8 Radiological Dose Assessment

Brookhaven National Laboratory routinely assesses its operations to ensure that any potential radiological dose to the public, BNL workers, and the environment is "As Low As Reasonably Achievable." All scientific and research activities at BNL that can adversely affect health and safety or contribute to dose are evaluated for mitigation. The potential radiological dose to the public is calculated as the maximum dose to a hypothetical Maximally Exposed Individual (MEI) at the BNL site boundary. Doses are calculated by considering all direct and indirect pathways, such as radiation sources, inhalation, ingestion, and skin absorption. Radiological dose assessment has routinely shown that the Effective Dose Equivalent from BNL operations is well below the EPA and DOE regulatory dose limits to the public and the environment.

The yearly ambient external dose was 64 ± 10 mrem (640 ± 100 µSv) on site and 61 ± 9 mrem (610 ± 90 µSv) at off-site locations. Both of these measurements include contributions from cosmic and natural background radiation sources. A statistical comparison of the average doses from 56 on-site and 18 off-site thermoluminescent dosimeters showed that there was no additional contribution to dose from BNL operations above natural background radiation. The Effective Dose Equivalent from the air pathway was calculated as 5.96E-2 mrem (0.6 µSv) to the MEI. The ingestion pathway dose was estimated as 2.18 mrem (22 µSv) from venison consumption and 0.19 mrem (1.9 µSv) from consumption of fish caught at Swan Pond. BNL's total annual dose to the MEI from all pathways was estimated as 2.43 mrem (24 µSv). In comparison, EPA's annual regulatory dose limit is 10 mrem (100 µSv) for the air pathway, and DOE's annual dose limit is 100 mrem (1,000 µSv) from all pathways.

Dose to aquatic and terrestrial biota also were evaluated and found to be well below the DOE regulatory limits. Remediation and waste management projects conducted in 2003 were evaluated for radiological emissions and dose impact. It was concluded that there was no significant dose and radiological risk to the public or the environment from these activities. The dose impact from all BNL activities in 2003 was found to be insignificant above natural background radiation levels.

8.1 DIRECT RADIATION MONITORING

External direct radiation monitoring is implemented at BNL to measure the direct dose impact to members of the public and workers from radiation sources. This is achieved by measuring direct penetrating radiation exposures both on and off site. The direct measurements taken at the off site locations are with the premise that off-site exposures are true natural background radiation (contribution from cosmic and terrestrial) exposures and represent no contribution from BNL operations. On- and off-site external doses are then compared to each other's averages (using the statistical t-test) to evaluate variation and the contribution from BNL operations above natural background radiation.

Direct penetrating beta-gamma radiation is measured using thermoluminescent dosimeters (TLDs). The principle of TLD operation is that when certain crystals are exposed to radiation, impurities in the crystals' low-temperature trapping sites for the electrons are excited to higher energy states. These electrons remain in a high-energy state at normal ambient temperature. When the TLDs are heated, electrons return to the lower energy state. The electrons emit photon energy (i.e., light), which is measured with a photomultiplier tube; the light intensity given out is directly proportional to the absorbed dose of radiation. The environmental TLDs used at BNL are composed of calcium fluoride and lithium fluoride. The TLDs' accuracy is verified by using TLDs exposed to known sources of radiation as controls, and by participating in the inter-comparison testing programs. The instrument that reads the dosimeter is calibrated to read absorbed dose—that is, quantity of energy deposited by radiation in the tissue or mass of the material.

8.1.1 Ambient Monitoring

To assess the impact of direct radiation from BNL operations, TLDs are deployed at the BNL site and in the 16 wind sectors of the surrounding communities. On-site TLD location selection criteria are based on the potential for exposure to gaseous plumes, atmospheric particulates, and radiation-generating facilities. Also, BNL perimeter areas are posted with TLDs to assess potential impact beyond the Laboratory boundary. On- and off-site areas are divided into grids and each TLD is assigned an identification code based on these grids.

Fifty-six TLDs were deployed on site and 18 were deployed off site in 2003, as shown in Figures 8-1 and 8-2, respectively. An additional 30 control TLDs were stored in a lead-shielded container in Building 490; the average of the control TLDs is reported as "075-TLD4" in Tables 8-1 and 8-2, for comparison. Note that it is not possible to completely shield the control devices from all natural background and cosmic radiation or completely eliminate residual dose on the control TLDs;

