8

Radiological Dose Assessment

All Laboratory operations, scientific experiments, and research projects are evaluated for safety and dose to workers and the environment before their implementation. Radiological assessment of operations, experiments, and remediation projects are performed as necessary, to ensure that the overall radiological dose impact from these activities is "As Low As Reasonably Achievable" (ALARA) to members of the public, BNL workers, visitors, and the environment. The assessments also ensure that facilities and operations are in compliance with federal, state, and local regulations. The potential radiological dose to members of the public is calculated at the site boundary as the maximum dose that could be received by a hypothetical individual defined as the "maximally exposed individual" (MEI). Therefore, all individual members of the public will receive dose less than the MEI. The dose to the MEI is the sum total from direct and indirect dose pathways to an individual via air immersion, inhalation of particulates and gases, and ingestion of local fish and deer meat. The 2008 Total Effective Dose Equivalent (TEDE) from Laboratory operations was well below the EPA and DOE regulatory dose limits for the public, workers, and the environment.

The average annual on-site external dose from ambient sources was 69 ± 13 mrem (690 ± 130 µSv) and 63 ± 11 mrem (630 ± 110 µSv) at off-site locations. Both on- and off-site dose measurements include the contribution from natural terrestrial and cosmic background radiation. A statistical comparison of the average doses measured using thermoluminescent dosimeters (TLDs) at 49 on-site and 15 off-site locations showed that there was no external dose contribution from BNL operations above the natural background radiation level. An additional nine TLDs were used to measure on-site areas known to have radiation dose slightly elevated above natural background. The results of these measurements are described in Section 8.1.2.

The effective dose equivalent (EDE) from air emissions was calculated as 6.12E-02 mrem (0.61 µSv) to the MEI. The dose from the ingestion pathway was estimated as 12.48 mrem (125 µSv) from the consumption of deer meat, and 0.09 mrem (0.9 µSv) from the consumption of fish caught in the vicinity of the Laboratory. The total annual dose to the MEI from all the pathways was estimated as 12.63 mrem (126 µSv). The BNL dose from the air inhalation pathway was less than 1 percent of EPA's annual regulatory dose limit of 10 mrem (100 µSv). The total dose was less than 13 percent of DOE's annual dose limit of 100 mrem (1,000 µSv) from all environmental pathways.

Doses to aquatic and terrestrial biota were also evaluated and found to be well below DOE regulatory limits. Other short-term projects, such as remediation work and waste management disposal activities, were assessed for radiological emissions; the potential dose impacts from these activities were below regulatory limits and there was no radiological risk to the public, BNL employees, visitors, or the environment. In summary, the overall dose impact from all Laboratory activities in 2008 was comparable to natural background radiation levels.

8.1 DIRECT RADIATION MONITORING

Direct, penetrating beta and gamma radiation is measured using TLDs. The principle of TLD function is that when certain crystals are exposed to radiation, impurities in the crystals' low-temperature trapping sites are excited to higher energy states. These electrons remain in a high-energy state at normal ambient temperature. When the TLDs are heated (annealed), electrons return to the lower energy state, emitting photon energy (light), which is measured with a photomultiplier tube; the light intensity is directly proportional to the absorbed radiation dose. The environmental TLDs used at the Laboratory are composed of calcium fluoride and lithium fluoride crystals. Accuracy is verified by exposing the TLD to a known and characterized radiation source. BNL participates in the inter-comparison proficiency testing programs sponsored by DOE, as a check of its ability to measure radiation doses accurately.

A direct radiation-monitoring program is used to measure the external dose contribution to members of the public and workers from radiation sources at the Laboratory. This is achieved by measuring direct penetrating radiation exposures at both on- and off-site locations. The direct measurements taken at the off-site locations are with the premise that off-site exposures represent true natural background radiation (with contribution from both cosmic and terrestrial sources) and represent no contribution from BNL operations. On- and off-site external dose measurements were averaged, and then compared with each other using the statistical t-test to measure any variations in the averages and thus the contribution, if any, from Laboratory operations.

