8 Radiological Dose Assessment

Brookhaven National Laboratory assessed the potential environmental radiological dose from scientific research activities for calendar year 2002. The radiological dose was calculated from ambient external sources, inhalation, ingestion, and skin absorption pathways to the hypothetical "maximally exposed individual" (MEI) at the BNL site boundary. The effective dose equivalents (EDEs) were found to be well below dose limits for the environment and members of the public that were set by the U.S. Environmental Protection Agency and the Department of Energy.

The average annual ambient external dose reading on site was 71 ± 15 mrem (710 ± 150 μSv) and off site was 66 ± 10 mrem (660 ± 100 μSv). Both measurements include contributions from cosmic and natural background sources. A statistical comparison of the average dose values from 41 on-site and 18 off-site thermoluminescent detectors indicated no additional dose contribution from BNL operations. The annual air pathway dose to the MEI was estimated as 0.086 mrem (0.86 μSv). The annual ingestion pathway doses to the MEI were estimated as 2.2 mrem (22 μSv) for venison and 0.25 mrem (2.5 μSv) mrem for fish caught at Donahue's Pond. The total annual dose to the MEI from all pathways was estimated to be 2.54 mrem (25 μSv). In comparison, the annual EPA regulatory limit for the air pathway is 10 mrem (100 μSv) and the annual DOE limit from all pathways is 100 mrem (1,000 μSv).

Additionally, 10 on-site remediation and waste management projects were evaluated for radiological emissions to the environment. The dose impact from all BNL activities was found to be insignificant in comparison to natural background levels. Dose to aquatic and terrestrial biota at the site was screened and found to be well below the DOE limits.

8.1 DIRECT RADIATION MONITORING

The main purpose of external dose monitoring is to measure the dose to members of the public and uninvolved workers from direct gamma external radiation sources. BNL measures direct penetrating radiation exposures off site with the premise that off-site exposures are true background doses (i.e., no contribution from BNL operations). On- and off-site external doses are compared to each other (using the statistical t-test) to estimate the contribution from BNL operations above the natural background radiation.

Direct penetrating gamma radiation is measured using thermoluminescent dosimeters (TLDs). The principle of TLD operation is that when certain crystals are exposed to penetrating gamma 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 state of energy. 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 accuracy of the TLDs is verified using known sources of radiation exposure and inter-comparison programs. The device that reads the dosimeter is calibrated to read *absorbed* dose—that is, quantity of energy deposited by radiation in the mass of the material.

8.1.1 Ambient Monitoring

To evaluate the potential impact from operations, TLDs are deployed at the BNL site and the surrounding communities, in 16 wind sectors. On-site TLD locations are selected based on the potential for exposure to gaseous plumes, atmospheric particulates, and radiation-generating facilities. The BNL perimeter locations are posted with TLDs to assess potential impact at the Laboratory boundary. On- and off-site areas are divided into grids and the TLDs are assigned IDs based on these grids.

Forty-one TLDs were deployed on the BNL site and 18 were deployed off site in year 2002, as shown in Figures 8-1 and 8-2, respectively. An additional 30 control TLDs were stored in a lead-shielded container in Building 535; the average of these control TLDs (075-TLD4) is reported in Table 8-1 as a reference. Note that it is not possible to completely shield the control devices from all natural and cosmic radiation; therefore, small doses are measured by the control TLDs.

The on- and off-site TLDs are collected and read on a quarterly basis to determine the direct external radiation dose impact to members of the public and the environment.

In 2002, the TLD location identifiers were modified to accommodate the new Environmental Information Management System. The grid numbers were retained to preserve the historical link to previous TLD data, but the suffixes were changed to "TLD" in the particular wind sector (for example, 011-400 was changed to 011-TLD1).

Table 8-1 shows the quarterly on-site radiation measurements. The on-site average external doses for the first, second, third, and fourth quarters were 19.9 ± 4.2, 16.3 ± 4.0, 15.3 ± 4.2,