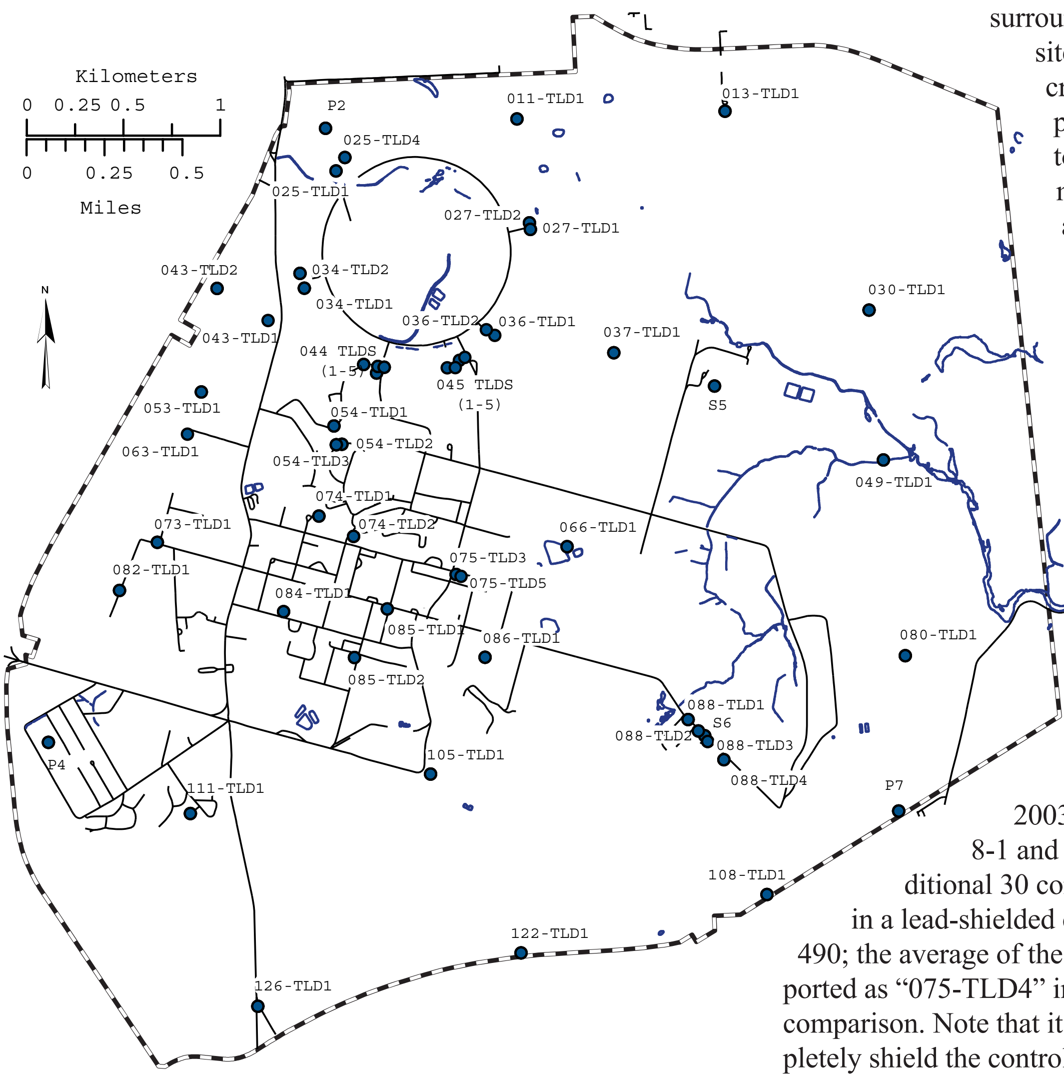

Figure 8-1. On-Site TLD Locations.

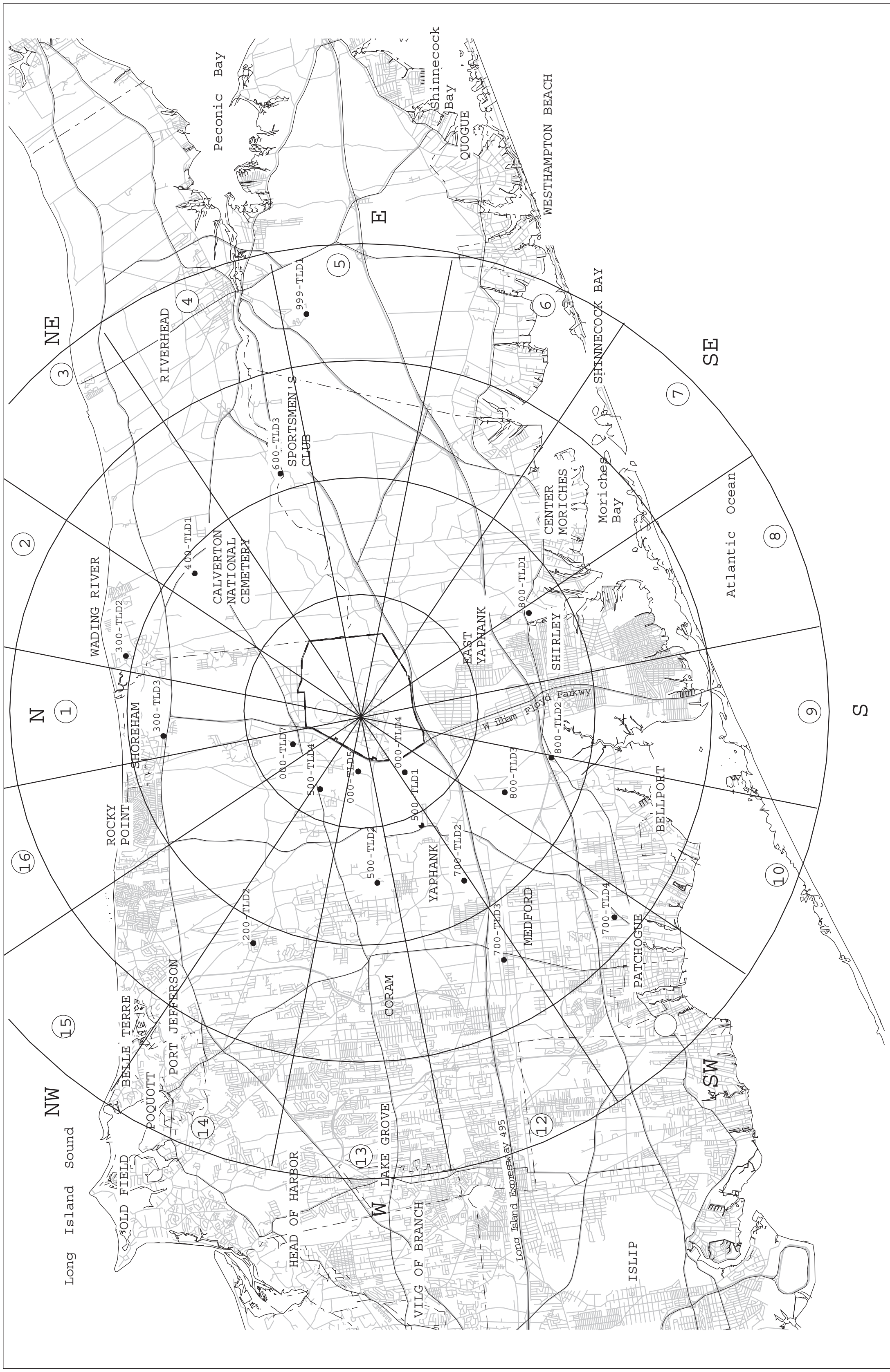

Figure 8-2. Off-Site TLD Locations.

therefore, small doses are measured by the control TLDs. The on- and off-site TLDs were collected and read quarterly to determine the direct external radiation dose.