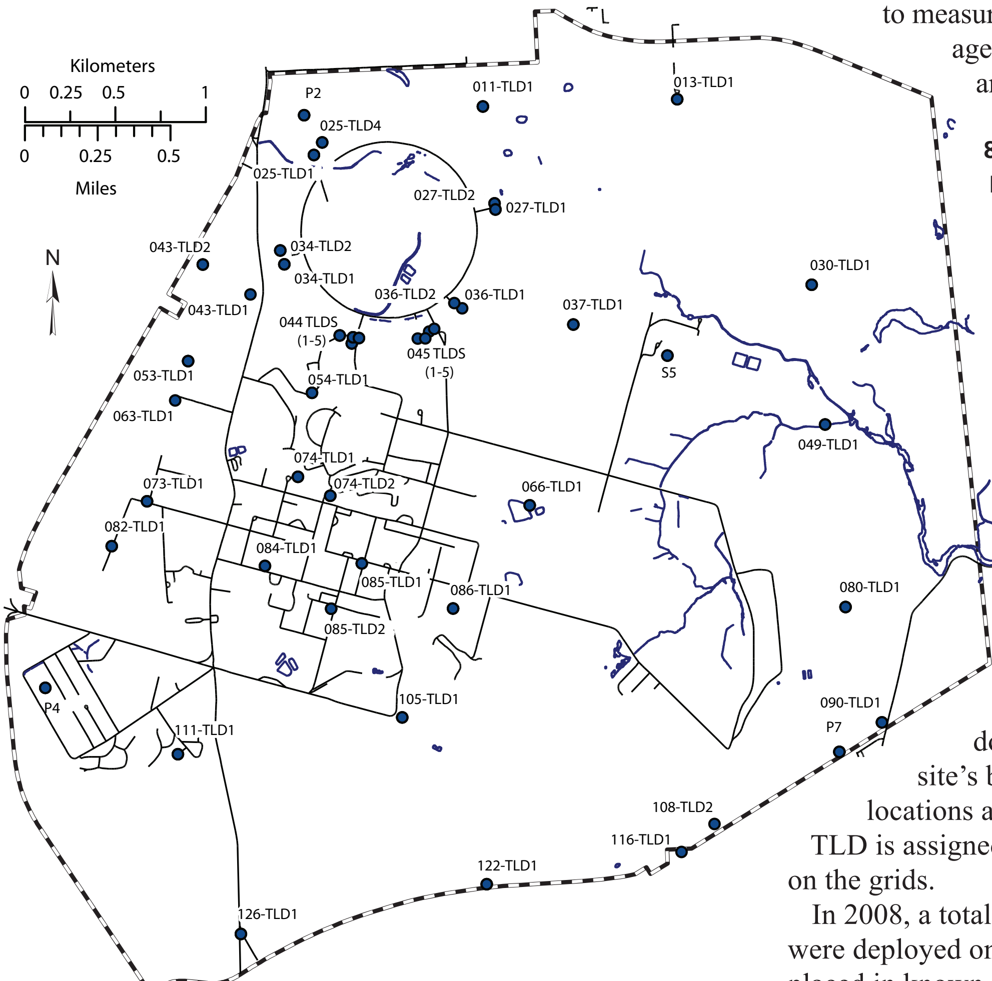

Figure 8-1. On-Site TLD Locations.

8.1.1 Ambient Radiation Monitoring

To assess the dose impact of direct radiation from BNL operations, TLDs are deployed on site and in the surrounding communities. On-site TLD locations are determined based on the potential for exposure to gaseous plumes, atmospheric particulates, scattered radiation, and the location of radiation-generating devices. The Laboratory perimeter is also posted with TLDs to assess the dose impact, if any, beyond the site's boundaries. On- and off-site locations are divided into grids, and each TLD is assigned an identification code based on the grids.

In 2008, a total of 58 environmental TLDs were deployed on site, of which nine were placed in known radiation areas. Another 15 TLDs were deployed at off-site locations (see Figures 8-1 and 8-2 for locations). An addi-

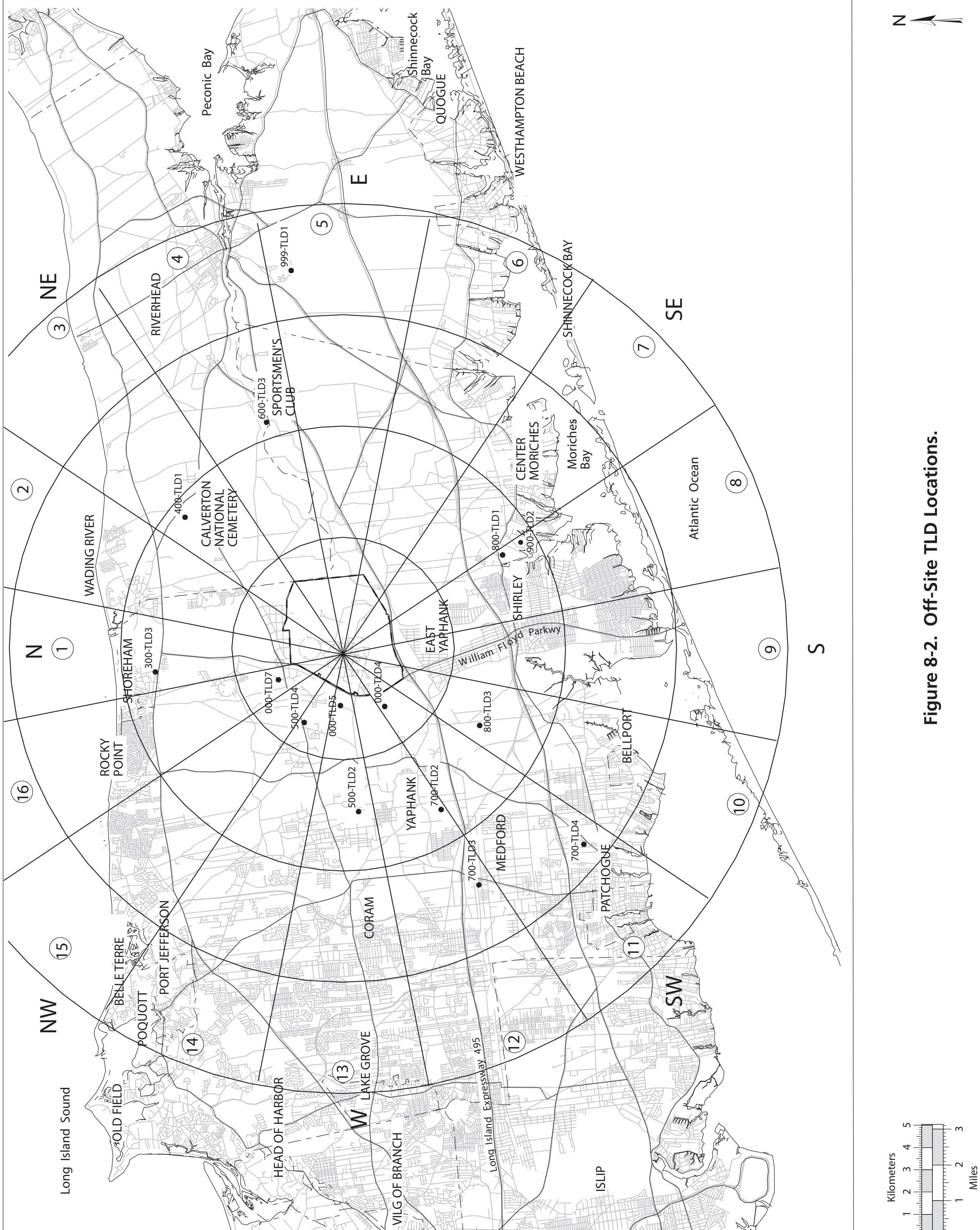

Figure 8-2. Off-Site TLD Locations.

tional 30 TLDs were stored in a lead-shielded container in Building 490 for use as reference and control TLDs for comparison purposes. The average of the control TLD values was reported as "075-TLD4" in Tables 8-1 and 8-2. Note that a small "residual" dose was reported for the control TLDs when they were annealed, because it is not possible to completely anneal and shield the TLDs from all natural background and cosmic radiation sources. The on- and off-site TLDs were collected and read quarterly to determine the external radiation dose measured.

