Radiological Dose Assessment

CHAPTER 9

This chapter discusses the potential radiological doses to offsite individuals and the surrounding population from Brookhaven National Laboratory radioactive airborne emissions. Special case exposures such as fish and deer meat consumption are also discussed. These potential doses are based on calculations using 1998 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, i.e., the total dose which would be received by an individual in the 50 years following radionuclide uptake.

9.1 EXTERNAL PENETRATING RADIATION MEASUREMENTS

The Brookhaven National Laboratory (BNL) measures environmental background radiation through a network of onsite and offsite dosimeter units. These units, called thermoluminescent dosimeters, or TLDs, measure gamma radiation originating from cosmic and terrestrial sources (see Chapter 4 for discussion) as well as any contribution from Laboratory operations. Calcium fluoride (CaF_2:Dy) type TLDs are used. There are a total of 24 onsite locations which have TLDs in place (see Figure 9-1 for locations). In addition to the dosimeters located on BNL property, 21 offsite locations were also monitored in 1998 (see Figure 9-2 for locations). These offsite measurements provide background comparison values and are used to determine whether BNL operations have had an impact on the ambient radiation levels of the surrounding area.

Onsite 1998 TLD data are summarized in Table 9-1. The second quarter data for these TLDs were invalidated due to the loss of the control dosimeter used to subtract exposure occurring between collection and read-out. However, the remaining three quarters show values which are consistent with previous years and typical of exposure from natural cosmic and terrestrial sources. Average quarterly dose values were between 15 and 20 mrem (150 and 200 μSv.