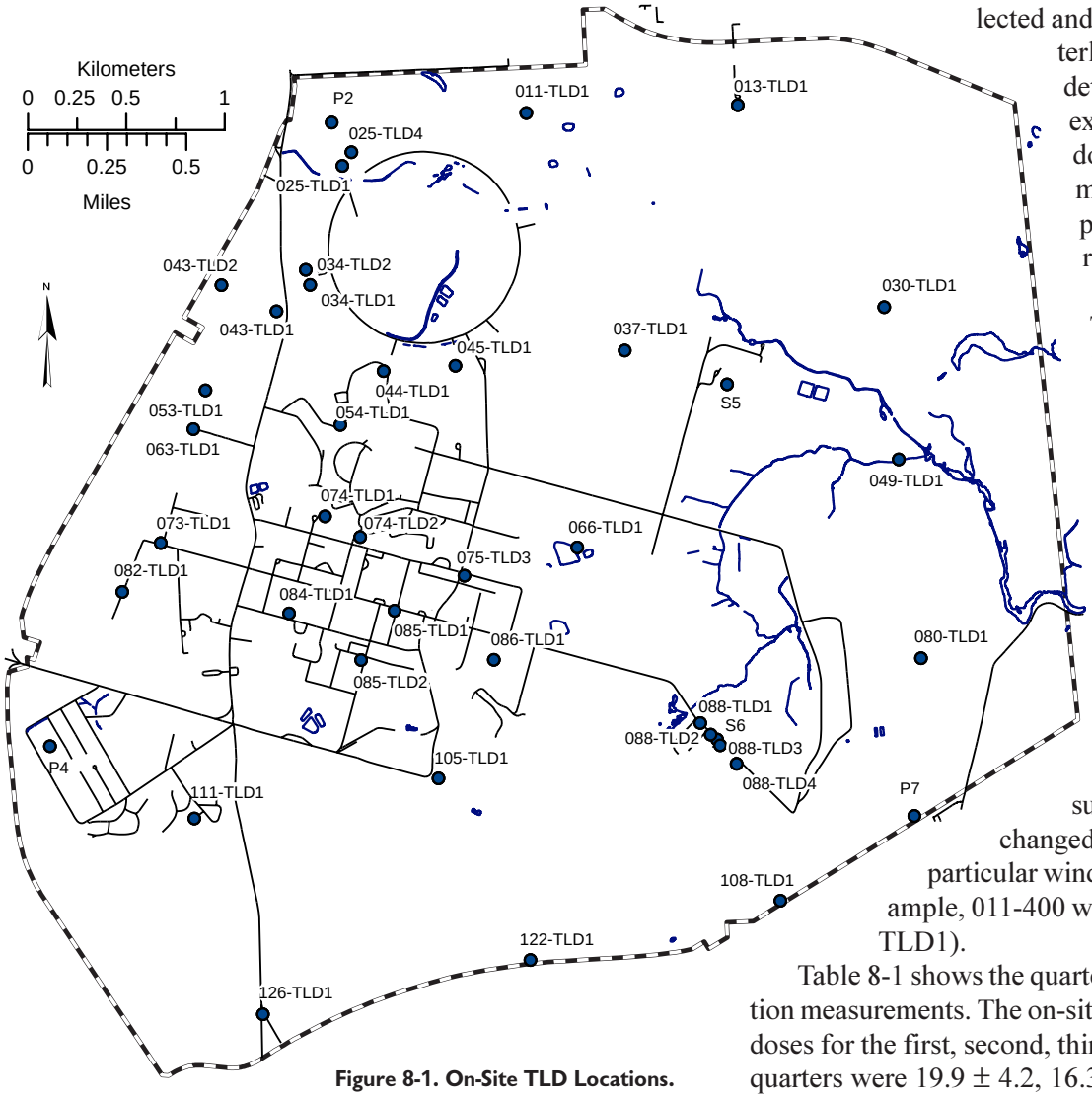

Figure 8-1. On-Site TLD Locations.