Table 8-1 shows the quarterly and yearly on-site radiation dose measurements for 2008. The on-site average external doses for the first, second, third, and fourth quarters were 18.7 ± 4.3, 16.5 ± 3.3, 15.7 ± 3.7, and 17.7 ± 3.6 mrem, respectively. The on-site average annual external dose from all potential environmental sources, including cosmic and terrestrial radiation sources, was 69 ± 13 mrem (690 ± 130 µSv).

Table 8-2 shows the quarterly and yearly off-site radiation dose measurements. The off-site average external doses for the first, second, third, and fourth quarters were 17.5 ± 2.7, 15.4 ± 2.6, 14.8 ± 3.4, and 15.0 ± 3.0 mrem, respectively. The off-site average annual ambient dose from all potential environmental sources, including cosmic and terrestrial radiation sources, was 63 ± 11 mrem (630 ± 110 µSv).

To determine the BNL contribution to the external direct radiation dose, a statistical t-test between the measured on- and off-site external dose averages was conducted. The t-test showed no significant difference between the off-site dose (63 ± 11 mrem) and on-site dose (69 ± 13 mrem) at the 95 percent confidence level. From the measured TLD doses, it can be safely concluded that there was no measurable external dose contribution to on- and off-site locations from Laboratory operations in 2008.

8.1.2 Facility Area Monitoring

Nine on-site TLDs were designated as facility-area monitors (FAMs) because they were

Table 8-1. On-Site Direct Ambient Radiation Measurements.

TLD#	Location	1st Quarter (mrem)	2nd Quarter (mrem)	3rd Quarter (mrem)	4th Quarter (mrem)	Avg./Qtr. ± 2σ (95%) (mrem)	Annual Dose ± 2σ (95%) (mrem)
011-TLD1	North firebreak	15.8	13.6	11.8	14.6	14 ± 3	56 ± 13
013-TLD1	North firebreak	18.2	14.7	14.8	15.8	16 ± 3	64 ± 13
025-TLD1	Bldg. 1010 beam stop 1	16.4	16.5	14.8	15.8	16 ± 2	64 ± 6
025-TLD4	Bldg. 1010 beam stop 4	17.3	15.3	14.4	17.0	16 ± 3	64 ± 11
027-TLD1	Bldg. 1002A South	15.9	15.2	14.6	15.1	15 ± 1	61 ± 4
027-TLD2	Bldg. 1002D East	16.3	15.5	14.3	15.8	15 ± 2	62 ± 7
030-TLD1	Northeast firebreak	18.1	15.8	15.8	17.3	17 ± 2	67 ± 9
034-TLD1	Bldg. 1008 collimator 2	20.7	17.5	15.7	18.9	18 ± 4	73 ± 17
034-TLD2	Bldg. 1008 collimator 4	18.1	15.9	14.9	17.8	17 ± 3	67 ± 12
036-TLD1	Bldg. 1004B East	15.9	13.9	12.6	15.7	15 ± 3	58 ± 12
036-TLD2	Bldg. 1004 East	20.1	17.1	17.2	16.9	18 ± 3	71 ± 12
037-TLD1	S-13	17.4	15.4	15.2	16.6	16 ± 2	65 ± 8
043-TLD1	North access road	19.0	16.8	16.3	18.6	18 ± 3	71 ± 10
043-TLD2	North of Meteorology Tower	18.3	16.9	16.4	17.0	17 ± 2	69 ± 6
044-TLD1	Bldg. 1006	18.3	16.5	15.7	17.7	17 ± 2	68 ± 9
044-TLD2	South of Bldg. 1000E	22.5	15.6	15.3	16.2	17 ± 7	70 ± 27

(continued on next page)

Table 8-1. On-Site Direct Ambient Radiation Measurements *(concluded).*

TLD#	Location	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Avg./Qtr. ± 2σ (95%)	Annual Dose ± 2σ (95%)
		(mrem)					
044-TLD3	South of Bldg. 1000P	17.0	14.3	13.1	15.7	15 ± 3	60 ± 13
044-TLD4	North-east of Bldg. 1000P	18.0	16.7	16.9	17.9	17 ± 1	70 ± 5
044-TLD5	North of Bldg. 1000P	17.7	15.2	15.3	17.5	16 ± 3	66 ± 11
045-TLD1	Bldg. 1005S	17.9	17.0	15.2	19.3	17 ± 3	69 ± 13
045-TLD2	East of Bldg. 1005S	19.0	16.5	17.3	17.7	18 ± 2	71 ± 8
045-TLD3	South-east of Bldg. 1005 S	20.6	15.6	14.1	16.8	17 ± 5	67 ± 22
045-TLD4	South-west of Bldg. 1005 S	18.1	15.4	14.4	16.2	16 ± 3	64 ± 12
045-TLD5	West South-west of Bldg. 1005 S	16.5	15.0	15.2	14.5	15 ± 2	61 ± 7
049-TLD1	East firebreak	17.3	15.1	16.8	19.3	17 ± 3	69 ± 14
053-TLD1	West firebreak	20.3	20.0	16.9	18.9	19 ± 3	76 ± 12
054- TLD1	Bldg. 914	19.0	15.2	12.7	18.4	16 ± 6	65 ± 23
063-TLD1	West firebreak	20.0	19.6	17.8	20.2	19 ± 2	78 ± 9
066-TLD1	Waste Management Facility	17.4	14.7	13.1	15.7	15 ± 4	61 ± 14
073-TLD1	Meteorology Tower/Bldg. 51	18.5	17.1	17.4	18.5	18 ± 1	72 ± 6
074-TLD1	Bldg. 560	22.4	17.2	17.4	19.0	19 ± 5	76 ± 19
074-TLD2	Bldg. 907	19.8	17.4	14.4	20.8	18 ± 6	72 ± 22
080-TDL1	East firebreak	20.6	18.4	21.6	21.0	20 ± 3	82 ± 11
082-TLD1	West firebreak	21.2	19.7	17.8	20.2	20 ± 3	79 ± 11
084-TLD1	Tennis courts	17.7	15.8	15.0	18.3	17 ± 3	67 ± 12
085-TDL2	Upton gas station	26.5	17.9	16.2	20.4	20 ± 9	81 ± 35
085-TLD1	Diversity Office	19.1	16.4	15.3	19.4	18 ± 4	70 ± 16
086-TLD1	Baseball fields	22.3	20.1	19.4	20.7	21 ± 2	83 ± 10
090-TLD1	North Street Gate	17.2	15.9	16.4	18.1	17 ± 2	68 ± 8
105-TLD1	South firebreak	20.7	19.4	17.5	17.3	19 ± 3	75 ± 13
108-TLD1	Water tower	16.8	14.7	19.0	15.8	17 ± 4	66 ± 14
108-TLD2	Tritium pole	23.4	20.0	14.9	22.5	20 ± 7	81 ± 30
111-TLD1	Trailer park	18.0	17.7	16.5	17.9	18 ± 1	70 ± 5
122-TLD1	South firebreak	17.1	16.0	16.2	16.5	16 ± 1	66 ± 4
126-TLD1	South gate	18.9	19.0	16.8	20.4	19 ± 3	75 ± 12
P2		14.8	14.6	13.0	17.5	15 ± 4	60 ± 15
P4		17.3	15.1	13.9	17.0	16 ± 3	63 ± 13
P7		18.0	15.7	16.0	16.1	16 ± 2	66 ± 8
S5		19.0	15.5	13.8	15.7	16 ± 4	64 ± 17
On-site average		**18.7**	**16.5**	**15.7**	**17.7**	**17 ± 3**	**69 ± 13**
Std. dev. (2 σ)		**4.3**	**3.3**	**3.7**	**3.6**		
075-TLD4	**Control TLD average**	**9.0**	**8.6**	**9.3**	**8.9**	**8.9 ± 1**	**36 ± 2**

