River would result in a dose of 0.3 mrem (3 μSv), and consumption of deer meat taken exclusively from the BNL site would result in 4.2 mrem (42 μSv). In comparison, the average effective dose equivalent from eating various foods that contained naturally occurring radionuclides would result in 40 mrem (0.4 mSv) per year.

8.1 AMBIENT RADIATION MEASUREMENTS

BNL measures environmental background radiation through a network of onsite and offsite dosimeter units. These units, called thermoluminescent dosimeters, or TLDs, measure beta/gamma radiation originating from cosmic and terrestrial sources (see Appendix C for sources) as well as any contribution from Laboratory operations. Calcium fluoride type (CaF2:Dy) TLDs were used. There were a total of 31 onsite locations that had TLDs in place (see Figure 8-1 for locations). In addition to the dosimeters located on BNL property, 20 offsite locations were also monitored in 1999 (see Figure 8-2 for locations). The offsite TLD measurements provide background comparison values and are used to determine whether BNL operations had an impact on the ambient external radiation levels of the surrounding area.

Onsite 1999 TLD data are summarized in Table 8-1. The quarterly average dose was lowest (14 mrem or 0.14 mSv) at location 011-400 and highest (26 mrem or 0.26 mSv) at the 075-402 location. The average onsite TLD reading was 19 mrem (0.19 mSv), whereas the average background TLD reading was 21 mrem (0.21 mSv). The location 054-400 reading was higher than normal for the first and fourth quarter of 1999. After investigation it was determined that readings were elevated due to the sky-shine