Table 8-1 shows the quarterly and yearly on-site radiation dose measurements. The on-site average external dose for the first, second, third, and fourth quarters was 16.4 ± 3.6, 15.0 ± 3.0, 14.8 ± 3.2, and 17.7 ± 3.8 mrem, respectively. The annual on-site external dose from all potential sources, including the contribution from cosmic and terrestrial radiation sources was 64 ± 10 mrem. Table 8-2 shows the quarterly and yearly off-site radiation dose measurements to determine the BNL contribution to the ambient external radiation dose. The off-site average external dose for the first, second, third, and fourth quarters was 16.0 ± 2.7, 14.4 ± 2.6, 14.1 ± 2.4, and 16.0 ± 2.8 mrem, respectively. The annual off-site average ambient dose was 61 ± 9 mrem. A statistical t-test between the external dose averages shows no significant difference from off site (61 ± 9 mrem) and on site (64 ± 10 mrem) locations. In conclusion, there was no external dose contribution to on- and off-site locations from BNL operations.

8.1.2 Facility Area Monitoring

Seven of the 56 on-site TLDs were designated as the Facility Area Monitors (FAM). These TLDs were deployed at locations known to have radiation sources or radiological contamination with significantly higher probability to contribute to the external radiation doses. Table 8-3 shows the external doses measured with the FAM TLDs. TLDs are posted at the S-6 blockhouse location and on the fence of the Former Waste Management Facility (FWMF) (088-TLD1 through 088-TLD4). These TLDs measured much higher external dose than typical natural background dose measured in the vicinity and the doses were above the on-site average. The high external dose measured can be attributed to the presence of radioactive materials, contaminated soil, and radioactive sources that were being repackaged for shipment to a radiological waste disposal site. Dose rate comparison from the previous years has shown that the dose rates are declining contiuously as the radioactive materials are being removed and other remediation actions are implemented. The FWMF is currently posted as a radiological area and only radiation-trained personnel wearing personal dosimeters are allowed inside the facility until all the contaminated soil is removed or remediated.

Two TLDs (075-TLD3 and 075-TLD5) posted near Building 356 also showed higher quarterly averages, 29 ± 8 mrem and 33 ± 9 mrem, respectively. The yearly doses were recorded to be as high as 118 ± 34 mrem for 075-TLD3, and 131 ± 36 mrem for 075-TLD5. The doses are significantly higher than on-site annual average. These elevated measurements can be attributed to the sky-shine phenomenon and shielding buildup in Building 356 that has a cobalt source, which is used to irradiate materials, parts, and electronic circuit boards. The potential radiological exposure from Building 356 is in the parking lot area, but because the occupancy factor for the parking lot is low, the dose impact to the worker was minimal.

8.2 AIR EMISSIONS

EPA regulates emission 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 monitoring and requirements for reporting the 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 emissions greater than 10 mrem (100 µSv) per year from DOE operations. The emission monitoring requirements are set forth in Subpart H, Section 61.93(b) which include the use of a reference method for continuous monitoring at major release points (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 are discussed in more detail in Chapter 4, Section 4.1.

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

TLD#	Location	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Avg./Qtr. +/- 2σ (95%)	Annual Dose +/- 2σ (95%)
		(mrem)					
011-TLD1	North firebreak	14.3	NP	14.8	15.2	15 ± 1	59 ± 4
013-TLD1	North firebreak	15.1	13.5	12.9	16.3	14 ± 3	58 ± 12
025-TLD1	Bldg. 1010 beam stop 1	16.9	14.3	12.6	15.8	15 ± 4	60 ± 15
025-TLD4	Bldg. 1010 beam stop 4	20.0	14.2	15.4	16.3	16 ± 5	66 ± 20
027-TLD1	Bldg. 1002A South	13.5	13.8	13.0	14.7	14 ± 1	55 ± 6
027-TLD2	Bldg. 1002D East	13.5	15.9	14.0	15.9	15 ± 2	59 ± 10
030-TLD1	NE Firebreak	15.2	12.9	14.5	16.6	15 ± 3	59 ± 12
034-TLD1	Bldg. 1008 collimator 2	16.1	15.7	13.7	17.2	16 ± 3	63 ± 11
034-TLD2	Bldg. 1008 collimator 4	16.3	16.1	15.0	16.3	16 ± 1	64 ± 5
036-TLD1	Bldg. 1004B East	15.1	13.8	12.2	15.9	14 ± 3	57 ± 13
036-TLD2	Bldg. 1004 East	17.3	18.9	15.6	19.7	18 ± 4	72 ± 14
037-TLD1	S-13	16.4	14.4	13.3	17.2	15 ± 4	61 ± 14
043-TLD1	North access road	16.8	15.5	14.9	18.1	16 ± 3	65 ± 11
043-TLD2	North of Met. Tower	18.4	15.5	16.7	17.7	17 ± 2	68 ± 10
044-TLD1	Bldg. 1006	20.0	15.0	14.3	16.6	16 ± 5	66 ± 20
044-TLD2	South of Bldg. 1000E	14.5	15.4	13.8	17.2	15 ± 3	61 ± 12
044-TLD3	South of Bldg. 1000P	14.7	15.7	13.5	16.0	15 ± 2	60 ± 9
044-TLD4	NE of Bldg. 1000P	16.0	17.4	15.0	17.9	17 ± 3	66 ± 10
044-TLD5	N of Bldg. 1000P	14.8	16.5	14.3	17.2	16 ± 3	63 ± 11
045-TLD1	Bldg. 1005S	16.4	15.3	14.6	17.8	16 ± 3	64 ± 11
045-TLD2	East of Bldg. 1005S	15.8	17.4	14.8	21.5	17 ± 6	70 ± 23
045-TLD3	S/E of Bldg. 1005 S	15.2	17.3	15.1	17.9	16 ± 3	66 ± 11
045-TLD4	S/W of Bldg. 1005 S	14.3	14.7	15.6	16.5	15 ± 2	61 ± 8
045-TLD5	WS/W of Bldg. 1005 S	13.1	13.8	11.8	14.9	13 ± 3	54 ± 10
049-TLD1	East firebreak	15.5	12.6	14.9	16.2	15 ± 3	59 ± 12
053-TLD1	West firebreak	18.3	15.9	18.0	18.8	18 ± 3	71 ± 10
054- TLD1	Bldg. 914	17.2	13.7	12.5	15.7	15 ± 4	59 ± 16
054-TLD2	N/E of Bldg. 913-B	16.5	16.0	15.6	20.7	17 ± 5	69 ± 19
054-TLD3	N/W of Bldg. 913-B	15.1	15.4	13.2	21.3	16 ± 7	65 ± 27
063-TLD1	West firebreak	17.4	14.0	16.6	18.8	17 ± 4	67 ± 16
066-TLD1	New HWM Facility	14.7	11.0	13.3	17.3	14 ± 5	56 ± 21
073-TLD1	West Met. Twr. /Bldg. 51	17.9	16.2	16.1	18.7	17 ± 3	69 ± 10
074-TLD1	Bldg. 197	19.1	17.4	15.1	17.9	17 ± 3	70 ± 13
074-TLD2	Bldg. 907	16.6	15.6	15.6	16.5	16 ± 1	64 ± 4
080-TDL1	East firebreak	17.0	14.7	18.3	23.0	18 ± 7	73 ± 27
082-TLD1	West firebreak	17.8	16.6	15.9	18.2	17 ± 2	69 ± 8
084-TLD1	Tennis courts	18.4	14.4	16.1	18.5	17 ± 4	67 ± 15
085-TDL2	Upton gas station	16.3	14.2	15.8	20.7	17 ± 5	67 ± 22
085-TLD1	TFCU (Credit Union)	17.6	15.4	16.3	20.2	17 ± 4	70 ± 16
086-TLD1	Baseball fields	19.6	16.3	18.9	22.3	19 ± 5	77 ± 19
105-TLD1	South firebreak	22.0	14.1	15.7	17.8	17 ± 7	70 ± 27
108-TLD1	Water tower	16.0	16.2	14.9	16.4	16 ± 1	64 ± 5
111-TLD1	Trailer park	16.0	13.2	15.6	16.5	15 ± 3	61 ± 11
122-TLD1	South firebreak	16.0	13.2	14.7	17.5	15 ± 4	61 ± 14
126-TLD1	South gate	17.7	14.0	17.4	19.5	17 ± 4	69 ± 18
P2		14.3	12.6	11.7	15.4	13 ± 3	54 ± 13
P4		15.9	15.7	13.8	16.2	15 ± 2	62 ± 9
P7		16.0	14.3	13.7	16.4	15 ± 3	60 ± 10
S5		15.7	13.6	13.4	19.1	15 ± 5	62 ± 21
On-site average		**16.4**	**15.0**	**14.8**	**17.7**	**16 ± 3**	**64 ± 10**
Std. dev. (2 σ)		**3.6**	**3.0**	**3.2**	**3.8**		
075-TLD4	**Control TLD average**	11.5	12.2	10.4	9.4	11 ± 2	44 ± 10