Notes:
See Figure 8-1 for TLD locations.
L = TLD lost
NP = TLD not posted

Table 8-2. Off-Site Direct Radiation Measurements.

TLD#	Location	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Avg./Qtr. ± 2σ (95%)	Annual Dose ± 2σ (95%)
		(mrem)					
000-TLD4	Private property	17.9	13.6	13.6	13.5	15 ± 4	59 ± 17
000-TLD5	Longwood Estate	17.4	16.5	L	14.2	15 ± 3	61 ± 13
000-TLD7	Mid-Island Game Farm	16.4	15.7	L	16.4	16 ± 1	64 ± 4
300-TLD3	Private property	NP	NP	14.4	17.3	16 ± 0	63 ± 0
400-TLD1	Calverton Nat. Cemetary	17.9	17.9	18.8	19.3	18 ± 1	74 ± 5
500-TLD2	Private property	15.9	14.9	14.1	13.9	15 ± 2	59 ± 7
500-TLD4	Private property	18.8	L	L	NP	19 ± 0	75 ± 0
600-TLD3	Sportsmen's Club	17.6	15.7	14.8	15.8	16 ± 2	64 ± 9
700-TLD2	Private property	17.0	14.1	14.4	13.0	15 ± 0	59 ± 0
700-TLD3	Private property	17.3	13.8	14.4	15.4	15 ± 3	61 ± 12
700-TLD4	Private property	21.1	15.7	16.0	15.6	17 ± 5	68 ± 21
800-TLD1	Private property	17.8	NP	L	12.6	15 ± 7	61 ± 29
800-TLD3	Suffolk County CD	17.3	15.7	15.0	16.8	16 ± 2	65 ± 8
900-TLD2	Private property	15.5	NP	12.1	14.9	14 ± 0	57 ± 0
999-TLD1	Private property	NP	NP	NP	NP		
Off-site average		**17.5**	**15.4**	**14.8**	**15.3**	**16 ± 3**	**64 ± 11**
Std. dev. (2 σ)		**2.7**	**2.6**	**3.4**	**3.7**		
075-TLD4	**Control TLD average**	**9.5**	**9.8**	**9.7**	**10.0**	**9.8 ± 0**	**39 ± 2**

Notes:
See Figure 8-2 for TLD locations.
CD = Correctional Department
NP = TLD not posted for the quarter
L = TLD lost

posted in known radiation areas (near "facilities"). Table 8-3 shows the external doses measured with the FAM-TLDs. The environmental TLDs 088-TLD1 through 088-TLD4 are posted at the S-6 blockhouse location and on the fence of the former Hazardous Waste Management Facility (HWMF). These TLDs measured external doses that were slightly elevated compared to the normal natural background radiation doses measured from other areas of BNL. The elevated external dose measured at the former HWMF can be attributed to the presence of small amounts of soil contamination. However, a comparison of the 2008 dose rates to doses from previous years show that the dose rates have declined significantly since the removal of most of the radioactive soil contained within the former HWMF. As recorded in Table 8-3, the dose is currently just slightly above natural background levels. The former HWMF is fenced; access is controlled, and only trained staff members are allowed inside the facility.

Two TLDs (075-TLD3 and 075-TLD5) near Building 356 showed much higher than normal quarterly averages: 25 ± 6 mrem (250 ± 60 µSv) and 27 ± 7 mrem (270 ± 70 µSv), respectively. The yearly doses were measured at 100 ± 24 mrem (1000 ± 240 µSv) for 075-TLD3, and 110 ± 28 mrem (1100 ± 280 µSv) for 075-TLD5. The direct doses are higher than the on-site annual average because Building 356 houses a cobalt-60 (Co-60) source, which is used to irradiate materials, parts, and electronic circuit boards. The elevated dose from Building 356 is attributed to the "sky-shine" phenomenon. Although it is conceivable that individuals who use the parking lot adjacent to Building 356 could receive a dose from this source, the dose

Table 8-3. Facility Area Monitoring.