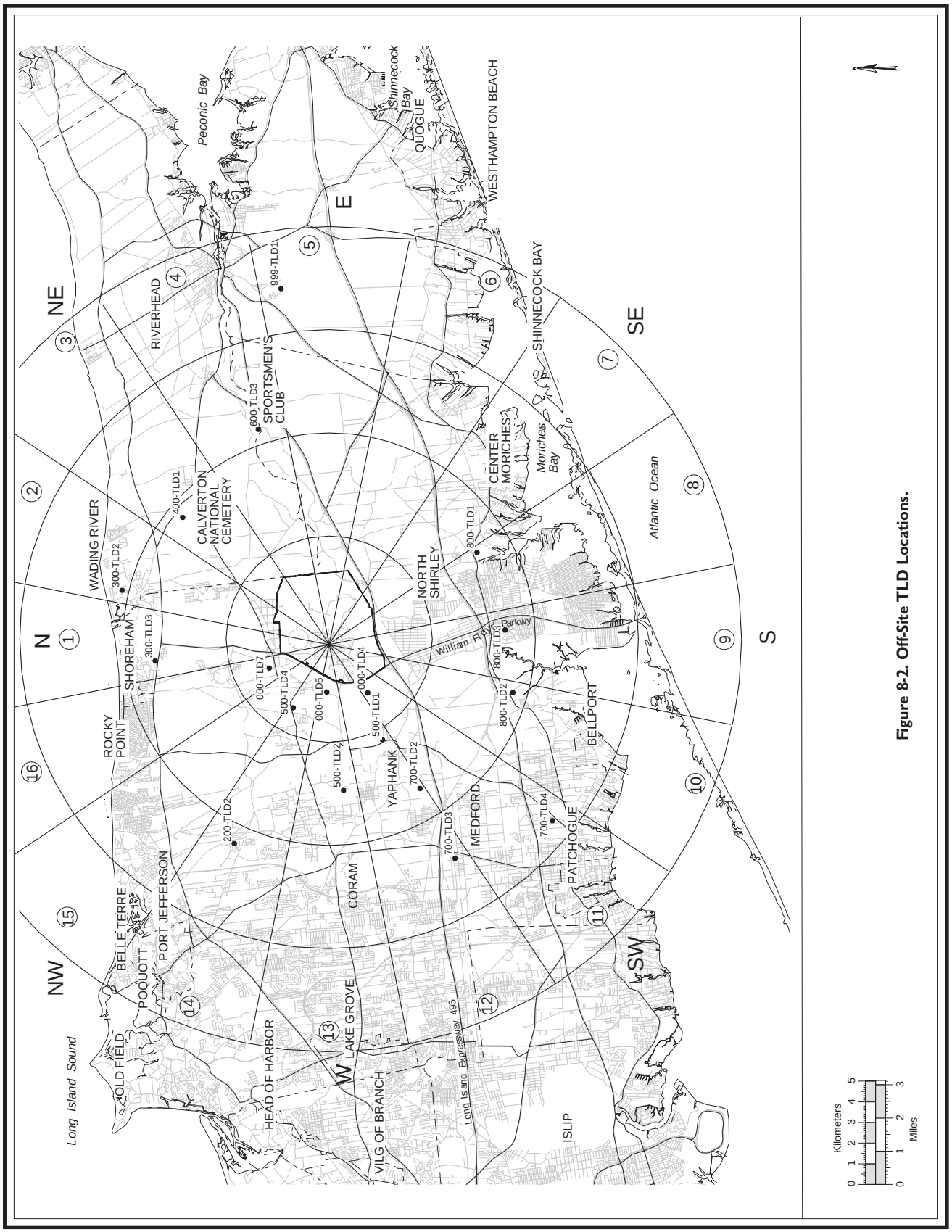

Figure 8-2. Off-Site TLD Locations.

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

TLD#	Location	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Average 2σ (95%)	Annual Dose 2σ (95%)
		(mrem)					
011-TLD1	Firebreak	19.6	15.4	12.7	NR	16 ± 7	64 ± 27
013-TLD1	North Firebreak	17.5	17.1	14.9	17.2	17 ± 2	67 ± 9
025-TLD1	Bldg. 1010 beam-stop 1	20.0	13.8	21.8	17.8	18 ± 7	73 ± 27
025-TLD4	Bldg. 1010 beam-stop 4	19.2	13.7	14.7	18.8	17 ± 5	66 ± 22
030-TLD1	NE Firebreak	17.9	14.7	12.9	18.5	16 ± 5	64 ± 21
034-TLD1	Bldg. 1008 collimator 2	19.7	17.5	14.0	17.8	17 ± 5	69 ± 19
034-TLD2	Bldg. 1008 collimator 4	18.5	14.3	17.2	18.9	17 ± 4	69 ± 16
037-TLD1	S-13	17.1	14.9	14.1	17.0	16 ± 3	63 ± 12
043-TLD1	North Access Road	19.6	18.3	14.6	19.0	18 ± 4	72 ± 18
043-TLD2	North of Met.	21.2	18.5	16.7	18.7	19 ± 4	75 ± 15
044-TLD1	Bldg. 1006	21.5	17.8	14.5	18.1	18 ± 6	72 ± 22
045-TLD1	Bldg. 1005S	19.4	15.8	15.3	19.1	17 ± 4	70 ± 17
049-TLD1	East Firebreak	19.1	14.1	13.1	16.9	16 ± 5	63 ± 21
053-TLD1	West Firebreak	21.3	17.2	15.6	19.8	18 ± 5	74 ± 20
063-TLD1	West Firebreak	20.1	17.2	15.5	20.6	18 ± 5	73 ± 19
066-TLD1	New HWM Facility	16.7	12.8	11.7	16.8	15 ± 5	58 ± 21
073-TLD1	West Met./Bldg. 51	22.1	16.6	NR	19.9	20 ± 5	78 ± 22
074-TLD1	Bldg. 197	22.1	19.8	15.9	21.0	20 ± 5	79 ± 21
074-TLD2	Bldg. 907	22.3	17.3	15.1	17.9	18 ± 6	73 ± 24
075-TLD3	Bldg. 356	25.9	20.7	21.6	29.8	25 ± 8	98 ± 33
080-TDL1	East Firebreak	19.7	13.8	14.7	19.5	17 ± 6	68 ± 24
082-TLD1	West Firebreak	21.9	16.0	16.6	20.3	19 ± 6	75 ± 22
084-TLD1	Tennis Courts	19.5	17.8	16.0	20.5	18 ± 4	74 ± 16
085-TDL2	Upton gas station	21.1	13.6	14.2	19.2	17 ± 7	68 ± 29
085-TLD1	TFCU (Credit Union)	23.3	17.7	16.5	19.7	19 ± 6	77 ± 23
086-TLD1	BERA ball fields	22.1	19.0	16.9	20.5	20 ± 4	79 ± 17
105-TLD1	South Firebreak	23.2	20.1	18.3	23.3	21 ± 5	85 ± 19
108-TLD1	Water Tower	17.1	16.7	15.2	18.5	17 ± 3	68 ± 11
111-TLD1	Trailer Park	17.5	14.7	14.9	18.6	16 ± 4	66 ± 15
122-TLD1	South Firebreak	17.0	14.5	13.2	19.2	16 ± 5	64 ± 21
126-TLD1	South Gate	20.8	16.6	14.8	18.4	18 ± 5	71 ± 20
P2		17.8	13.6	14.0	16.0	15 ± 4	61 ± 15
P4		18.2	15.1	14.5	18.1	16 ± 4	66 ± 15
P7		18.5	15.2	13.9	18.2	16 ± 4	66 ± 18
S5		17.6	17.5	13.4	19.3	17 ± 5	68 ± 20
Quarterly On-Site Average		**19.9**	**16.3**	**15.3**	**19.2**	**18 ± 4**	**71 ± 15**
Std. Dev. (2 Sigma)		**± 4.2**	**± 4.0**	**± 4.2**	**± 4.6**		
075-TLD4	**Control TLD Average**	**9.9**	**9.6**	**11.4**	**10.5**	**10 ± 2**	**41 ± 6**