Notes:
NP = TLD not posed for the quarter.
See Figure 8-1 for TLD locations.

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	14.4	13.3	13.7	14.6	14	±	1	56	±	5
000-TLD5	Smith Estate	16.1	14.6	13.4	15.5	15	±	2	60	±	9
000-TLD7	Mid-Island Game Farm	15.6	13.6	14.2	17.1	15	±	3	61	±	12
200-TLD2	Private property	18.1	16.9	16.4	17.8	17	±	2	69	±	6
300-TLD2	Private property	16.0	16.5	15.2	NP	16	±	1	64	±	5
300-TLD3	Private property	17.9	13.3	14.4	15.1	15	±	4	61	±	15
400-TLD1	Calverton Nat. Cem.	L	15.2	NP	18.1	17	±	4	67	±	16
500-TLD1	Private property	13.5	11.7	11.7	12.8	12	±	2	50	±	7
500-TLD2	Private property	14.5	12.6	13.1	14.7	14	±	2	55	±	8
500-TLD4	Private property	15.2	14.0	14.3	16.7	15	±	2	60	±	10
600-TLD3	Sportsmen's Club	15.1	15.0	13.7	15.6	15	±	2	59	±	6
700-TLD2	Private property	15.0	NP	13.6	15.0	15	±	2	58	±	6
700-TLD3	Private property	15.9	14.4	13.1	16.9	15	±	3	60	±	13
700-TLD4	Private property	18.8	15.0	16.0	17.4	17	±	3	67	±	13
800-TLD1	Private property	16.0	13.9	14.6	15.6	15	±	2	60	±	7
800-TLD2	Private property	17.1	14.9	NP	NP	16	±	3	64	±	12
800-TLD3	Suffolk County CD	16.3	15.2	14.9	17.1	16	±	2	64	±	8
999-TLD1	Private property	15.7	13.9	12.7	15.2	14	±	3	58	±	11
Off-site average		**16.0**	**14.4**	**14.1**	**16.0**	**15**	**±**	**2**	**61**	**±**	**9**
Std. dev. (2 σ)		**2.7**	**2.6**	**2.4**	**2.8**						
075-TLD4	Control TLD average	11.5	12.2	10.4	9.4	11	±	2	44	±	10

Notes:
L = TLD lost in the field.
NP = TLD not posted for the quarter.
See Figure 8-2 for TLD locations.

Table 8-3. Facility Area Monitoring.

TLD#	Location	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Avg./Qtr. +/- 2σ (95%)			Annual Dose +/- 2σ (95%)		
		(mrem)									
S6		29.0	24.8	27.9	34.8	29	±	8	116	±	33
088-TLD1	FWMF-50' East of S-6	38.6	35.8	34.4	41.6	38	±	6	150	±	25
088-TLD2	FWMF-50' West of S-6	39.8	37.2	37.7	52.7	42	±	14	167	±	57
088-TLD3	FWMF-100' West of S-6	36.6	33.7	36.3	43.6	38	±	8	150	±	33
088-TLD4	FWMF-150' West of S-6	22.4	20.7	20.4	25.4	22	±	4	89	±	18
075-TLD3	Bldg. 356	34.1	24.4	27.5	31.6	29	±	8	118	±	34
075-TLD5	North Corner of Bldg. 356	39.6	30.6	29.4	31.3	33	±	9	131	±	36