TLD#	Location	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Average ± 2σ (95%)	Annual Dose ± 2σ (95%)
		(mrem)					
054-TLD2	North-east of Bldg. 913-B	26.3	17.9	14.6	19.1	19 ± 10	78 ± 39
054-TLD3	North-west of Bldg. 913-B	20.3	15.6	15.1	15.8	17 ± 5	67 ±19
S6		18.9	17.8	17.5	19.1	18 ± 2	73 ± 6
088-TLD1	FWMF-50' East of S-6	20.5	16.6	17.5	18.6	18 ± 3	73 ± 13
088-TLD2	FWMF-50' West of S-6	21.8	20.7	19.7	20.0	21 ± 2	82 ± 7
088-TLD3	FWMF-100' West of S-6	22.1	19.3	19.5	20.1	20 ± 3	81 ± 10
088-TLD4	FWMF-150' West of S-6	19.4	17.4	17.7	18.6	18 ± 2	73 ± 7
075-TLD3	Bldg. 356	29.4	23.3	22.8	24.8	25 ± 6	100 ± 24
075-TLD5	North Corner of Bldg. 356	32.6	26.0	26.6	24.5	27 ± 7	110 ± 28

Notes:
See Figure 8-1 for TLD locations.
FWMF = Former Waste Management Facility

would be minimal due to the limited time an individual spends in the parking lot.

Two FAM-TLDs placed on the fence northeast and northwest of Building 913-B (the Alternating Gradient Synchrotron tunnel access) showed higher than average ambient external dose. The first-quarter dose at that site was measured at 26.3 mrem for 054-TLD2 and 20.3 mrem for 054-TLD3 (compared to the sitewide first-quarter dose of 18.7 ± 4.3). For the remaining three quarters, both TLDs showed dose comparable to the natural background radiation.

8.2 DOSE MODELING

EPA regulates radiological emissions from DOE facilities under the requirements set forth in 40 CFR 61, Subpart H, National Emission Standards for Hazardous Air Pollutants (NESHAPs). This regulation specifies the compliance and monitoring requirements for reporting radiation doses received by members of the public from airborne radionuclides. The regulation mandates that no member of the public shall receive a dose from DOE operations that is greater than 10 mrem (100 μSv) in a year. The emission monitoring requirements are set forth in Subpart H, Section 61.93(b) and include the use of a reference method for continuous monitoring at major release points (defined as those with a potential to exceed 1 percent of the 10 mrem standard), and a periodic confirmatory measurement for all other release points. The regulations also require DOE facilities to submit an annual NESHAPs report to EPA that describes the major and minor emission sources and dose to the MEI. The dose estimates from various facilities are given in Table 8-4, and the actual emissions for 2008 are discussed in detail in Chapter 4.

As a part of the NESHAPs review process at BNL, any source that has the potential to emit radioactive materials is evaluated for regulatory compliance. Although the activities conducted under the Environmental Restoration (ER) Program are exempt under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), these activities are also monitored and assessed for any potential to release radioactive materials, and to determine their dose contribution, if any, to the environment. Any new processes or activities are evaluated for compliance with NESHAPs regulations using EPA's approved dose modeling software (see Section 8.2.1 for details). Because this model was designed to treat all radioactive emission sources as continuous over the course of a year, it is not well suited for estimating short-term or acute releases. Consequently, it overestimates potential dose contributions from short-term projects and area sources. For that

Table 8-4. MEI Effective Dose Equivalent From Facilities or Routine Processes.

Building No.	Facility or Process	Construction Permit No.	MEI Dose (mrem) (a)	Notes
348	Radiation Protection	None	ND	(b)
463	Biology Facility	None	ND	(b)
490	Medical Research	BNL-489-01	5.70E-11	(b)
490A	Energy and Environment National Security	None	ND	(b)
491	Brookhaven Medical Research Reactor	None	ND	(e)
510	Calorimeter Enclosure	BNL-689-01	ND	(f)
510A	Physics	None	ND	(b)
535	Instrumentation	None	ND	(b)
555	Chemistry Facility	None	ND	(b)
725	National Synchrotron Light Source	None	ND	(b)
750	High Flux Beam Reactor	None	1.07E-4	(c)
801	Target Processing Lab	None	1.14E-6	(b), (c)
802B	Evaporator Facility	BNL-288-01	NO	(e)
820	Accelerator Test Facility	BNL-589-01	ND	(d)
830	Environmental Science Department	None	ND	(d)
865	Reclamation Building	None	ND	(c)
906	Medical-Chemistry	None	ND	
925	Accelerator Department	None	ND	(b)
931	Brookhaven Linac Isotope Producer	None	6.12E-2	(c)
938	REF/NBTF	BNL-789-01	ND	(g)
942	Alternate Gradient Syncrotron Booster	BNL-188-01	ND	(h)
---	Relativistic Heavy Ion Collider	BNL-389-01	ND	(d)
Total Potential Dose from BNL Operations			**6.13E-2**	
EPA Limit			**10.0 mrem**	

Notes:
Diffuse, Fugitive, and Other sources are not included in this table since they are short-term emissions.
MEI = Maximally Exposed Individual
NBTF = Neutron Beam Test Facility
REF = Radiation Effects Facility
(a) "Dose" in this table means effective dose equivalent to MEI.
(b) Dose is based on emissions calculated using 40 CFR 61, Appendix D methodology.
(c) Emissions are monitored at the facility.
(d) ND = No dose from emissions source in 2008.
(e) NO = Not operational in 2008.
(f) This has become a zero-release facility since original permit application.
(g) This facility is no longer in use; it produces no radioactive emissions.
(h) Booster ventilation system prevents air release through continuous air recirculation.

reason, the results are considered to be "conservative"—that is, erring on the side of caution.