Notes:
NR = TLD dose not reported
See Figure 8-1 for TLD Locations.

and 19.2 ± 4.6 mrem, respectively. The annual on-site external dose from all potential sources, including the contribution from cosmic and terrestrial radiation sources, was 71 ± 15 mrem.

Table 8-2 shows the quarterly off-site radiation measurements taken to determine the BNL contribution, if any, to external radiation dose. The annual off-site average ambient dose was 66 ± 10 mrem. A statistical t-test showed no significant difference between the external dose averages off site (66 ± 10 mrem) and on site (71 ± 15 mrem). Conclusion: There was no measurable external dose contribution from BNL operations.

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

TLD#	Location	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Average 2σ (95%)	Annual Dose 2σ (95%)
		(mrem)					
000-TLD4	Private Property	16.5	12.3	16.1	16.6	15 ± 4	62 ± 16
000-TLD5	Longwood Estate	18.6	13.9	13.7	18.3	16 ± 5	65 ± 21
000-TLD7	Mid-Island Game Farm	21.3	15.1	14.5	17.4	17 ± 6	68 ± 24
200-TLD2	Private Property	NP	NP	17.3	19.7	19 ± 3	74 ± 13
300-TLD2	Private Property	18.5	18.3	16.9	19.7	18 ± 2	73 ± 9
300-TLD3	Private Property	NP	NP	14.8	16.1	15 ± 2	62 ± 7
400-TLD1	Calverton Nat. Cem.	21.5	17.2	15.0	20.7	19 ± 6	74 ± 24
500-TLD1	Private Property	15.5	11.9	12.8	15.3	14 ± 4	56 ± 14
500-TLD2	Private Property	16.4	14.4	13.5	16.5	15 ± 3	61 ± 12
500-TLD4	Private Property	17.8	15.1	16.4	17.4	17 ± 2	67 ± 9
600-TLD3	Sportsmen's Club	16.0	15.1	14.1	17.0	16 ± 2	62 ± 10
700-TLD2	Private Property	19.5	13.8	15.2	17.1	16 ± 5	66 ± 19
700-TLD3	Private Property	20.2	13.3	13.5	17.9	16 ± 7	65 ± 27
700-TLD4	Private Property	NP	NP	15.2	17.9	17 ± 4	66 ± 15
800-TLD1	Private Property	19.4	14.2	14.7	16.3	16 ± 5	65 ± 18
800-TLD2	Private Property	20.0	15.0	16.2	18.5	17 ± 4	70 ± 18
800-TLD3	Suffolk Cty CD	17.0	14.2	14.3	16.9	16 ± 3	62 ± 12
999-TLD1	Private Property	20.1	13.9	12.9	16.4	16 ± 6	63 ± 25
Off-Site Average Std. Dev. (2 Sigma)							**66 ± 10**

Notes:
NP = TLD not posted for the quarter
See Figure 8-2 for TLD Locations.