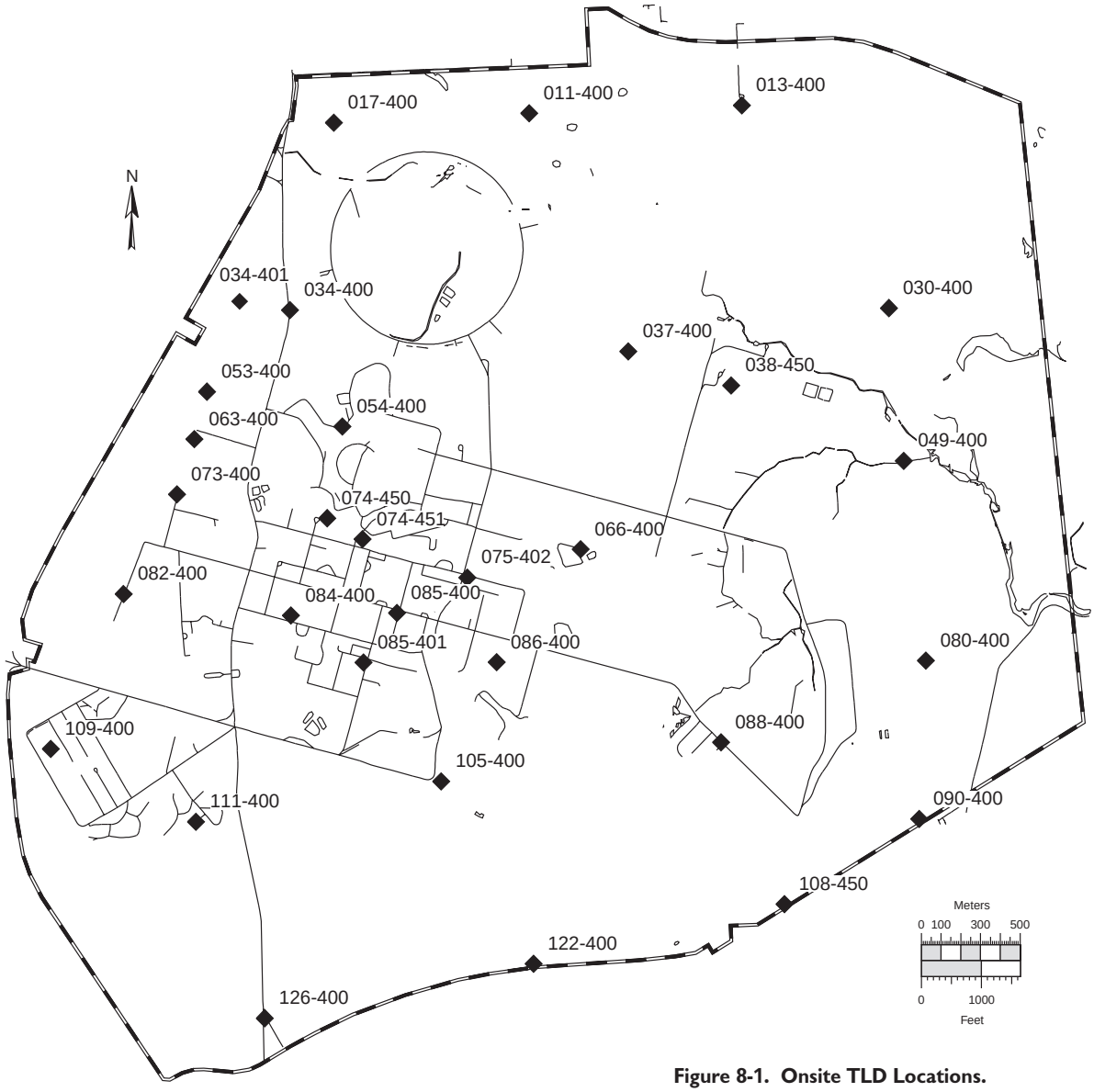

Figure 8-1. Onsite TLD Locations.

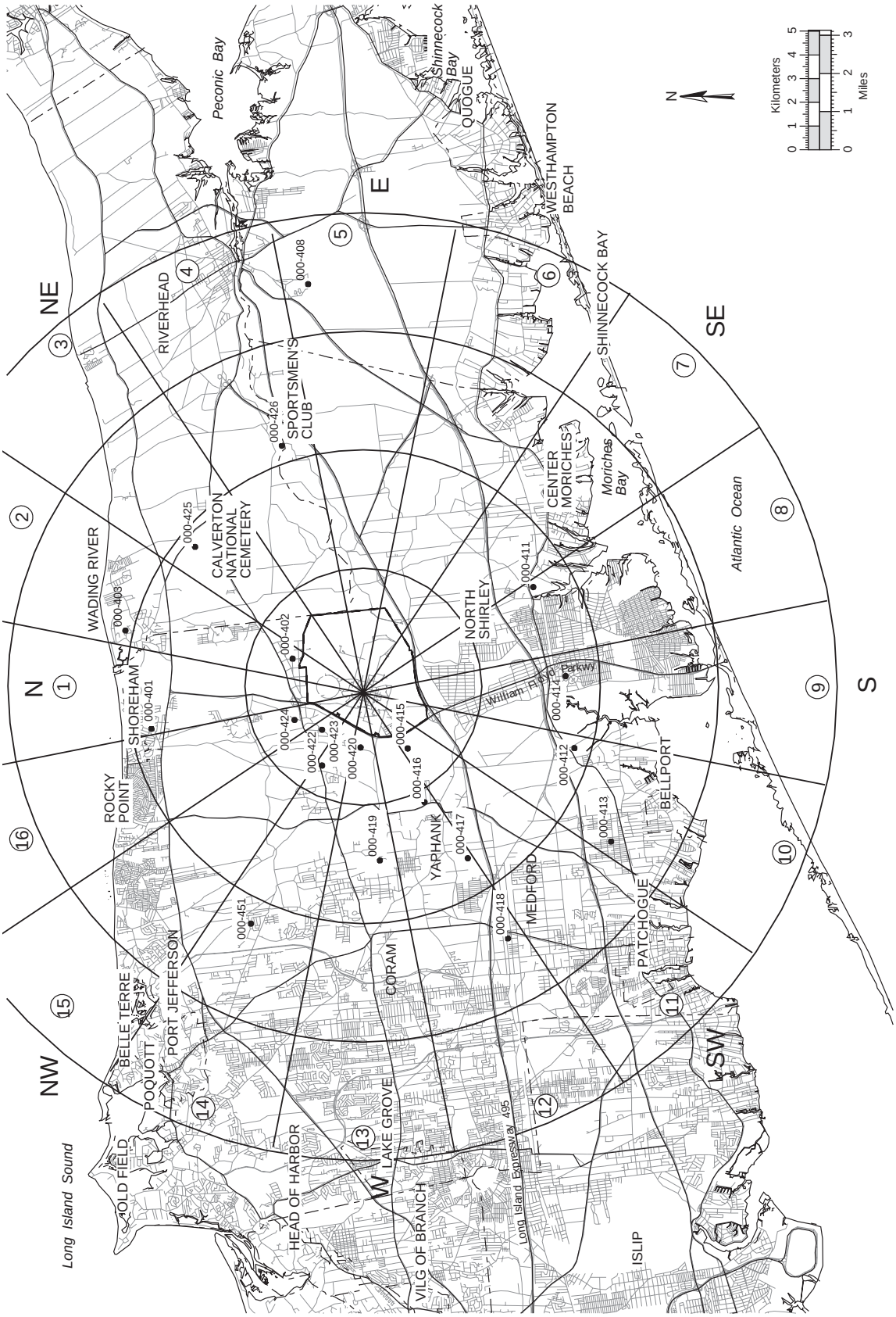

Figure 8-2. Offsite TLD Locations.