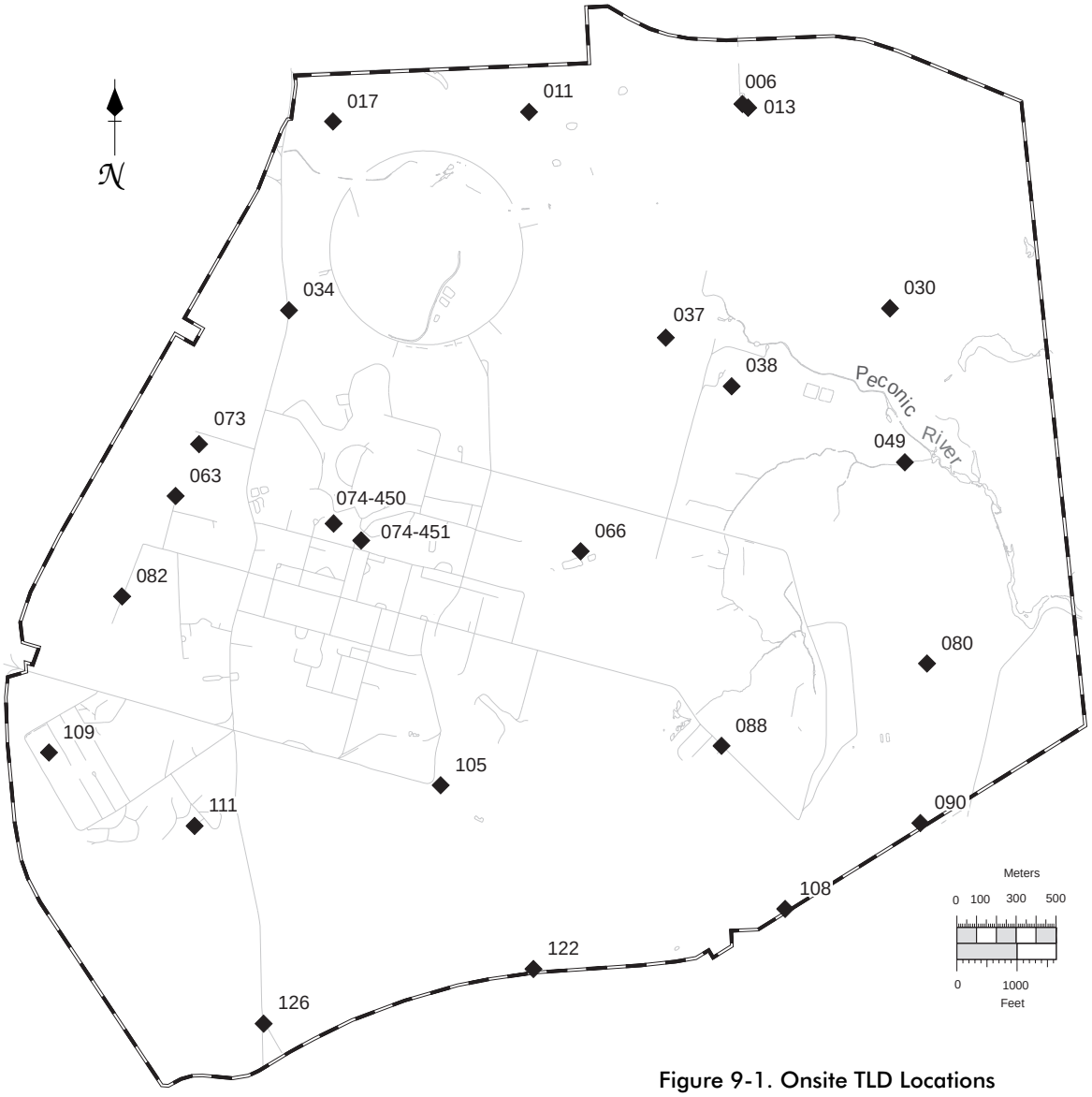

Figure 9-1. Onsite TLD Locations

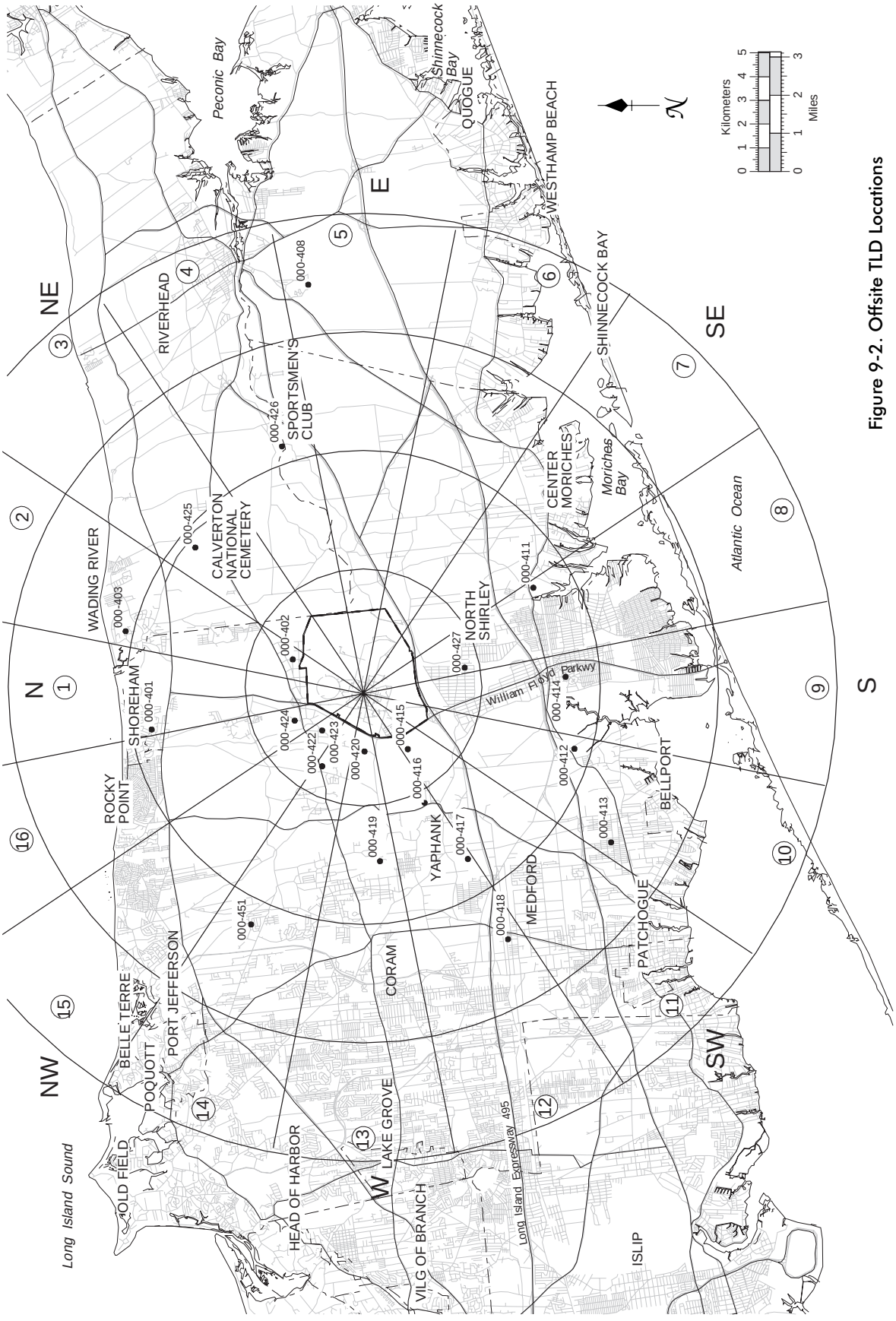

Figure 9-2. Offsite TLD Locations

Table 9-1. Quarterly Onsite Ambient Radiation Measurements

Station	Qtr. 1 (mrem)	Qtr. 2 (mrem)	Qtr. 3 (mrem)	Qtr. 4 (mrem)
011-400	13.0	(a)	14.6	18.5
013-400 (P9)	(b)	(a)	(b)	19.3
017-400 (P2)	13.1	(a)	13.6	18.0
030-400	13.9	(a)	13.5	19.9
034-400	15.6	(a)	16.5	20.6
034-401	15.0	(a)	20.0	22.1
037-400	16.4	(a)	16.4	19.6
038-450 (S5)	15.0	(a)	14.8	19.3
049-400	14.0	(a)	13.3	19.3
053-400	16.0	(a)	17.9	21.1
063-400	17.0	(a)	16.9	22.0
066-400	12.8	(a)	12.8	17.3
073-400	17.1	(a)	16.6	23.9
074-450 (Bldg. 197)	16.2	(a)	17.7	22.7
074-451 (Bldg. 907)	13.6	(a)	13.7	19.4
080-400	17.5	(a)	15.8	24.3
082-400	15.6	(a)	15.9	20.6
090-400 (P7)	14.8	(a)	15.5	19.8
105-400	16.2	(a)	15.6	20.6
108-450	14.6	(a)	16.0	21.5
109-400 (P4)	13.8	(a)	14.3	20.1
111-400	14.2	(a)	15.1	21.1
122-400	14.3	(a)	14.2	19.8
126-400	15.2	(a)	15.5	20.7
Average	15.0	N/A	15.5	20.5
Median	15.0	N/A	15.5	20.3
Population Std. Dev.	1.3	N/A	1.7	1.6

Notes:
a. All onsite qtr. 2 dosimeters invalidated due to loss of control dosimeter.
b. Dosimeter reported missing.

Table 9-2. Quarterly Offsite Ambient Radiation Measurements

Station	Qtr. 1 (mrem)	Qtr. 2 (mrem)	Qtr. 3 (mrem)	Qtr. 4 (mrem)	Annual Dose* (mrem/yr)
000-401	12.9	17.4	15.3	14.2	61.3
000-402	13.0	20.9	16.9	18.4	69.9
000-403	13.4	24.6	20.7	17.3	78.8
000-408	15.4	19.3	15.5	15.8	65.0
000-411	16.3	19.2	18.5	17.5	71.4
000-412	16.6	20.7	17.0	20.7	75.9
000-413	15.4	21.5	17.2	19.7	74.7
000-414	16.1	19.4	16.6	17.7	70.2
000-415	12.6	20.9	15.5	18.4	69.9
000-416	14.2	17.6	13.4	16.4	61.4
000-417	15.3	21.4	15.8	16.3	66.1
000-418	15.6	20.3	16.0	18.4	70.0
000-419	15.0	20.1	15.4	16.3	65.3
000-420	15.1	21.3	16.0	18.4	71.2
000-422	16.3	19.4	(a)	18.7	69.3
000-423	14.8	20.0	14.1	16.6	65.5
000-424	(a)	18.1	15.6	17.2	71.5
000-425	15.8	20.3	12.8	17.1	66.4
000-426	15.4	19.7	16.0	18.3	69.7
000-427	18.6	20.9	(b)	(b)	77.8
000-451	(c)	(c)	19.9	21.5	76.2
Average	15.1	20.2	16.2	17.8	69.9
Median	15.4	20.2	16.0	17.6	69.9
Population Std. Dev.	1.4	1.5	1.9	1.6	4.8

* Dose rate normalized to 365 day year.