8.1.2 Facility Area Monitoring

Six of the 41 on-site TLDs are facility area monitors (FAM). These TLDs were deployed at locations known to have radiological contamination and a much higher probability to contribute to the external radiation dose. Table 8-3 shows the external dose measured from the FAM TLDs. The TLDs posted at the S-6 location and on the fence of the old Waste Management area (088-TLD1 through 088 -TLD4) showed higher external dose than typical background dose in the vicinity. The higher external dose was attributed to the presence of radioactive materials, contaminated soils, and radioactive sources being repackaged for shipment to contractors' waste disposal sites. In comparison to data from previous years, exposures have generally decreased as the radioactive materials have been removed and shipped

Table 8-3. Facility Area Monitoring.

TLD#	Location	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Average 2σ (95%)	Annual Dose 2σ (95%)
		(mrem)					
S6		57.6	38.8	33.6	34.5	41 ± 22	165 ± 88
088-TLD1	OWMF-50' East/S-6	70.4	57.6	47.5	51.8	57 ± 20	227 ± 78
088-TLD2	OWMF-50' West/S-6	58.7	55.9	42.8	46.3	51 ± 15	204 ± 59
088-TLD3	OWMF-100' West/S-6	90.8	59.8	38.7	40.5	57 ± 47	230 ± 190
088-TLD4	OWMF-150' West/S-6	83.4	37.9	23.7	23.8	42 ± 55	169 ± 222
054-TLD1	Bldg. #914	62.4	84.5	13.3	18.7	45 ± 68	179 ± 270

Notes:
See Figure 8-1 for TLD Locations.

from this area. The old Waste Management facility is posted as a radiological area; only appropriately radiation-trained personnel wearing personal dosimeters are allowed inside the facility.

The FAM TLD near Building 914 (054-TLD1) showed 62.4 and 84.5 mrem for the first and second quarters, respectively, which is above the natural background radiation. The elevated readings during the first and second quarters were attributed to the sky-shine phenomenon during the operation of the Booster and beam transfer operation in Building 914.

8.1.3 Building 650 Sump Outfall Monitoring

The former Reclamation Facility, also known as Building 650, was originally constructed for decontaminating radioactively contaminated clothing and heavy equipment. The facility was designed so decontamination could occur inside and outside of the building. During the 1950s and 1960s, radioactively contaminated water from the outdoor steam cleaning operation collected in a drain in the middle of a sloping concrete pad known as the Building 650 Sump. It was assumed that the contaminated water from the Building 650 Sump drained into the sanitary sewer system or into underground tanks. However, an investigation revealed that the drainage pipe from the outdoor pad behind the building led to a storm water drainage system, which discharged to a natural depression in a wooded area, and not to the sewage treatment plant or the underground tanks. This area consequently had become radiologically contaminated. The Building 650 Sump Outfall area was fenced and posted as a radiological area to prevent unauthorized entry and was continuously monitored with TLDs, beginning in 1997. Excavation of soil and remediation work started in March 2002 and was completed in June 2002 under the Environmental Restoration Program as Operable Unit (OU) IV, Area of Concern (AOC) 6. After the soil was excavated, a minimum of 6 inches of clean fill was placed over the remediated areas. The ground will be hydro seeded to minimize erosion of the cover material. Radiological soil contamination in the Building 650 Sump Outfall area has been remediated to acceptable soil concentrations in accordance with interagency agreements (IAG) among DOE, EPA, and New York State. The cleanup levels are also protective of groundwater quality. During the period of land use by the federal government, remediated sites are restricted but can be used to support industrial laboratory operations with proper operational engineered controls and permits. Federal ownership of the site is expected through the year 2055 and BNL site security limits public access to this site. Any transfer of this site must meet EPA requirements 120(h) of the Comprehensive Environmental Response, Conservation and Liability Act (CERCLA) to ensure that future users are not exposed to unacceptable levels of contamination. The performance of these controls will be assessed internally on an annual basis via BNL's Assessment Program (as discussed in Chapter 2). BNL and DOE are committed to notifying the IAG members of any failures of the Land Use/Institutional Control (LU/IC) promptly, in accordance with the Occurrence Reporting and Processing System or the Laboratory's internal reporting procedures.

8.2 AIR EMISSIONS

The EPA regulates emissions from DOE facilities under requirements set forth in 40 CFR 61, Subpart H, *National Emissions Standard for Hazardous Air Pollutants* (NESHAPs). This regulation specifies the compliance monitoring and requirements for reporting radiation doses received by members of the public from airborne radionuclides. The regulations mandate that no member of the public shall receive a dose from air emissions greater than 10 mrem (100 μSv) per year from DOE operations. The emissions monitoring requirements set forth in Subpart H of 40 CFR Section 61.93(b) 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 program 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 maximally exposed individual (MEI). The dose estimates from various facilities are given in Table 8-4.