Table 8-1. Onsite Ambient Radiation Measurements (1999).

Station	1st Quarter (mrem)	2nd Quarter (mrem)	3rd Quarter (mrem)	4th Quarter (mrem)	Average (mrem)	Annual Dose* (mrem/yr)
011-400	14.0	14.1	13.1	(a)	13.8	65.4
013-400	17.0	17.8	19.9	16.8	17.9	52.5
017-400	15.0	16.4	18.6	16.0	16.5	48.0
030-400	15.8	16.7	18.8	16.3	16.9	49.1
034-400	17.5	17.8	19.7	16.8	17.9	52.3
034-401	19.0	20.3	22.0	19.8	20.3	58.9
037-400	17.4	18.7	20.6	17.8	18.6	54.0
038-450	16.6	16.8	19.4	(a)	17.6	66.9
049-400	15.4	14.9	19.3	15.9	16.4	47.1
053-400	18.6	19.4	21.2	19.4	19.6	56.7
063-400	18.6	18.8	20.7	19.0	19.3	55.7
066-400	15.3	16.5	(b)	14.0	15.3	57.0
073-400	19.1	20.9	22.0	20.1	20.5	59.1
074-450	19.9	19.4	22.6	19.8	20.4	59.3
074-451	17.9	18.4	19.9	17.7	18.5	53.4
075-402	33.9	23.8	24.9	22.4	26.3	79.2
080-400	18.0	18.4	20.5	18.7	18.9	54.2
082-400	19.8	19.2	21.5	19.5	20.0	57.9
084-400	17.6	18.0	20.2	17.3	18.3	53.5
085-400	17.5	17.9	20.5	17.5	18.4	53.6
085-401	17.8	16.5	20.9	16.8	18.0	52.9
086-400	18.3	18.7	21.1	19.0	19.3	55.3
090-400	17.3	18.4	20.1	17.3	18.3	53.1
105-400	18.2	18.9	21.2	19.0	19.3	55.4
108-450	18.0	20.0	20.9	19.3	19.6	56.1
109-400	17.4	18.3	20.0	17.2	18.2	53.4
111-400	17.6	18.0	20.0	17.1	18.2	53.3
122-400	16.7	17.0	19.4	16.6	17.4	50.5
126-400	17.8	18.0	20.8	(c)	18.9	71.7
054-400	179.3(d)	17.4(d)	20.0(d)	99.5(d)	71.9(d)	207.6(d)
088-400	82.2(d)	68.9(d)	60.3(d)	58.5(d)	67.5(d)	200.9(d)
075-000 (Background)	17.3	21.1	16.6	28.0	20.8	57.2
Average	18.0	18.2	20.4	18.0	18.6	56.4
Median	17.6	18.3	20.5	17.6	18.4	54.2
Population Std. Dev.	3.3	1.8	1.9	1.7	2.1	6.8

Notes:
See Figure 8-1 for station locations.
*Dose rate normalized to 365 day year.
(a) Sample vandalized
(b) Harshaw error
(c) No data available
(d) Results not included in any statistics.

phenomenon observed during the operation of the Alternating Gradient Synchrotron. The 1999 first and fourth quarter results for location 054-400 were not included in the statistics because they would bias the average; and, therefore, it would be prudent to observe them individually for each quarter. The 088-400 location TLD average reading was 68 mrem because of its proximity to the waste management site.

Offsite 1999 TLD data are summarized in Table 8-2. The average annual offsite external radiation dose was 71 ± 7 mrem (0.71 ± 0.07 mSv). This is consistent with the annual dose rates of 67 ± 5 mrem (0.67 ± 0.05 mSv) and 70 ± 5 mrem (0.7 ± 0.05 mSv) measured in 1997 and 1998, respectively. These values are statistically indistinguishable from one another and are within the normal background exposure range typical of the northeastern part of the United States (NCRP 1987). This indicates that BNL operations had no measurable effect on local ambient radiation exposure levels.