8.2.1 Dose Modeling Program

Compliance with NESHAPs regulations is demonstrated through the use of EPA dose modeling software and the Clean Air Act Assessment Package-1988 (CAP88-PC), Versions 2.1 and 3.0. This computer program uses a Gaussian plume model to estimate the average dispersion of radionuclides released from elevated stacks or diffuse sources. It calculates a final value of the projected dose at the specified distance from the release point by computing dispersed radionuclide concentrations in air, rate of deposition on ground surfaces, and intake via the food pathway (where applicable). CAP88-PC calculates both the EDE to the MEI and the collective population dose within a 50-mile radius of the emission source. In most cases, the CAP88-PC model provides conservative doses. For the purpose of modeling the dose to the MEI, all emission points are located at the center of the developed portion of the BNL site. The dose calculations are based on very low concentrations of environmental releases and on chronic, continuous intakes in a year. The input parameters used in the model include radionuclide type, emission rate in curies (Ci) per year, stack parameters such as height and diameter, and emission exhaust velocity. Site-specific weather and population data are factored into the dose assessment. Weather data are supplied by measurements from the Laboratory's meteorological tower. These measurements include wind speed, direction, frequency, and air temperature (see Chapter 1 for details). Population data used in the model are based on the Long Island Power Authority population survey (LIPA 2000). Because visiting researchers and their families may reside at the BNL on-site apartment area for extended periods, these residents are included in the population file used for dose assessment.

8.2.2 Dose Calculation Methods and Pathways

8.2.2.1 Maximally Exposed Individual

The MEI is defined as a hypothetical person who resides at the site boundary and has a lifestyle such that no other member of the public could receive a higher dose than the MEI. This person is assumed to reside 24 hours a day, 365 days a year at the BNL site boundary in the downwind direction, and to consume significant amounts of fish and deer containing radioactivity attributable to Laboratory operations based on projections from the New York State Department of Health (NYSDOH). In reality, it is highly unlikely that such a combination of "maximized dose" to any single individual would occur, but the concept is useful for evaluating maximum potential risk and dose to members of the public.

8.2.2.2 Effective Dose Equivalent

The EDE to the MEI for low levels of radioactive materials dispersed into the environment was calculated using the CAP88-PC dose modeling program, Versions 2.1 and 3.0. Site meteorology data were used to calculate annual dispersions for the midpoint of a given wind sector and distance. Facility-specific radionuclide release rates (Ci/yr) were used for continuously monitored facilities. For small sources, the emissions were calculated using the method set forth in 40 CFR 61, Appendix D. The Gaussian dispersion model calculated the EDE at the site boundary and the collective population dose values from immersion, inhalation, and ingestion pathways. These dose and risk calculations to the MEI are based on low emissions and chronic intakes.

8.2.2.3 Dose Calculation: Fish Ingestion

To calculate the EDE from the fish consumption pathway, the intake is estimated. Intake is the average amount of fish consumed by a person engaged in recreational fishing in the Peconic River. Based on a NYSDOH study, the consumption rate is estimated at 15 pounds (7 kg) per year (NYSDOH 1996). For each radionuclide of concern for fish samples, the dry weight activity concentration was converted to picocuries per gram (pCi/g) wet weight, since "wet weight" is the form in which fish are caught and consumed. A dose conversion factor was used for each radionuclide to convert the activity concentration into the EDE. For example, the committed dose equivalent conversion factor for cesium-137 (Cs-137) is 5.0E-02 rem/µCi, as set forth in DOE/EH-0071. The dose was calculated as: *dose* (rem/yr) = *intake* (kg/yr) × *activity in flesh* (µCi/kg) × *dose factor* (rem/µCi).

8.2.2.4 Dose Calculation: Deer Meat Ingestion

The dose calculation for the deer meat ingestion pathway is similar to that for fish consumption. The Cs-137 radionuclide dose conversion factor was used to estimate dose, based on the U.S. Environmental Protection Agency Exposure Factors Handbook (EPA 1996). The total quantity of deer meat ingested during the course of a year was estimated as 64 pounds (29 kg) (NYSDOH 1999).

8.3 SOURCES: DIFFUSE, FUGITIVE, "OTHER"

Diffuse sources are described as releases of radioactive contaminants to the atmosphere that do not have a well-defined emission point such as a stack or vent. Such sources are also known as nonpoint or area sources. Fugitive sources include releases to the air not through an actively ventilated air stream (i.e., leaks from vents are fugitive sources). As a part of the NESHAPs review process, in addition to stack emissions, any fugitive or diffuse emission source that could potentially emit radioactive materials to the environment is evaluated. Although CERCLA-prompted actions, such as remediation projects, are exempt from the procedural requirements to obtain federal, state, or local permits, any BNL activity or process with the potential to emit radioactive material must be evaluated and assessed for dose impact to members of the public. The following radiological sources were evaluated in 2008 for potential contribution to the overall site dose.

8.3.1 Brookhaven Graphite Research Reactor

The Brookhaven Graphite Research Reactor (BGRR) has been identified as an Area of Concern (AOC), and is being decontaminated under the Interagency Agreement and a Record of Decision (ROD) among DOE, EPA, and New York State. In 2008, a preliminary NESHAPs evaluation for the BGRR was performed for the removal of the graphite pile and the bioshield. The graphite pile is housed within the biological shield and acted as the neutron moderator during the operation of the reactor. The graphite pile is a 25-foot cube made from 60,000 graphite blocks of various sizes and shapes. Both the graphite pile and bioshield are contaminated with activation and fission products due to routine "fuel failures." The following radionuclides were identified as major contaminants: H-3, C-14, Co-60, Ni-63, I-129, Cs-137, Sr-90, Eu-152, Eu-154, Am-241, Th-232, Pu-238, Pu-239, and Pu-240.

During the decontamination of the graphite pile and bioshield, approximately 1.4 million pounds of activated graphite blocks and 5,000 tons of activated concrete from the bioshield will be removed, packaged, transported and disposed at an off-site location. The graphite pile removal actions will be performed within a fire-retardant, contamination containment enclosure (CCE) with a remote controlled Brokk manipulator. Multiple engineering barriers, special remote tools, and administrative controls will be used to minimize the generation and spread of dispersible contaminants. The CCE will have a dedicated filtration system with alarms to detect releases above the derived air concentration (DAC) guide limits.