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

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
463	Biology Facility	None	2.84E-11	(b)
490	Medical Research	BNL-489-01	7.91E-12	(b)
490	Radiation Protection (ASL)	None	1.61E-6	(b)
491	BMRR	None	ND	(c), (e)
510	Calorimeter Enclosure	BNL-689-01	ND	(f)
510A	Physics	None	2.91E-9	(b)
535	Instrumentation	None	5.81E-13	(b)
555	Chemistry Facility	None	1.29E-10	(b)
703	Analytical Laboratory	None	ND	
725	National Synchrotron Light Source	None	1.44E-10	(b)
750	HFBR	None	2.63E-6	(c)
801	Target Processing Lab	None	1.09E-10	(b), (c)
802B	Evaporator Facility	BNL-288-01	N.O.	(e)
820	Accelerator Test Facility	BNL-589-01	ND	(d)
830	Environmental Science Department	None	4.48E-10	(d)
865	Reclamation Building	None	6.19E-7	(c)
906	Medical-Chemistry	None	2.22E-9	
931	BLIP	None	5.96E-2	(c)
938	REF/NBTF	BNL-789-01	ND	(g)
942	AGS Booster	BNL-188-01	ND	(h)
---	RHIC	BNL-389-01	ND	(d)
Total Potential Dose from BNL Operations			**5.96E-2**	
EPA Limit			**10.0 mrem**	

Notes:
Diffuse, Fugitive, and Other sources are not included in this table since they are short term emissions
AGS = Alternating Gradient Synchrotron
BLIP = Brookhaven Linac Isotope Producer
BMRR = Brookhaven Graphite Research Reactor
HFBR = High Flux Beam Reactor
MEI = Maximally Exposed Individual
NBTF = Neutron Beam Test Facility
REF = Radiation Effects Facility
RHIC = Relativistic Heavy Ion Collider

(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 2003.
(e) N.O. = Not operational in 2003.
(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.

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 monitored and assessed for any potential to release radioactive materials, and to determine dose contribution, if any, to the environment. A number of ER and Waste Management (WM) activities were evaluated in 2003 for NESHAPs compliance. EPA's approved dose modeling software was used in dose calculations (see Section 8.2.1 for details). Because this software was designed to treat all radioactive emission sources as continuous chronic emissions that occur over the course of a year, it is not well suited for estimating short-term or acute releases. Consequently, it overestimates potential contributions to dose from such sources and 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 software, the Clean Air Act Assessment Package-1988 (CAP88-PC). Beta version 3.0 of the software was used for calculations in 2003, except for calculations involving the Brookhaven Linac Isotope Producer (BLIP), for which version 2.0 was used. 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 for 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 effective dose equivalent (EDE) to the MEI and the collective population dose within a 50-mile radius of the emission source. The CAP88-PC model provides very conservative (overestimated) dose, 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 BNL site. The dose calculations are based on very low-level environmental releases and chronic intakes for a year. The 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 factored into the dose assessment. Weather data are supplied by measurements from BNL's meteorological tower, which includes wind speed, direction, frequency, and temperature (see Chapter 1 for details). Population data used in the model are based on the Long Island Power Authority population survey (LIPA 1999). Because visiting researchers and their families may reside at the BNL on-site apartment area for extended periods of time, these residents are also included in the population file used for dose assessment.

8.2.2 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 boundary in the downwind direction, and consumes significant amounts of contaminated fish and deer based on projections from the New York State Department of Health (NYSDOH, 1999). In reality, it is a highly unlikely, worst-case scenario that such a combination of "maximized dose" to any single individual would occur, but it is used to evaluate the maximum potential risk and dose.

8.2.3 Doses from Diffuse, Fugitive, and Other Sources

Diffuse sources are radioactive contaminants (emissions) released into the atmosphere that do not have a well-defined source point. Such sources are also known as nonpoint or area sources. The following potential radiological diffuse sources were evaluated in 2003 for their contribution to the overall BNL site dose.

8.2.3.1 BGRR Remediation Project

The Brookhaven Graphite Research Reactor (BGRR) has been identified as Area of Concern (AOC) 9B (Removal Action #3) in the Interagency Agreement between EPA, DOE, and the New York State Department of Environmental Conservation (NYSDEC). The Below Ground Duct (BGD) is located in Building 701 of BGRR. As part of the BGRR decommissioning project, the removal of the BGD filters was initiated in 2003. The removal of the duct liner will follow after the removal of the filters is completed. The Duct Service Building (DSB) is a temporary structure (30 ft wide, 76 ft long, and 30 ft high at the center, on a 10-in. concrete slab) that was erected to facilitate the removal of the contaminated filters and duct liners.

Two Brokk Model 360 diesel-powered, radio-remote controlled manipulators were used to remove the contaminated filters. The remote manipulators were used because the area is highly contaminated and the exposure rates are extremely high. All controls for the Brokk machines were located at a video console in the instrument room. Each Brokk machine has two forward video cameras and one rear-facing camera. The Brokk machines could be fitted with various tools (such as, a steel plate sawing system, clamshell bucket, impact hammer, shearing tools, and tool holders) to remotely perform any required task. These tools were used to size reduce the filters into pieces small enough to be carried through the vacuum hose to a cyclone separator in the DSB. Any loose surface contamination and debris were removed via vacuuming. The separated solids and pieces that could not be reduced in size were then packaged into shipping containers for off-site disposal.

The DSB and BGD were maintained at negative pressure with high-efficiency particulate air (HEPA) filters to prevent release of contamination and particulate emission. Two self-contained skid-mounted 6,000 cfm HEPA-filtered ventilation units were used to minimize contaminant release. Airborne particulate and charcoal monitoring was implemented in accordance with the ANSI/HPS N13.1-1999 standard at the exhausts of the single 26-in.-diameter duct for decommission and decontamination (D&D) work. The source term was based on the Table of Isotopic Radionuclides Concentrations in the Safety Analysis Document (BGRR-SE-03-01). The potential EDE was calculated to be 1.50E-05 mrem in a year to the MEI. The air particulate samples and charcoal samples collected at the BGRR exhaust duct showed that emission to the environment was well below the minimum detection levels. Therefore, it was concluded that there was no dose risk or any significant impact to the environment from D&D work at the BGRR.