8.1.1 BUILDING 650 SUMP OUTFALL

From approximately 1959 to 1969, decontamination of radiologically-contaminated heavy

Table 8-2. Offsite Ambient Radiation Measurements (1999).

Station	1st Quarter (mrem)	2nd Quarter (mrem)	3rd Quarter (mrem)	4th Quarter (mrem)	Average (mrem)	Annual Dose* (mrem/yr)
000-401	14.5	15.3	23.4	16.0	17.3	66.5
000-402	18.6	19.0	21.5	17.9	19.3	75.6
000-403	20.0	20.1	23.0	18.9	20.5	79.7
000-408	17.5	17.3	19.5	(a)	18.1	63.2
000-411	18.3	18.3	21.2	18.7	19.1	71.6
000-412	20.0	19.8	22.2	(a)	20.7	73.6
000-413	18.8	19.0	20.0	18.1	19.0	73.4
000-414	18.2	18.7	21.0	19.2	19.3	73.9
000-415	17.0	16.0	19.0	15.6	16.9	64.3
000-416	16.1	15.4	18.1	15.7	16.3	63.9
000-417	18.2	17.8	19.1	18.3	18.4	73.1
000-418	18.2	19.3	19.9	16.6	18.5	70.2
000-419	17.5	16.4	20.3	16.9	17.8	68.5
000-420	17.9	18.1	20.9	18.9	19.0	72.7
000-422	19.4	22.5	20.8	21.2	21.0	81.8
000-423	16.4	17.4	20.5	16.7	17.8	71.0
000-424	17.8	17.7	20.6	18.0	18.5	71.0
000-425	20.1	20.4	22.0	20.2	20.7	79.3
000-426	17.9	18.0	20.5	18.8	18.8	72.1
000-451	(b)	20.4	21.7	(a)	21.1	51.1
075-000 Background	17.3	21.1	16.6	28.0	20.8	57.2
Average	18.0	18.4	20.8	18.0	18.9	70.8
Median	18.2	18.2	20.7	18.1	18.9	71.9
Population Std. Dev.	1.4	1.8	1.3	1.5	1.3	6.8

Notes:
See Figure 8-2 for station locations.
*Dose rate normalized to 365 day year.
(a) Sample not returned
(b) Error occured in processing of TLD .

equipment was performed on a concrete pad adjacent to Building 650. The drainage from this pad was contained in underground storage tanks. In 1969 it was determined that under certain valve conditions, liquid from the underground tanks was inadvertently being routed to a depression in a wooded area approximately 800 feet northeast of Building 650. This depression is referred to as the Building 650 Sump Outfall. The sump outfall is a source of localized radiological soil and groundwater contamination that is being remediated under the environmental restoration program (Operable Unit [OU] IV, Area of Concern [AOC] 6). Radionuclides identified in the soil in this area include strontium-90, cesium-137, and isotopes of europium and plutonium.

In 1997, as part of the OU IV Interim Remedy Plan, the outfall was fenced to exclude pedestrian traffic, and a network of 16 TLDs, Lithium Fluoride type (LiF:Mg,Ti), was installed to monitor gamma radiation exposure levels in the area (see Figure 8-3). Four fence perimeter dosimeters were also installed, as well as two background dosimeters located onsite in an area not influenced by AOC 6 or other site radiation sources. In 1998, five locations were added to this TLD network: C5, D5, E3, E4, and E5. These TLDs were added when elevated readings from dosimeters D2 through D4 indicated that influence of the radionuclides related to the Building 650 Sump Outfall probably also extended to the southeast, just beyond the existing network. The new stations were installed to monitor this area, though previous soil sampling and fence dosimeter showed that radionuclides related to Building 650 were localized within the fenced area.

Consistent with the previous year, 1999 data from the Building 650 Sump Outfall TLD network indicated that the highest concentration of radionuclides was located in the area of position C4, where an annual dose rate of