As part of the NESHAPs review process at BNL, all emission sources that have any potential to emit radioactive emissions are evaluated for compliance. Activities conducted by the Environmental Restoration Division (ERD) that might generate emissions are exempt under CERCLA from NESHAPs review, but these activities are monitored and assessed for any potential to release radioactive emissions, and to determine dose contribution, if any, to the environment and members of the public. A number of ERD and Waste Management (WM) operations were evaluated for NESHAPs compliance in 2002. 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 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 short-term sources and its results can be considered "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's CAP88-PC (Clean Air Act Assessment Package-1988), version (v.) 2. This computer program uses a Gaussian plume model equation to estimate the average dispersion of radionuclides released from elevated stacks or diffuse sources (EPA 1992). The program 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 food pathway (where applicable). The program supplies both the calculated 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 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 BNL site. Calculations are based on low-level environmental releases and chronic intakes. 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 assessments. Weather data are supplied by measurements from BNL's meteorological tower; these include wind speed, direction, frequency, and temperature (details in Chapter 1). 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. This person is assumed to reside 24 hours a day, 365 days a year at the BNL boundary in the downwind direction, and to consume significant amounts of contaminated fish and deer during the year. In reality, it is a highly unlikely, worst-case scenario that such a combination of maximized dose to any single individual would occur.

8.2.3 Dose from Diffuse (Nonpoint) and Other Sources

Diffuse sources are radioactive contaminants (emissions) released into the atmosphere that do not have a defined source point. Such sources are also known as nonpoint or area sources. BNL evaluated the following potential radiological diffuse sources in calendar year 2002.

8.2.3.1 Building 490

In addition to other scientific research, the Medical Department (Building 490) conducts radiotracer research on animals. The Medical Department synthesizes compounds with small amounts of radiotracers, typically 2 to 20 millicuries (mCi) of radioiodines (I-131), in Room 9-508. Approximately 24 experiments may be conducted over the course of a year, inside a Lucite enclosure that contains an activated carbon filter within a laboratory fume hood. Room 9-133C is used to inject chemical compounds labeled with tritium (half life: 12.28 years) and

carbon-14 (half-life: 5,730 years). The NESHAPs source term is based on the annual usage and inventory of nuclides listed by the department on the Assessment Form, as required by the *Radiological Airborne Emissions* SBMS subject area. The I-131 (half-life: 8.04 days) may be used 24 times per year, with a maximum activity of 20 mCi. Tritiated chemicals may also be used 24 times per year, with a maximum activity of 1 mCi. Up to 100 mCi of carbon-14 may be used.

In calculations, the modeling software assumes that 100 percent of the total inventory was released to the environment (a highly unlikely, worst-case scenario). The tritium-labeled chemicals and C-14 were in solution and therefore were corrected for chemical form with an emission factor to estimate potential airborne releases; radioiodines were treated as gases (i.e., 100 percent vented). The potential annual EDE from radiological emissions in Building 490, Rooms 9-508 and 9-133C was calculated by the program to be 3.89E-03 mrem to the MEI at the southeast boundary.

8.2.3.2 Soil Activation Studies

A nondestructive Soil Carbon Measurement (SCM) system is being developed at BNL to quantify carbon distribution in the top 50 cm of soil based on nondestructive, inelastic scattering of fast neutrons (INS). The SCM system will activate the soil using a double sealed 14 MeV neutron accelerator.

Based on this source term, the synopsis report from the CAP88-PC modeling program estimated an EDE of 4.48E-8 mrem to the MEI at the southeast boundary. Although this EDE is well below 1 percent of the 10 mrem standard, radioactive air emissions were monitored because BNL is committed to the environmental ALARA (as low as reasonably achievable) policy.

8.2.3.3 Building 901

The Chemistry Department (Building 901) uses radiotracers for neuroimaging research. The radiotracers are fabricated in the form of ^{11}C labeled compounds. The procedure is initiated by trapping the $^{11}CO_2$ in a molecular sieve and reacting it with hydrogen to convert it into $^{11}CH_4$. Then it is converted to ^{11}CN by reacting it with NH_3. The complete procedure is performed in a laboratory hood and the waste gases are collected in an 8-foot weather balloon encased in a secondary polyethylene bag. The ^{11}C collected in the weather balloon is decayed for ten half-lives and then vented to the outside. All of the work is performed in Room 112 (the Hot Lab) and in the processing area where the balloons are kept, known as the "cave area." Alternatively, the waste may be vented to a soda lime trap inside the laboratory hood within a shielded Hot Cell for decay (ten half-lives). Fluorine-18, produced by irradiating ^{18}O water, is used as a tracer. An aqueous form of ^{18}F for subsequent experiments is extracted by transferring the mixture of ^{18}F and ^{18}O water into a resin column, then eluting ^{18}F off the column using potassium/calcium carbonate. The potential sources of emissions from this operation are ^{11}C (half-life: 20.38 minutes) and ^{18}F (half-life: 109.77 minutes).