8.2.3.2 Medical-Chemistry Building 906

The Chemistry Department uses radiotracers for animal neuroimaging research in Building 906. The potential emission source is the exhalation of butane labeled with carbon-11 (C-11, half-life: 20.38 minutes). A mushroom type fan is located on the west side of Building 906, about 3 meters above ground level, which exhausts the room air to the outside.

The source term was based on the potential estimate of the C-11–labeled butane used during the year, nearly 5.0E-02 Ci. The source term calculations were based on 10 mCi of C-11–labeled butane gas that was injected into the animal, with a total of five experiments planned over the course of year, so the total source available for dispersion would be 50 mCi. Even though only a miniscule fraction of this activity would be released in the work area via exhalation, it was assumed that the complete inventory of 50 mCi of C-11 was released into the environment. Also, the decay correction was not performed, to assume a worst-case scenario. A conservative (overestimated) EDE to the MEI from the neuroimaging experiment was 2.9E-06 mrem in a year. Furthermore, this dose calculation was based on five experiments, but only two experiments were completed during the year; therefore, the actual dose consequences would be even less than the estimated dose.

8.2.3.3 Former Waste Management Facility Remediation

The FWMF was a Resource Conservation and Recovery Act (RCRA) permitted facility for processing and storage of radioactive and mixed wastes generated at BNL. The FWMF is located south of Brookhaven Avenue in the southeast wind sector of the Laboratory. Eight buildings and structures were scheduled for D&D, as follows:

1. Building 444 was used for handling chemical waste and incinerating waste materials. This metal building had an area of approximately 1,500 ft^2 and was built on a concrete slab. There was a 1,000-gallon No.2 fuel oil underground storage tank (UST) on the east side of the building in an unpaved area. The initial phases of the D&D project included removal, stabilization, and repackaging of the UST, oil-contaminated soil, and the associated pipes. On the west side of Building 444, there was a drywell (buried open-top 55-gallon drum with a gravel base). The remediation work included demolition of

Building 444 and removal and disposal of the UST, dry well, and associated concrete slab, along with the debris.

2. Building 445 was an office building constructed with concrete block walls, a concrete slab floor, and a metal roof. The floor area was approximately 3,700 ft^2. The remediation project encompassed the demolition of Building 445 and removal of its concrete slab, an associated UST and septic tank, and other debris. A 1,000-gallon No. 2 fuel oil UST was located on the west side of Building 445 (outside of the radiological boundaries). A septic tank on the south side of Building 445 was included in the D&D work.
3. Building 446 was a radioactive waste-sorting barn constructed with insulated metal walls and a metal roof, built on a concrete slab. The building's area was approximately 1,600 ft^2. On the north side of Building 446 was a 275-gallon No. 2 fuel oil aboveground storage tank on a concrete slab. This tank met the free-release criteria. The D&D work included the demolition and removal of Building 446 and its concrete slab.
4. Building 447, approximately 580 ft^2 in size, was a rigging shed made of insulated metal and built on a concrete slab. The D&D work included demolition and removal of the building and its concrete slab.
5. Building 448, a 1,500-ft^2 metal building, was used as the chemical receiving barn. The D&D work included the demolition and removal of Building 448 and its concrete slab.
6. Building 483 was a 2,000-ft^2, three-sided fiberglass-panel shed with a metal roof, used for waste storage. Framing consisted of steel columns and girders. The D&D work included the demolition and removal of the building.
7. The detonation-viewing bunker (Structure 625) was a concrete bunker used to confine the detonation of unstable chemicals. It was approximately 11 ft long, 11 ft wide, and 9 ft high. The D&D work included demolition of the concrete bunker and removal of the debris.
8. The Sprung/Tent structure was a temporary, octagonal tent used as an enclosure to mitigate the spread of contaminants during the removal of waste items. The remediation project included dismantling the tent structure, reducing it to small pieces, and subsequent packaging for off-site disposal.

The buildings in the FWMF were mostly built of metal or concrete, and had only small amounts of radioactive removable surface contamination. Because of the impracticality of conducting demolition in confined space and the prohibitive expense to install dedicated ventilation, HEPA filters, or a containment tent, the D&D work of the structures was performed in open area. The demolition was completed using heavy equipment, mechanical shearing, saw cutters or torch cutters, a ramhoe, or other viable means and methods to reduce the size of large components. Mobilization equipment (crane, clamshell, forklift, and flatbeds) was used to load the packaged radiological waste on to rail cars.

Workers used dust suppression control techniques such as spraying water mist on soil and applying adhesive to loose surface contamination to minimize and reduce the resuspension of aerodynamic particulates during all D&D work. An air particulate filter sample collection station was set up in the downwind direction to monitor releases, if any, during the D&D work. The radiological contamination characterization work at the FWMF was reviewed in order to develop the source term for dose calculations. Previous characterization work included radiological swipes of the walls and floors, area surveys, and soil sample analyses. The surface area and estimated volume of debris that was to be removed from the D&D work for the buildings listed above was considered in development of the source term. Dose modeling was based on the radionuclides characterized in the soil analyses. An EDE to the MEI was calculated to be 4.64E-02 mrem in a year at the southeast location. The downwind particulate filter sampling analyses showed that the actual airborne concentrations were well below the minimum detection levels, and therefore there was no dose contribution from the remediation activities.

8.2.3.4 Waste Management Facility

A NESHAPs review was completed for the proposed release of krypton-85 (Kr-85), an inert gas, through a fume hood that exhausts via a 30-ft stack in Building 865. The emission source was a small copper tube with 60 mCi of Kr-85 gas, dated 2/8/1988. It was decay-corrected to 22 mCi for the purpose of the dose calculation. For the release of the Kr-85 gas, the CAP88-PC synopsis report provided a conservative estimate of an EDE of 1.03E-08 mrem in a year to the MEI at the southeast location.