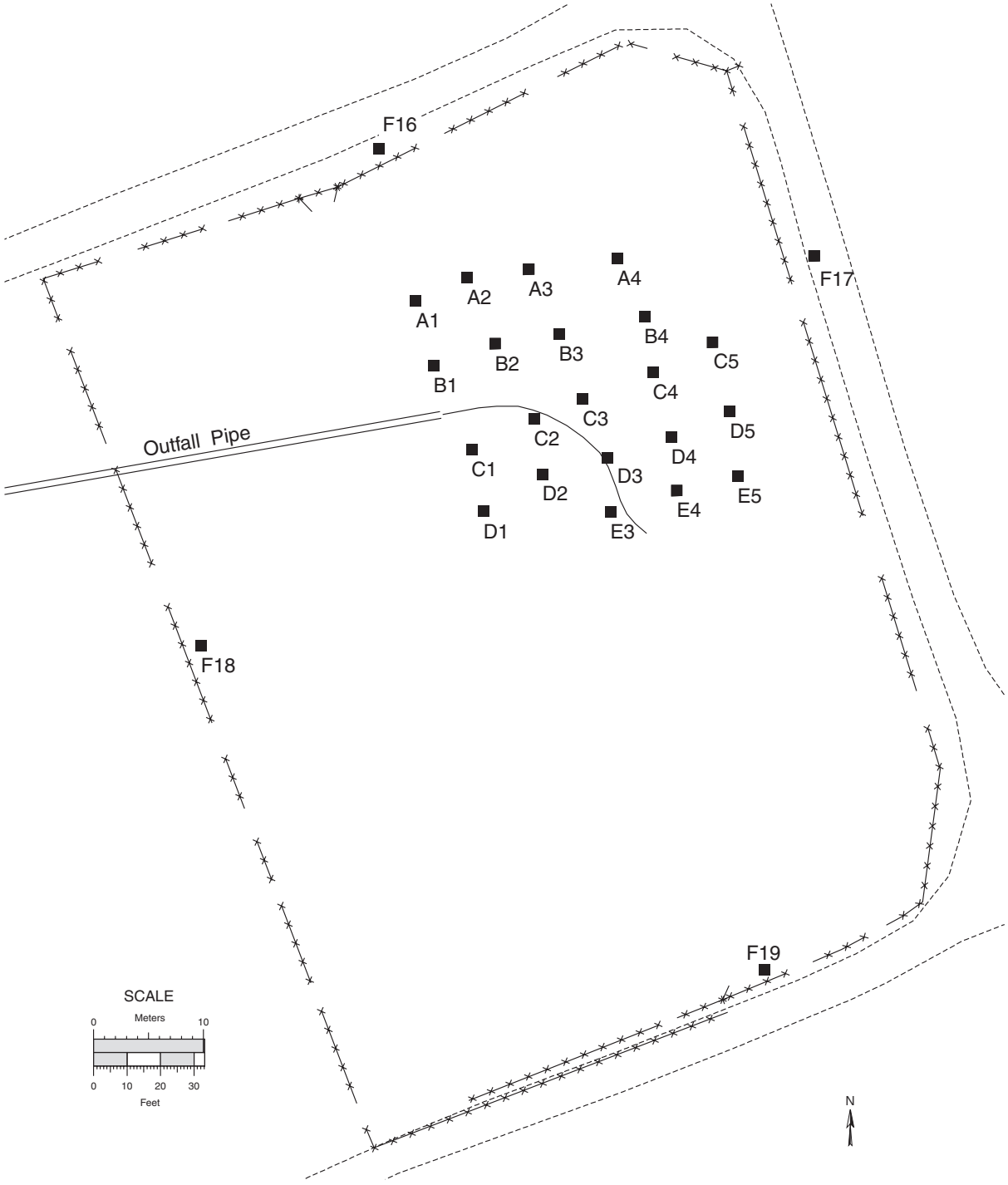

Figure 8-3. Building 650 Sump Outfall TLD Network.

1.4 rem (14 mSv) was recorded (Table 8-3). The annual dose rate south of the C4 monitoring grid decreased to 0.8 rem (8 mSv) at the D4 location. The annual dose rate decreased to 0.3 rem (3 mSv) at the B3 grid. Fence dosimeters showed no elevated dose rates and were consistent with the two distant background TLDs, demonstrating that the radiation field generated by the Building 650 Sump Outfall contaminants were limited to the immediate area of the outfall itself. Due to the localization of contaminants, the Building 650 Sump Outfall was not an exposure hazard for either site workers or members of the public.

Table 8-3. Building 650 Sump Outfall TLD Network Data (1999).