Notes:
a. Dosimeter reported missing.
b. Station relocated after 2nd quarter, became station 000-451.
c. Station relocated from station 000-427 after 2nd quarter.

Offsite 1998 TLD data are summarized in Table 9-2. The average annual offsite external radiation dose value was 70 ± 5 mrem (0.7 ± 0.05 mSv) (the error term represents the standard deviation of the sample population). This is consistent with the value of 67 ± 5 mrem/yr (0.67± 0.05 mSv/yr) measured in 1997. 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), indicating that BNL operations had no measurable effect on local radiation exposure levels. (Note that measurements recorded by TLDs measure direct radiation only and cannot be used to assess exposure due to internally deposited radionuclides.)

9.1.1 BUILDING 650 SUMP OUTFALL

From approximately 1959 to 1969, decontamination of radiologically contaminated heavy equipment took place 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 which is being remediated under the Environmental Restoration program (Operable Unit [OU] IV, Area of

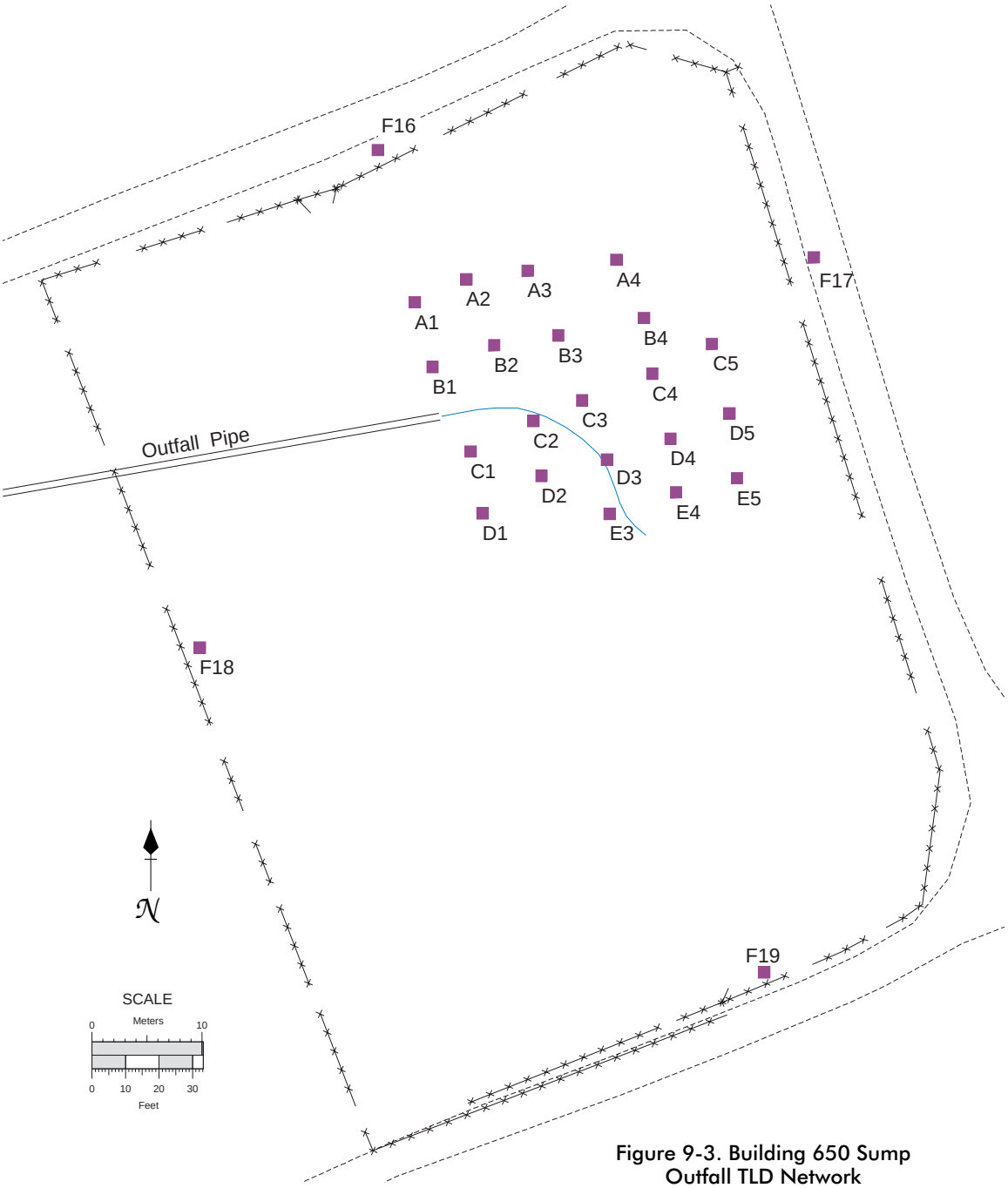

Figure 9-3. Building 650 Sump Outfall TLD Network

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 (LiF:Mg,Ti type) was installed to monitor gamma radiation exposure levels in the area (see Figure 9-3). 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 D5 indicated that radionuclides related to the Building 650 Sump Outfall were probably also located to the southeast, just beyond the existing network.

Table 9-3. Building 650 Sump Outfall TLD Network Data

Location	Qtr. 1 (mrem)	Qtr. 2 (mrem)	Qtr. 3 (mrem)	Qtr. 4 (mrem)	Annual Dose* (mrem/yr)
A1	19	19	20	21	78
A2	69	74	72	77	292
A3	25	24	26	25	101
A4	19	19	20	20	78
B1	16	16	17	17	66
B2	36	37	38	38	148