The NESHAPs evaluation was completed with the assumption that the complete, undecayed source inventory was emitted. The CAP88-PC dispersion modeling program provided an EDE of 1.33E-02 mrem to the MEI at the southeast boundary. The EDE from the ^{11}C and ^{18}F emissions was well below 1 percent of the 10-mrem limit.

In actual fact (as opposed to the computer model), the radioactive emissions were minimized in accordance with BNL's commitment to ALARA by decaying the emission gases for ten half-lives before discharging them to the environment. This process effectively eliminates emissions. Therefore, Building 901 is not included in Table 8-4.

8.2.3.4 Waste Management – BLIP Transfers

The Waste Management group has the responsibility to store, characterize, consolidate, and repackage radioactive waste materials for shipment to an off-site disposal location. Up to 30 times in a year, WM transfers waste from the Brookhaven Linac Isotope Producer (BLIP). In a BLIP transfer, waste units the size of a 1-gallon paint can are moved from one shipping container to another. Because the cans may have loose radiological contamination on their outside surfaces that in the transfer pro-

Table 8-4. Effective Dose Equivalent from Facilities.

Building	Facility or Process	Construction Permit No.	MEI Dose (a) (mrem)	Notes (a)
463	Biology Facility	None	8.45E-11	(b)
490	Medical Research	BNL-489-01	1.17E-05	(b)
491	BMRR	None	ND	
510	Calorimeter Enclosure	BNL-689-01	ND	
555	Chemistry Facility	None	6.96E-14	(b)
725	National Synchrotron Light Source	None	1.22E-08	(b)
750	HFBR	None	1.25E-05	
801	Target Processing Lab	None	8.40E-08	
802B	Evaporator Facility	BNL-288-01	ND	(c)
820	Accelerator Test Facility	BNL-589-01	ND	(d)
865	Reclamation Building	none	1.78E-04	
919	Liquid Effluent Storage Tankers	None	ND	
931	BLIP	None	8.60E-02	
938	REF/NBTF	BNL-789-01	ND	(c)
942	AGS Booster	BNL-188-01	ND	(e)
—	RHIC	BNL-389-01	ND	
Total from BNL Operations			**8.62E-02**	
EPA Limit			**10.0 mrem**	

Notes:
(a) "Dose" as used in this table means effective dose equivalent in a year.
(b) Calculations are based on 40 CFR 61, Appendix D methodology.
(c) This has become a zero emission facility since the original permit.
(d) This facility is no longer in use.
(e) Booster ventilation system prevents air release through continuous air recirculation.
ND = No-dose facility: not operational and/or zero air emissions in 2002.

cess could generate airborne particulates, a NESHAPs evaluation is completed.

The transfer process is conducted in open space within Building 865 in the High Bay Area where a portable HEPA ventilation system protects radiological workers. In the modeling program, the source term is based on previous bioassay calculations for a radiological worker, actual results from breathing zone air (BZA) analyses, and maximum loose radiological contamination on the external surface of the BLIP transfer cans. The dose calculations were completed using standard air dispersion equations because most radionuclides are not available in the CAP88-PC library. The modeling program estimated an EDE of 3.59E-06 mrem to the MEI at the southeast location. The MEI dose calculated with the air dispersion equation was estimated to be 1.12E-05 mrem. The dose from the BLIP transfers was well below the annual limit as specified in 40 CFR 61, Subpart H, and below the 0.1 mrem limit that triggers the requirement for a NESHAPs permit from EPA with continuous monitoring of the emission source. Therefore, only an annual administrative review of the emission source was required for the BLIP transfer operation.

8.2.3.5 Waste Management – Respirator Cleaning

The Respirator Cleaning Operation in Building 865 decontaminates and cleans radiologically and nonradiologically contaminated respirators for reuse. The cleaning process consists of two steps: decontamination and sanitization. The decontamination is conducted in Room 114 and consists of hand washing the respirator using a solution containing FK 300 Special Respirator Cleaner. The resultant wash fluid contains FK 300 cleaner, wash water, and low-level radioactive waste. The wash fluid is collected and transported to Building 811 for off-site disposal. The sanitation process consists of mechanically washing the respirator again with FK 300 cleaner. The resultant wash fluid consists of FK 300 cleaner and water. The water is discharged to the sanitary sewer system. The vapors and particulates

from this process could become airborne; therefore, a separate exhaust system with HEPA filter (EF-102) vents the air to the environment. One thousand respirators were decontaminated and sanitized in 2002.