Location	1st Quarter (mrem)	2nd Quarter (mrem)	3rd Quarter (mrem)	4th Quarter (mrem)	Annual Dose* (mrem/yr)
A1	19.6	19.8	19.6	20.5	79
A2	71.9	75.8	66.4	75.0	289
A3	27.1	25.2	27.0	25.9	105
A4	21.1	20.4	20.7	20.7	83
B1	17.6	18.4	17.2	17.6	71
B2	34.4	38.4	37.9	33.4	144
B3	78.3	79.1	79.9	78.7	316
B4	39.7	39.4	38.6	38.3	156
C1	20.7	21.5	22.0	21.9	86
C2	48.9	47.9	48.2	48.4	193
C3	173.8	173.8	175.2	168.9	692
C4	367.3	344.7	355.0	342.6	1,410
C5	34.5	33.0	33.1	31.9	133
D1	22.9	19.2	20.9	20.1	83
D2	29.0	31.5	30.4	31.6	123
D3	115.5	129.6	129.4	119.4	494
D4	195.6	191.9	194.1	187.0	769
D5	61.1	59.7	60.7	59.3	241
E3	101.1	99.7	101.1	99.8	402
E4	156.1	141.3	144.7	136.1	578
E5	104.9	96.8	74.3	99.8	376
F16 (Fence N)	14.0	13.4	14.1	14.2	56
F19 (Fence S)	13.3	12.3	12.5	13.4	52
F17 (Fence E)	15.8	14.2	15.1	14.4	60
F18 (Fence W)	15	14.3	15.1	NA	44
Background #1(1)	17.2	15.0	16.2	16.3	65
Background #2(1)	16.1	19.3	16.4	13.9	66

Notes:
See Figure 8-3 for locations
*Dose rate normalized to a 365-day year.
NA=Not Available
(1)Distant background locations.

8.2 AIR EMISSIONS

BNL operations were subjected to the requirements of 40 CFR Part 61, Subpart H, National Emission Standards for Hazardous Air Pollutants (NESHAPs). This U.S. Environmental Protection (EPA) rule establishes national policy regarding the airborne emission of radionuclides. It specifies the monitoring and reporting requirements for various types of radionuclides and establishes the public dose limit for the airborne pathway as 10 mrem (0.1 mSv) per year.

8.2.1 AIR DISPERSION MODEL

Compliance with NESHAPs regulations was demonstrated through the use of the EPA's CAP88-PC (Clean Air Act Assessment Package-1988) computer model. The CAP88-PC model uses a Gaussian plume equation to estimate the average dispersion of radionuclides released from elevated stacks or area sources (EPA 1992). The program computes radionuclide concentrations in air, rates of deposition on ground surfaces, and concentrations in food (where applicable) to arrive at a final value for projected dose at the specified distance from the release point. The program supplies both the calculated effective dose equivalent (EDE) to the maximally exposed individual (MEI) and the collective population dose within a 50-mile radius of the emission source. This model provides very conservative dose estimates in most cases. For purposes of modeling the dose to the MEI, all emission points are located at the center of the developed portion of the site.

Input parameters used in the model include radionuclide type, emission rate in curies per year, stack parameters such as height and diameter, and emission exhaust velocity. Site-specific weather and population data are also used. Weather data are supplied by measurements from BNL's meteorological tower. Data include wind speed, direction, frequency, and temperature. For this emission assessment year, wind data recorded during 1999 were used. Population data for the surrounding area are based on customer records of the Long Island Power Authority (LIPA 1999). Since visiting researchers and their families may reside at the onsite apartment area for extended periods of time, these residents are also considered in the population file used for dose assessment.

8.2.2 EFFECTIVE DOSE EQUIVALENT CALCULATIONS - AIRBORNE PATHWAY

In 1999, the effective dose equivalent to the MEI from all radiological airborne emission sources combined was 0.13 mrem (1 μSv). The MEI is a hypothetical member of the public who

resides at the BNL boundary in the downwind direction. Argon-41 (gaseous, half-life=1.8 hours) released from the Brookhaven Medical Research Reactor (BMRR) was the major contributor of this dose. By comparison, this is only one percent of the EPA airborne dose limit of 10 mrem (0.1 mSv) and is statistically insignificant to the effective dose equivalent received annually from natural background radiation. The MEI dose projected for emissions from each facility is shown in Table 8-4.

8.3 EFFECTIVE DOSE EQUIVALENT CALCULATIONS-FISH CONSUMPTION

Calculations were also made to determine the potential dose to an individual consuming fish taken exclusively from the Peconic River. As discussed in Chapter 6, fish from the Peconic River and Peconic-fed water bodies continue to be analyzed for radiological content because of known historical radionuclide discharges from the BNL Sewage Treatment Plant. These releases occurred primarily in the 1950s and 1960s. In 1999, fish samples collected from the Peconic River were analyzed for gamma-emitting radionuclides; only potassium-40 and cesium-137 were above the minimum detection limit. The maximum concentration of cesium-137 (0.70 ± 0.13 pCi/g or 26 ± 4.8 mBq/g, wet weight) was detected in Chain Pickerel flesh samples. When bone and viscera were analyzed, the concentration was found to be 0.53 ± 0.13 pCi/g (19.6 ± 4.8 mBq/g) wet weight. The measured concentration in a Yellow Perch from the same location, analyzed as a whole sample, was 0.37 ±0.20 pCi/g (13.7 ± 7.4 mBq/g) wet weight. The average concentration of 0.42 ± 0.09 pCi/g (16 ± 3 mBq/g) of Cs-137 for Chain Pickerel (whole) was used for dose calculations.