B3	77	76	79	78	309
B4	37	35	39	38	149
C1	20	21	22	21	84
C2	44	45	47	47	182
C3	164	162	173	165	664
C4	338	328	348	337	1,352
C5	30	31	32	32	126
D1	20	20	20	20	80
D2	28	31	30	32	121
D3	123	123	126	126	497
D4	185	182	191	185	743
D5	58	56	59	59	232
E3	96	95	96	98	386
E4	136	133	139	139	547
E5	93	90	101	99	383
F16 (Fence N)	13	14	13	14	55
F19 (Fence S)	13	12	13	13	51
F17 (Fence E)	14	14	15	15	58
F18 (Fence W)	14	13	15	15	57
Bkg 1**	15	15	15	16	60
Bkg 2**	15	15	15	16	61

Notes:
* Dose rate normalized to a 360 day year.
** Distant background location.

The new stations were installed to monitor this area, though previous soil sampling and fence dosimeters show that radionuclides related to Building 650 are localized within the fenced area.

Consistent with the previous year, 1998 data from the Building 650 Sump Outfall TLD network indicated that the highest concentration of radionuclides are located in the area of position C4, where a dose rate of 1.4 rem/yr (14 mSv/yr) was recorded (Table 9-3). Other locations in the monitoring grid continued to show dose rates varying from background levels up to 743 mrem/yr (7.4 mSv/yr). Fence dosimeters showed no elevated dose rates and were consistent with the two distant background TLDs, demonstrating that the radiation field generated by the Sump Outfall contaminants is limited to the immediate area of the outfall itself. Due to the localization of contaminants, the Building 650 Sump Outfall is not an exposure hazard for either site workers or members of the public.

9.2 AIRBORNE PATHWAY

BNL is subject to the requirements of Title 40 CFR Part 61, Subpart H, National Emission Standards for Hazardous Air Pollutants (NESHAPs). This U.S. Environmental Protection (USEPA) 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.