The enclosure will be maintained at a slightly negative pressure with respect to Building 701 by a temporary high-efficiency particulate air (HEPA) ventilation system. Four 6,000-cfm HEPA fan units will be installed outside Building 701 in a weather-tight enclosure that will have common inlet and outlet ducts. The fan units will have two-stage HEPA filters with single-stage pre-filter systems. At any given time, three fan units will be operational, providing 18,000 cfm airflow, and one unit will remain in standby mode.

A preliminary NESHAP evaluation for the graphite pile and bioshield removal process gave an effective dose equivalent of 1.29E-01 mrem/year to the MEI. Since the potential dose exceeds 0.1 mrem, the facility will be continuously monitored for the stated radionuclides in accordance with the ANSI N13.1-1999 standard during the removal of the graphite pile and bioshield.

8.3.2 National Synchrotron Light Source II

The National Synchrotron Light Source II (NSLS-II) is a new research facility being constructed to achieve very high average brightness, intensity, position, energy, and flux of the synchrotron radiation in order to study materials. NSLS-II will enable research on materials with 1 nanometer spatial resolution, 0.1 meV energy resolutions, and with sufficient sensitivity to image the spectrum of a single atom. During the normal operation of the NSLS II, small quantities of the short-lived radioactive gases (C-11, N-13, and O-15) will be produced inside the accelerator enclosure by photon–neutron interactions. The short-lived gases will remain inside the accelerator enclosure with the exception of some fugitive and diffusive losses through apertures and openings at the facility. The diffuse source term calculations were based on the saturation activities of the short-lived gases for 5,000 hours of NSLS II operations in a year. During operations, potential beam loss locations include the Linac beam stop, booster beam stop, booster extractor magnet, and storage ring septum. In order to estimate the source term, it was assumed that the fugitive losses were in a steady state with the environment. The source term was assumed to have an area of 49, 941 m^2 with a height of 4 meters. The total steady state activity of the short-lived gases used in the calculations was C-11 at 21.4 µCi, N-13 at 349.5 µCi, and O-15 at 16.1 µCi. Based on the site-specific input parameters, the EDE from NSLS-II operations was calculated to be 2.95E-08 mrem in a year. Therefore, the dose impact to members of the public from the new NSLS-II facility will be negligible.

8.3.3 Waste Management Facility (Building 865)

The EF-108 fume hood in Building 865 was utilized to empty residual radioactive gases in glassware before their disposition at a licensed facility. A NESHAPs evaluation was completed to assess the risk to the members of public from this release. The source term was based on the process knowledge as Ar-39 at 4.7 µCi, Ar-42 at 0.013 µCi, C-14 at 1.16 µCi and Kr-85 at 0.005 µCi. The effective dose equivalent to the MEI for the release was estimated to be 1.58E-09 mrem/year. Based on the dose risk evaluation, it was concluded that there was no adverse impact to the environment and members of public.

In 2008, it was confirmed that there were no other emissions from the six stacks in Building 865, which are used during the process of repackaging and segregating radioactive waste materials for disposal at a licensed off-site facility. The stacks are sampled every year or during their use to show compliance with NESHAPs regulations.

8.3.4 Center for Functional Nanomaterials

The Center for Functional Nanomaterials provides state-of-the-art capabilities for atomic-level fabrication and study of nanomaterials. Because nanoscience is a recent development, there have been concerns about the emission of nanomaterials to the environment. Therefore, all work involving unbound nanomaterials is handled and processed in HEPA-filtered exhaust hoods, glove boxes, or sealed enclosures. The uncertainties of possible nanomaterial hazards are handled by minimizing the use of unbound nanomaterials, using a precautionary approach, and minimizing the release of nanomaterials into the environment.

8.4 DOSE FROM POINT SOURCES

8.4.1 Brookhaven Linac Isotope Producer

Source term descriptions for point sources are given in Chapter 4. The Brookhaven Linac Isotope Producer (BLIP) facility is the only emission source with any potential to contribute dose to members of the public greater than 1 percent of the EPA limit (i.e., 0.1 mrem, or 1.0 µSv). The BLIP facility uses the excess beam capacity of the Linear Accelerator (Linac) to produce short-lived radioisotopes for medical diagnostic procedures, medical imaging, and scientific research. During the irradiation process, the targets are cooled continuously by recirculating water in a 16-inch-diameter shaft. The principal gaseous radionuclides produced as a result of activation of the cooling water are O-15, C-11, and trace amounts of N-13. Because the BLIP facility has the potential to exceed 1 percent of the EPA emission limit, the facility emissions are directly measured using a low-resolution gamma spectrometer with an in-line sampling system connected to the air exhaust, to measure the short-lived gaseous products that cannot be sampled and analyzed by conventional analytical methods. Particulates and radioiodine are monitored with paper and granular activated charcoal filters, which are exchanged weekly for analysis by a contract analytical laboratory. A tritium sampler also operates continuously, with samples collected weekly.

In 2008, the BLIP facility operated over a period of 23 weeks. During the year, 856 Ci of C-11 and 1,774 Ci of O-15 were released from the facility. A small quantity of tritiated water vapor from activation of the targets' cooling water was also released at 4.57E-02 Ci. The EDE to the MEI was calculated to be 6.12E-02 mrem (0.61 µSv) in a year from BLIP operations. In 2008, anticipating an increase in usage of the facility and therefore a potential for increased emissions, BNL applied to EPA for a NESHAPs permit to increase dose from facility emissions to a maximum of 0.2 mrem. The EPA approved the increase in a letter dated September 25, 2008. EPA requested that the Laboratory continue its efforts to maintain the dose "as low as reasonably achievable."

8.4.2 High Flux Beam Reactor

In 2008, the High Flux Beam Reactor (HFBR) facility was in a "cold" shutdown mode and had been downgraded from a nuclear facility to a radiological facility in 2007. In June 2008, the frequency for tritium monitoring was increased from monthly to weekly when the reactor vessel, primary cooling water system, and fuel canal were filled with domestic water to prepare for removal of the control rod blades. The reactor vessel was periodically opened and, because of that, tritium levels in the building were much higher than observed in recent years. The total tritium emissions for 2008 were measured and calculated to be 20.1 curies, which could contribute to the MEI dose of 1.01E-4 mrem (1 nSv) in a year.