8.2.3.5 Neutron Am-Be Source

A 50-Ci americium-beryllium neutron source [^{241}Am-Be(α, n)] was acquired from Nuclear Materials and Equipment Corporation in 1965. The sealed neutron source was cylindrical and doubly encapsulated in a tantalum inner container and an outer stainless steel container. The ^{241}Am-Be(α, n) reaction had a flux intensity of 10^8 n/cm^2/sec, and average energy of 4.5 MeV. The activity after decay correction in 2003 was calculated to be 47 Ci. A radiological risk assessment was completed in case the integrity of the seal was breached, which would contaminate the building and could have dose consequences for the worker, other occupants of the building, and members of the public. Based on the loose surface contamination, resuspension factor, breathing rate under normal work conditions, and an occupancy factor, an intake of 2.08 E-05 µCi of americium was calculated. The americium derived air concentration was 3.0E-12 µCi. It was concluded that, if the source were breached, the intake of the worker would be below the annual limit on intake. The EDE to the MEI residing 2,500 meters in the southeast direction would be 0.1 mrem in a year if all the activity were to be released, which was an unlikely scenario. Again, it was concluded that the dose consequences would be minimal, in comparison to the regulatory limit of 100 mrem in a year.

8.2.4 Dose from Point Sources

8.2.4.1 Brookhaven Linac Isotope Producer

Source term descriptions for point sources are given in Chapter 4; however, an update on emissions from the BLIP is appropriate here because the BLIP is the only emission source with the potential to contribute dose to members of the public greater than 1 percent of the DOE limit. The BLIP facility uses the excess beam capacity of the 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-in.-diameter shaft. The principal gaseous radionuclides produced as a result of activation of the cooling water are oxygen-15 (O-15, with a 2-min. half-life), and C-11 (20.38-min. half-life).

Because the BLIP facility is considered a major emission source, 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 captured by conventional methods. Particulates and radioiodines are monitored with filter cartridges (conventional, and activated charcoal), which are exchanged weekly for analysis. The tritium sampler also operates continuously with weekly sample collection and analyses.

In 2003, the BLIP facility operated over a period of 16 weeks. The average proton beam current was measured to be 75 microamperes. During the year, 934 Ci of C-11 and 2,782 Ci of O-15 (both short-lived gases) were released from the facility. Tritium from activation of the targets' cooling water was also released, but in miniscule quantities. The EDE to the MEI was calculated to be 5.96E-02 mrem in a year from BLIP operations.

The total emissions from the facility decreased in 2003 in comparison to 2002, and an objective to further reduce emission is being pursued for the BLIP facility. Since moisture is the primary source of emissions (humidity from the Hot Cell's cooling water), a shroud seal was installed to enclose the cooling water surface (16-in.-diameter shaft), target holder transfer cases, chain drive assembly (including motor supports), and other associated appurtenances. The shroud seal engineering control is expected to significantly reduce (about 28 percent) the gaseous emissions from the BLIP facility. The shroud seal was installed in January 2003. An inspection team from the EPA Office of Radiation and Indoor Air, Radiation Protection Division visited BNL in January 2003 and conducted an inspection of the BLIP facility with the new shroud seal construction. There were no compliance issues identified during the inspection, but a few documents in relation to the NESHAPs modeling program were requested and were provided to EPA.

The efficiency test of the shroud seal was not satisfactorily completed in 2003 because the BLIP runtime was short (16 weeks), beam power was not stable, and the detector calibration was questionable. Therefore, the shroud test will be completed in 2004 when BLIP receives the proton beam and becomes operational.

8.2.4.2 Brookhaven Medical Research Reactor

In January of 2003, the fuel elements from the Brookhaven Medical Research Reactor (BMRR) were shipped to an off-site location, greatly reducing any potential for radioactive emissions from the facility. The semi-annual particulate and charcoal air sampling data showed no quantifiable radioactive emissions from the BMRR. In September 2003, BNL requested approval from EPA to stop monitoring emissions at the BMRR. However, EPA requested clarification of the sampling data submitted and also required an additional round of sampling before making a final determination to eliminate BMRR emissions sampling. The BMRR reactor vessel's evaporation rate of tritium was estimated to be 76.3 mCi in a year, and the dose consequences to the MEI from the tritium emission were insignificant.

8.2.4.3 Sr-90 Unplanned Release

Personnel at the Waste Management Facility (WMF) at BNL are responsible for collecting, characterizing, consolidating, and repackaging hazardous radioactive waste materials for shipment to the off-site licensed disposal facilities. Building 865 (Reclamation Building) is the primary facility for handling radioactive waste. The waste handling activities are performed in accordance with Radiological Work Permits, Technical Work Documents, and Health and Safety procedures for the facility. In 2003, WMF personnel performed a transfer and repackaging of $SrSiO_3$ sources for off-site disposal. The transfer and repackaging of these sources was performed inside the WMF Shielded Cell in Bldg. 865 with remote viewing and handling. After the transfer of the $SrSiO_3$ stainless steel clad strips from a shielded storage cask into five Type B containers, the Sr-90/Y-90 micro spheres became airborne and triggered the alarm, most likely due to ruptured cladding. Differential pressure in the Shielded Cell was maintained to minimize dispersion of any loose surface contamination. The event lasted for approximately 8 hours before containment.

A NESHAPs evaluation was conducted to evaluate the potential dose to a member of the public from the Sr-90 unplanned release. The source term estimation was based on the assumption that all the activity present inside the Building 865 Hi-Bay area became airborne and was therefore dispersed into the environment. Based on the monitoring data and information provided on the NESHAPs Assessment Form, the source term for the NESHAPs evaluation was taken to be the maximum airborne concentration during the event (3.1E-10 µCi/mL), and a total release volume of 43,000 m^3 (exhaust flow rate, 3,200 ft^3 /min, x 480 minutes, x feet-to-meters conversion factor 0.028). The estimated radioactivity released to the environment from the event was 13.33 µCi. The potential EDE to the MEI situated in the northeast sector was estimated at 6.19E-07 mrem in a year. Therefore, the dose consequence from this event to the members of the public was insignificant.

8.3 INGESTION PATHWAY

Deer and fish bioaccumulate radionuclides in their tissues and organs, and therefore samples of these species are 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 of the BNL site boundary used to assess the potential dose impact to the MEI. In order to estimate the dose impact, it was assumed that the MEI consumed 15 pounds of fish from the Peconic River and approximately 64 pounds of venison per year (NYSDOH 1999).