9.2.2 AIR DISPERSION MODEL

Compliance with NESHAPs regulations is demonstrated through the use of the USEPA'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 (USEPA, 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 an 80 km (50 mi) 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, and stack parameters such as height, 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 1998 were used. This is a change from previous years in which average wind data collected between 1980 and 1989 were used. Use of this updated wind data

Table 9-4. 1998 Airborne Radiological Dose by Facility as Calculated by CAP88-PC

Building	Facility or Process	Construction Permit No.	MEI Dose (mrem)*	Collective Dose (person-mrem)*	Notes
491	BMRR	None	2.1E-01	7.5E+03	
705	HFBR	None	2.7E-04	8.1E+01	
931	BLIP	None	1.1E-04	6.5E-02	
801	Target Processing Lab	None	6.9E-06	4.4E+01	
705	Evaporator Facility	BNL-288-01	2.1E-05	5.7E+00	
—	RHIC	BNL-389-01	0	0	
—	AGS Booster	BNL-188-01	0	0	a
—	AGS Cooling Tower #2	None	1.7E-05	5.3E-04	
930	Linac	None	3.3E-06	1.8E-05	
490	Radiation Therapy Facility	BNL-489-01	2.2E-04	9.3E+03	b
820	Accelerator Test Facility	BNL-589-01	0	0	c
938	REF/NBTF	BNL-789-01	0	0	d
510	Calorimeter Enclosure	BNL-689-01	0	0	d
463	Biology Dept.	None	9.7E-07	5.3E-02	e
555	Chemistry Dept.	None	3.2E-09	2.0E-04	e
318	Dept. of Applied Science	None	6.1E-08	3.3E-04	e
490A	Dept. of Applied Science	None	9.4E-09	4.4E-04	e
490	Medical Research Center	None	1.8E-07	5.1E-03	e
703W	Dept. of Advanced Tech.	None	6.0E-14	2.8E-09	e
		Total	2.1E-01	7.6E+03	

* "Dose" as used in this table means committed effective dose equivalent.

Notes:
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.

had the effect of increasing the dose value somewhat, even though 1998 air emissions were consistent with those of previous years.

Population data for the surrounding area are based on customer records of the Long Island Power Authority (LILCO, 1996). 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.

9.2.4 EFFECTIVE DOSE EQUIVALENT CALCULATIONS - AIRBORNE PATHWAY

In 1998, the EDE to the MEI from all radiological airborne emissions sources combined was 0.2 mrem (2 μSv). Argon-41 released from the Brookhaven Medical Research Reactor (BMRR) contributed 98 percent of this dose. By comparison, this is 50 times less than the USEPA airborne dose limit of 10 mrem (0.1 mSv) and about 1,500 times smaller than the EDE received annually from natural background radiation. Such a dose is too small to distinguish from background radiation sources using the most sensitive environmental TLDs. The MEI dose projected for emissions from each facility is shown in Table 9-4.

9.3 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 Section 7.2.2, 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 60s. In 1998, samples were analyzed for gamma-emitting radionuclides only; no analyses for strontium were performed (see Section 7.8.1 of the 1996 BNL Site Environmental Report for strontium test data). As in previous years, the only anthropogenic gamma-emitting radionuclide detected in fish

Table 9-5. Summary of Dose From All Environmental Pathways, 1998

Pathway	Primary Contributing Radionuclide	Maximum Individual EDE (mrem)	Regulatory Pathway Limit (mrem)	Collective EDE (person-mrem)
Air	Ar-41	0.21	10	7510
Fish	Cs-137	0.26	NS	163
Deer Meat	Cs-137	7.1	NS	NA

Notes:
1. 1 mrem = 0.01 mSv.
2. EDE = Effective Dose Equivalent.
3. NS = None Currently Specified
4. NA = Not Applicable
5. Because all doses in this Table are calculated rather measured, they are potential rather than actual doses.
6. Fish dose calculation is based on measured Cs-137 concentrations only. Sr-90 analyses were not performed in 1998.
7. Deer dose is based on average onsite deer concentrations. Onsite sport hunting is not permitted.
8. Fish and deer dose clculations assume a consumption rate of 7 and 29 kg/yr, respectively.
9. No water consumption dose projected following connection of public water supply to homes adjacent to BNL.

samples was cesium-137. The maximum concentration of detected cesium-137 occurred in a fish collected near the BNL boundary at North Street. The fish was of the chain pickerel *(Esox niger)* species and contained 0.73 pCi/g (27 mBq/g) of cesium-137. This result was obtained from analysis of the flesh and skin portions of the segregated sample. The measured concentration in a pickerel from the same location analyzed as a whole was 0.41 pCi/g (15 mBq/g).