For dose evaluation, a maximally exposed individual is assumed to eat 15 pounds of fish during the course of the year (NYSDOH 1996). Exclusive consumption of Chain Pickerel at the rate and concentration given above would result in an EDE of 0.25 mrem (3 μSv) due to cesium-137 concentrations. By comparison, the average individual EDE caused by the ingestion of naturally occurring radionuclides in the U.S. is about 40 mrem (400 μSv) per year (NCRP 1987). Analyses results from shellfish, aquatic vegetation, marine waters, and sediments demonstrated that radionuclides were not detected above the minimum detection levels.

Table 8-4. Maximally Exposed Individual EDE From Air Emissions (1999).

Building	Facility or Process	MEI Dose (mrem)
491	Brookhaven Medical Research Reactor	1.3E-01
750	High Flux Beam Reactor	9.2E-05
931	Brookhaven LINAC Isotope Producer	2.8E-05
801	Target Processing Lab	7.1E-07
750	Evaporator Facility	4.2E-05
—	Relativistic Heavy Ion Collider	ND
942	Alternating Gradient Synchrotron Booster	0.0(a)
490	Radiation Therapy Facility	2.2E-04(b)
820	Accelerator Test Facility	ND(c)
938	Radiation Effects Facility/NBTF	ND(d)
510	Calorimeter Enclosure	ND(e)
463	Biology Facility	6.9E-09(e)
555	Chemistry Facility	1.3E-10(e)
830	Environmental & Waste Management	3.1E-11(e)
490D	Environmental Biology	ND(e)
490	Medical Research Center	5.8E-08(e)
703	Analytical Laboratory	ND(e)
Total from BNL Operations		0.13 mrem
EPA Limit		10 mrem

Notes:
"Dose" as used in this table means committed effective dose equivalent.
ND=No Dose- facility not operational or no source in 1999.
(a) Booster ventilation system prevents air release through continuous air recirculation.
(b) Based on conservative engineering calulations.
(c) This has become a zero-release facility since original permit application.
(d) This facility is no longer in use, it produces no radioactive air emissions.
(e) All doses based on emissions calculated using 40 CFR 61, Appendix D methodology.

8.4 EFFECTIVE DOSE EQUIVALENT CALCULATIONS - DEER MEAT CONSUMPTION

As discussed in Chapter 6, measurements were made of flesh samples collected from deer taken on BNL property as well as from offsite locations. Cesium-137 was detected in the flesh samples from onsite deer at concentrations higher than those found in comparable offsite deer. The onsite average concentration found in the flesh sample was 2.88 ± 0.53 pCi/g (0.11 ± 0.02 Bq/g) wet weight. In comparison, the offsite deer flesh sample had 1.95 ± 0.34 pCi/g (0.07 ± 0.01Bq/g) wet weight of cesium-137. While onsite sport hunting is not permitted, there are no physical barriers preventing deer from migrating beyond the site boundary. It is, therefore, conceivable that hunters may occasionally take a deer that resides predominantly on the BNL site.

In March 1999, the New York State Department of Health (NYSDOH) Bureau of Environ-

mental Radiation Protection issued a report examining the possible dose impacts to members of the public who consume deer that have grazed extensively on the BNL site (NYSDOH 1999). In the NYSDOH report, a 10 mrem/year dose was used as the limit for deer meat consumption. The annual consumption rate of venison was estimated using the EPA's Exposure Factors Handbook, which gives the average intake of game meat (for those who consume it) as approximately 1.1 grams per day per kilogram of body weight (EPA 1996). For a 154-pound individual, this corresponds to about 64 pounds of venison consumed per year. The same assumptions have been adopted for this report.