Twenty-one samples of deer meat (flesh) were used for the purpose of dose calculations. Potassium-40 (K-40) and cesium-137 (Cs-137) were the two radionuclides detected in these samples. K-40 is a naturally occurring radionuclide and is not related to BNL operations. The average K-40 concentrations were 3.2 ± 2.0 pCi/g in the flesh and 2.6 ± 0.3 pCi/g (wet weight) in the liver. The average Cs-137 concentrations were 1.5 ± 0.9 pCi/g in the flesh and 0.7 ± 0.1 pCi/g (wet weight) in the liver (average for the "off site and less than 1 mile radius" group). The potential dose from consuming deer meat with the average Cs-137 concentration was estimated as 2.18 mrem (22 µSv) per year. This is about 22 percent of the health advisory limit of 10 mrem (100 µSv) established by the New York State Department of Health.

In 2001, fish sampling was suspended on the BNL site because previous fish sampling had depleted the population of larger fish. As a result, it would require many smaller fish to be obtained for a sample size sufficiently large enough to complete all desired analyses and detection sensitivity. BNL will continue with the suspension to allow the on-site fish populations to recover and mature. In collaboration with the NYSDEC Fisheries Division, BNL maintains an ongoing program of collecting and analyzing fish from the Peconic River and surrounding freshwater bodies. In 2003, the largemouth bass samples collected by NYSDEC at Swan Pond had the highest concentration (0.55 pCi/g) of Cs-137, so this value was used to estimate EDE to the MEI (assuming consumption of 15 pounds of fish). The potential dose from consuming fish was estimated at 0.19 mrem (1.9 µSv) per year. It is highly unlikely that an individual would consume fish with the highest concentration from this location, but these data were used to estimate dose as a worst-case scenario to the MEI.

8.4 CUMULATIVE DOSE

Table 8-5 summarizes the potential cumulative dose from the BNL site. The total dose to the MEI from air and ingestion pathways was estimated to be 2.43 mrem (24 µSv), as shown in Table 8-5. 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 effective dose was well below the DOE and EPA regulatory limits, and the ambient dose was within normal background levels seen at the BNL 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.

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 about 300 mrem (3 mSv). A diagnostic chest x-ray would result in 5 to 20 mrem per exposure to a person. Using natural gas in homes yields about 9 mrem per year, cosmic radiation gives 26 mrem, and natural potassium in the body gives about 39 mrem of internal dose. Even with conservative estimates of dose from air pathway and ingestion of local deer meat and fish, the cumulative dose from BNL operations was well below the dose that could be received from a single chest x-ray.

Table 8-5. BNL Site Dose Summary.

Pathway	Dose to Maximally Exposed Individual	Percent of DOE 100 mrem/year Limit	Estimated Population Dose per year
Inhalation			
Air	0.059 mrem (0.6 micro Sv)	<1%	0.24 person-rem
Ingestion			
Drinking water	None	None	None
Fish	0.19 mrem (2 micro Sv)	<1%	Not tracked
Deer Meat	2.18 mrem (22 micro Sv)	<3%	Not tracked
All Pathways	2.43 mrem (24 micro Sv)	<3%	0.24 person-rem

8.5 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 environmental surveillance data. The RESRAD-BIOTA 1.0 biota dose screening 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 proposed Rule 10 CFR 834, Subpart F (66 FR 25380). The terrestrial animal and plant doses were evaluated based on 0.36 pCi/L of Sr-90 in surface waters at the HQ sampling location on the Peconic River (see Figure 5-8 for sampling stations). Soil samples were not collected, and therefore the terrestrial biota dose from soil was not evaluated. The dose to terrestrial animals was calculated to be 1.78E-07 Gy/day and to terrestrial plants at 2.76E-09 Gy/day. The doses to terrestrial animals and plants were well below the biota dose limit of 1 mGy. For calculating dose to aquatic animals, the Cs-137 sediment concentration of 1,470 pCi/kg at HM north; Am-241 at 252 pCi/kg at HM north, and Sr-90 concentration in surface water at HQ locations were used (see Figure 5-8 for sampling stations). The sum of aquatic animal dose was estimated to be 9.96E-06 Gy/day, and to riparian animals, the dose was 4.88E-05 Gy/day. Therefore, the dose to aquatic animals was well below the 10 mGy limit.

REFERENCES AND BIBLIOGRAPHY

40 CFR 61, Subpart H. National Emissions Standard for Hazardous Air Pollutants. U.S. Environmental Protection Agency, Washington, DC. 1989.

66 FR 25380. May 14, 2001. U.S. Department of Energy. 10 CFR 834, Radiation Protection of the Public and the Environment. Federal Register.

ANSI/HPS. 1999. Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities. N13.1-1999.

DOE. 2002. A Graded Approach for Evaluation of Radiation Doses to Aquatic and Terrestrial Biota. DOE-STD-1153-2002. U.S. Department of Energy, Washington, DC. July 2002.

DOE Order 5400.5. 1990. Radiation Protection of the Public and the Environment. U.S. Department of Energy, Washington, DC. Change 2: 1-7-93

EML-DOE. 2000. 12th International Intercomparison of Environmental Dosimeters. New York, NY.

EPA. 1992. User's Guide for CAP88-PC, Version 2. EPA 402B92001. U.S. Environmental Protection Agency, Washington, DC.

EPA. 2003. User's Guide for CAP88-PC, Version 3. EPA 402B92001. U.S. Environmental Protection Agency, Washington, DC.

EPA. 1996. Food Ingestion Factors, Exposure Factors Handbook-Volume II. EPA600P95002FB. U.S. Environmental Protection Agency, Washington, DC.

LIPA. 1999. Population Survey 1999: Current Population Estimates for Nassau and Suffolk Counties and the Rockaway Peninsula. Long Island Power Authority, Uniondale, NY. October 1999.

NCRP. 1987. Exposure of the Population of the United States and Canada from Natural Background Radiation. NCRP Report No. 94. National Council on Radiation Protection and Measurements, Bethesda, MD.

NYSDOH. 1993. Environmental Radiation in New York State. Bureau of Environmental Radiation Protection, New York State Department of Health, Albany, NY.

NYSDOH. 1996. Radioactive Contamination in the Peconic River. Bureau of Environmental Radiation Protection, New York State Department of Health, Albany, NY.

NYSDOH. 1999. Deer Meat Contaminated With Cs-137 at Brookhaven National Laboratory. Bureau of Environmental Radiation Protection, New York State Department of Health, Albany, NY.