For dose evaluation, an individual is assumed to eat 7 kg (15 lbs) of fish during the course of the year. Exclusive consumption of chain pickerel at the rate and the concentration given above would result in an EDE of 0.26 mrem (3 μSv) due to cesium-137. 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).

9.4 EFFECTIVE DOSE EQUIVALENT CALCULATIONS - MEAT CONSUMPTION

As discussed in Chapter 7, measurements were made of flesh samples collected from deer taken on BNL property as well as from offsite locations. Cesium-137 is detectable in meat samples from onsite deer at concentrations higher than those found in comparable offsite deer. 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 deer which reside predominantly on the BNL site may occasionally be taken by sportsmen during the hunting season. An estimate of the dose resulting from consumption of deer meat based on samples collected in 1998 is presented here.

In March of 1999, the New York State Department of Health (NYSDOH) Bureau of Environmental Radiation Protection issued a report examining the possible dose impacts to members of the public who consume deer which have grazed extensively on the BNL site. In the NYSDOH report, the annual consumption rate of venison was estimated using the USEPA's Exposure Factors Handbook, which gives the average intake of game meat (for those who consume it) as approximately 1.1 g per day per kg of body weight (USEPA, 1996). For a 70 kg (154 lb) individual, this corresponds to about 29 kg (63 lb) 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 onsite hind meat samples. The dose calculation uses a wet weight average concentration, i.e., the concentration in the flesh sample prior to drying for analysis, which is equal to 4.9 pCi/g (0.18 Bq/g). Under the stated assumptions, the committed EDE due to exclusive consumption of local deer meat would be equal to 7.1 mrem (71 μSv). By comparison, the average EDE from eating foods which contain naturally-occurring radionuclides is 40 mrem (0.4 mSv) per year (NCRP, 1987).

9.5 COLLECTIVE EFFECTIVE DOSE EQUIVALENT (EDE)

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 total number of individuals who routinely consume fish taken from portions of the Peconic River, close to the BNL site, is equal to 625, the collective EDE from this pathway is 163 person-mrem (1.6 person-mSv). This value is based on the maximum fish concentrations discussed above. 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 is prohibited, and the individual dose estimate resulting from meat consumption is a theoretical maximum based on site-resident deer only, collective EDE is not calculated for this pathway.

For the air exposure pathway, the CAP88-PC computer model provides collective EDE estimates using population data for the area within an 80 km (50 mi) radius of the BNL site. The population data are broken into the number of people living within each of the 16 compass sectors at 16 km radial intervals. Again, argon-41 emitted from the BMRR was the largest contributor to the total collective dose at 7,510 person-mrem (75 person-mSv). This constitutes 99 percent of the total collective dose projected for the population within an 80 km (50 mi) radius of BNL.

By comparison, the collective dose due to external radiation from natural background to the population within an 80 km radius of the Laboratory amounts to approximately 291,000 person-rem (2,910 person-Sv), and about 196,800 person-rem (1,968 person-Sv) from internal radioactivity deposited in the body from natural sources (excluding potential radon contributions).

9.6 SUMMARY AND CONCLUSION

Calculations of EDE from all BNL facilities which have the potential to release radionuclides to the atmosphere indicated that radiological doses attributable to Laboratory operations were far below the limits established by Federal regulations (see Table 9-5). 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).

The EDEs presented in this Chapter were based on the MEI for each scenario using the stated assumptions. Given this, it is 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 highest radionuclides concentrations calculated or observed in all samples collected in 1998. However, even if these pathways were to be summed, the total dose from all pathways would equal only 8 percent of the 100 mrem/yr (1 mSv/yr) DOE limit established for the protection of the public. This total is equivalent to approximately 3 percent of the average individual dose received annually from natural background sources, including radon (NCRP, 1987). These maximum credible doses demonstrate that in 1998, radioactive material associated with BNL operations had no impact on the health of the public or environment in the surrounding area.

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