8.4.3 Brookhaven Medical Research Reactor

In 2008, the Brookhaven Medical Research Reactor (BMRR) facility was in a "cold" shutdown mode. There was no dose contribution from the BMRR.

8.4.4 Unplanned Releases

There were no unplanned releases in 2008.

8.5 DOSE FROM INGESTION

Deer and fish bioaccumulate radionuclides in their tissues, bones, and organs; consequently, samples from deer and fish were analyzed to evaluate the dose contribution to humans from the ingestion pathway. As discussed in Chapter 6, deer meat samples collected off site and less than 1 mile from the BNL boundary were used to assess the potential dose impact to the MEI. Four samples of deer meat (flesh) were used to calculate the "off site and less than 1 mile" average concentration of radionuclides in tissue. Potassium-40 (K-40) and Cs-137 were the two radionuclides detected in the tissue samples. K-40 is a naturally occurring radionuclide and is not related to BNL operations. In 2008, the average K-40 concentrations in tissue samples (off site < 1 mile) were 3.3 ± 1.5 pCi/g (wet weight) in the flesh and 2.8 ±1.3 pCi/g (wet weight) in the liver. The maximum Cs-137 concentrations were 8.61 ± 0.57 pCi/g (wet weight) in the flesh and 2.03 ± 0.15 pCi/g (wet weight) in the liver (see Table 6-2). The average Cs-137 concentration was calculated at 1.89 ± 0.64 pCi/g; however, the maximum concentration of 8.61 pCi/g was used for the purpose of MEI dose calculations. The maximum estimated dose to humans from consuming deer meat containing the maximum Cs-137 concentration was estimated to be 12.48 mrem (125 μSv) in a year. The dose was above the health advisory limit of 10 mrem (100 μSv) established by NYSDOH; however, the maximized estimated dose is to a hypothetical individual and would not be actualized, as no deer hunting is permitted on the BNL site.

In collaboration with the New York State Department of Environmental Conservation (NYSDEC) Fisheries Division, BNL maintains an ongoing program of collecting and analyzing fish from the Peconic River and surrounding freshwater bodies. In 2008, chain pickerel samples collected in the Peconic River at the Manor Road site had the highest concentration of Cs-137, at 0.26 ± 0.04 pCi/g; this was used to estimate the EDE to the MEI. The potential dose from consuming 15 pounds of chain pickerel annually was calculated to be 0.09 mrem (0.9 μSv)—well below the NYSDOH health advisory limit of 10 mrem.

8.6 DOSE TO AQUATIC AND TERRESTRIAL BIOTA

DOE-STD-1153-2002, A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota, provides the guidelines for screening methods to estimate radiological doses to aquatic animals, terrestrial plants, and terrestrial animals, using site-specific environmental surveillance data. The RESRAD-BIOTA 1.21 biota dose level 2 program was used to evaluate compliance with the requirements for protection of biota specified in DOE Order 5400.5 (1990), Radiation Protection of the Public and the Environment, and DOE Order 450.1, General Environmental Protection Program.

Table 8-5. BNL Site Dose Summary.

Pathway	Dose to Maximally Exposed Hypothetical Individual	Percent of DOE 100 mrem/year Limit	Estimated Population Dose per year
Inhalation			
Air	0.06 mrem (0.61 µSv)	<1%	0.20 person-rem
Ingestion			
Drinking water	None	None	None
Fish	0.09 mrem (0.9 µSv)	<1%	Not tracked
Deer Meat	12.48 mrem (125 µSv)	<13%	Not tracked
All Pathways	12.63 mrem (125 µSv)	<13%	0.20 person-rem

In 2008, the terrestrial animal and plant doses were evaluated based on 0.22 pCi/g of Cs-137 found in the surface soils on the River Road farm and Sr-90 concentration of 3.87 pCi/L in the surface waters at Donahue Pond. The dose to terrestrial animals was calculated to be 0.01 mGy/day, and to plants, 9.97 E-04 mGy/day. The doses to terrestrial plants and animals were well below the biota dose limit of 1 mGy/day.

To calculate the dose to aquatic and riparian animals, Sr-90 radionuclide concentration values for surface water from Donohue's Pond and the average Cs-137 in the Peconic River sediments were used. The Cs-137 sediment concentration was 0.57 pCi/g, and the Sr-90 concentration in surface water was 3.87 pCi/L. The calculated dose to aquatic animals was 3.03E-06 Gy/day and to riparian animals was 1.95E-05 Gy/day. Therefore, the dose to aquatic and riparian animals was also well below the 10 mGy/day limit specified by the regulations.

8.7 CUMULATIVE DOSE

Table 8-5 summarizes the potential cumulative dose from the BNL site in 2008. The total dose to the MEI from air and ingestion pathways was estimated to be 12.63 mrem (126 µSv). In comparison, the EPA regulatory limit for the air pathway is 10 mrem (100 µSv) and the DOE limit from all pathways is 100 mrem (1,000 µSv). The cumulative population dose would be 0.20 person-rem (2 person-mSv) in a year. The effective dose was well below the DOE and EPA regulatory limits, and the ambient TLD dose was within normal background levels seen at the Laboratory site. The potential dose from drinking water was not estimated, because most of the residents adjacent to the BNL site get their drinking water from the Suffolk County Water Authority rather than private wells.

To put the potential dose impact into perspective, a comparison was made with other sources of radiation. The annual dose from all natural background sources and radon is approximately 300 mrem (3.0E-3 µSv). A diagnostic chest x-ray would result in a 5 to 20 mrem (50–200 µSv) dose per exposure. Using natural gas in homes yields approximately a 9 mrem (90 µSv) dose per year, cosmic radiation yields 26 mrem (260 µSv), and natural potassium in the body yields approximately 39 mrem (390 µSv) of internal dose. Even with worst-case estimates of dose from the air pathway and ingestion of local deer meat and fish, the cumulative dose from BNL operations was equivalent to the dose that could be received from a single chest x-ray.

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