The potential dose from deer meat consumption has been calculated using the arithmetic average of the cesium concentrations measured in flesh samples collected onsite. The dose calculation uses a wet weight average concentration (i.e., the concentration in the flesh sample prior to drying for analysis), which was equal to 2.88 pCi/g (0.11 Bq/g). Under the stated assumptions, the committed EDE due to consumption of local deer meat would be equal to 4.2 mrem (42 μSv) per year. By comparison, the average EDE from eating foods that contain naturally occurring radionuclides is 40 mrem (0.4 mSv) per year (NCRP 1987).

8.5 COLLECTIVE EFFECTIVE DOSE EQUIVALENT

Collective EDE, a value used to estimate potential health risks to a population, is the summation of the calculated EDE for each individual multiplied by the number of individuals in the population being considered.

Assuming that the total number of individuals who routinely consume fish taken from portions of the Peconic River close to the BNL site was equal to 625, the collective EDE from this pathway was 156 person-mrem (1.5 person-mSv). This value was based on the maximum fish concentrations discussed in section 8.3 above. In comparison, the collective EDE to the same population from consumption of naturally occurring radionuclides in food is 25,000 person-mrem (250 person-mSv) annually.

Since onsite deer hunting was prohibited, the individual dose estimate from meat consumption calculated in section 8.4 is based on average cesium-137 concentrations. Deer moving beyond BNL boundaries can be legally hunted and consumed resulting in collective dose. However, the number of people consuming deer meat in the vicinity of BNL was not tracked within the one-mile radius of BNL; therefore, the collective dose from deer meat consumption could not be calculated.

For the air exposure pathway, the CAP88-PC computer model provides collective EDE estimates using population data for the area within a 50-mile radius of the BNL site. The population data are broken into the number of people living within each of the 16 compass sectors at 10-mile radial intervals. Again, argon-41 emitted from the BMRR was the largest contributor to the total collective dose at 4,649 person-mrem (46 person-mSv). This constituted 99 percent of the total collective dose resulting from BNL operations projected for the population within a 50-mile radius of BNL.

8.6 SUMMARY AND CONCLUSION

Calculations of EDE from all BNL facilities that have the potential to release radionuclides to the atmosphere indicated that radiological

Table 8-5. Summary of Potential Dose from All Environmental Pathways (1999).

Pathway	Primary Contributing Radionuclide	Maximally Exposed Individual EDE (mrem)	Regulatory Pathway Limit (mrem)	Collective EDE (person-mrem)
Inhalation	Ar-41	0.13	10	4,649
Fish Consumption[1]	Cs-137	0.25	NS	156
Deer Meat Consumption[2]	Cs-137	4.2	NS	NA
Drinking Water[3]	NA	NA	NA	NA

Notes:
Because all doses in this table are calculated rather than measured, they are potential doses.
EDE=Effective Dose Equivalent.
NS=None Currently Specified.
NA=Not Applicable
[1]Fish dose calculation is based on measured Cs-137 concentration only. Sr-90 analyses were not performed in 1999. Calculation assumes a consumption of 15 lbs./yr.
[2]Deer Meat Dose is based on average onsite deer concentration. Calculation assumes a consumption of 64 lbs./yr.
[3]No drinking water dose projected following connection of public water supply to homes adjacent to BNL.

doses attributable to Laboratory operations were well below the limits established by federal regulations (see Table 8-5). Direct measurement of external radiation levels by TLD confirmed that exposure rates at the site boundary were consistent with background levels observed throughout New York State (NYSDOH 1993).

Additionally, it was assumed there was no internal dose to the public from the drinking water ingestion pathway since public water supply hookups have been provided to site neighbors.

The EDE calculations presented in this chapter were based on the maximally exposed individual for each scenario using the stated assumptions. Given this, it was not plausible that any single person could receive a radiological dose equal to the sum of these individual pathways. For this to occur, an individual would be required to breathe air and consume fish and deer at the radionuclide concentrations calculated or observed in all samples collected in 1999.

The hypothetical maximally exposed individual, defined as residing at the northeast boundary of BNL, breathing the air, and consuming 15 pounds of fish and 64 pounds of deer meat from onsite sources would receive 4.58 mrem/yr. of the total effective dose equivalent from inhalation and ingestion pathways (dose from drinking water is zero). This is an extremely unlikely worst case scenario, but was calculated to show that the dose from all pathways would still be less than 5 percent of 100 mrem/yr. dose limit set by DOE for the general public. The average annual dose from man-made, cosmic, terrestrial and ingestion paths, and radon is 360 mrem (NCRP 1987). These MEI doses demonstrate that in 1999 there was minimal radiological dose impact above the natural background to the public and the environment from BNL operations.

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