A NESHAPs evaluation was completed for this cleaning operation. The source term was based on the Trigger Level Calculation Form for the most restrictive Annual Limit on Intake (ALI) for radiation workers. The synopsis report from the CAP88-PC, v. 2.0 modeling program estimated an EDE of 8.54E-5 mrem to the MEI at the southeast boundary. A NESHAPs permit application was not required and only an annual administrative review of the Respirator Cleaning Operation is required.

8.2.3.6 Waste Management – Compacting

The compactor in Building 865 uses a hydraulic press to compress waste by applying 500,000 pounds of pressure per square inch. The compactor can accommodate a B-25 container, which has about 100 cubic feet of capacity. The compactor is primarily used for low-level radioactive waste streams (such as paper, plastic, personal protective equipment, glassware, etc.) generated from the scientific laboratories. The expected volume reduction ratio after compaction is about 4:1, which results in significant savings in disposal costs. During the compacting operation, there is a potential to generate airborne radionuclides; therefore, the compactor has its own exhaust system with a HEPA filtration system, which is inspected and maintained before each use.

The CAP88-PC, v. 2.0 modeling program estimated an EDE of 8.23E-08 mrem to the MEI at the southeast location—again, a conservative (overestimated) value. Although this dose estimate is very low, the compacting operation requires an annual review to confirm the absence of radioactive materials in forms and quantities not conforming to prescribed specifications and limits.

8.2.3.7 Waste Management – Hot Cell

A project in 2002 entailed safely transferring and consolidating three cobalt-60 sources for shipment to the Hanford Site. These sources were stainless steel/cobalt "tabs" arranged in an array held together by a stainless steel basket and shielded within a lead pig. The transfer and consolidation of the Co-60 sources was conducted inside the Hot Cell of Building 865. The first cobalt-60 source was labeled as a 5,600-curie source, with a width of 2 in., length about 6 to 12 in., and a quarter-inch thickness. It was manufactured by Oak Ridge National Laboratory in 1964. The second cobalt source was labeled as a 1,000-curie source and had about the same dimensions as the first source. The third source was labeled as a 2-curie source with dimensions of 6 in. long by 3 in. diameter.

Although there was a very small probability for loose surface contamination to spread outside of the Hot Cell, a NESHAPs evaluation was conducted to evaluate potential dose to members of the public. The synopsis report from the CAP88-PC, v. 2.0, modeling program estimated an 8.15E-08 mrem EDE to the MEI at the northeast location.

8.2.3.8 Sewage Treatment Plant

During the remediation project to remove abandoned sanitary lines, radiological contamination was found in manholes MH-192 through MH-201. The sludge in the manholes was removed and packaged for disposal at a licensed facility. The CAP88-PC, v. 2.0 modeling program estimated an EDE of 2.30 E-13 mrem to the MEI at the southeast location.

8.2.3.9 Mercury-Tritium Diffusion Pump

The purpose of this project was to dismantle the mercury-tritium diffusion pump and to characterize its contents and repackage it for disposal. Before dismantling began, a NESHAPs evaluation was performed. This evaluation was based on the label, which showed that the pump contained 50 curies of tritium as of January 8, 1976—although it was likely that no tritium remained in the apparatus because it had coils open to the air. The label also stated that the pump contained 1,000 cc of mercury; this would be drained into a pan after the flanges were opened and the apparatus had been dismantled. The dose estimate from the CAP88-PC, v. 2.0 modeling program was 3.03E-04 mrem EDE to the MEI at the southwest location. This EDE was well below 1 percent of the 10 mrem standard.

8.2.3.10 BGRR BGD Filter Removal

The Below Ground Duct (BGD), a part of the Brookhaven Graphite Research Reactor (BGRR) primary air cooling system, was constructed from steel-reinforced concrete. The BGD consists of two separate ducts, north and south, which are connected to the reactor exhaust air plenums. The Outlet Air Filters comprise a single filter bank in each of the north and south BGDs. Each of these filter banks contains a total of 320 filter elements, which are arranged in eight cells that form a "four V" configuration. Each filter cell contains 40 elements arranged five across and eight high. A recent radiation measurement taken at a distance of 1 foot from the filters was 1 roentgen per hour. The elements in the Outlet Air Filters were installed at the beginning of the reactor's operation and were in use throughout the 18 years of its operation. The filters were characterized in the year 2000; contaminants of interest are Co-60, Cs-137, Sr-90, Am-241, U-234, U-235, U-238, Pu-238, Pu-239, and Pu-240.

The EDE from removal of the BGRR BGD filters was estimated by the modeling program as 3.53E-05 mrem to the MEI at the southeast location. This potential EDE is well below the 10 mrem limit specified in 40 CFR 61, Subpart H, and below the 0.1mrem limit that would necessitate a NESHAPs permit and continuous monitoring of the emission source. Even though it is not required, continuous monitoring of the duct/stack will be implemented to maintain a record of actual emissions and to monitor any unplanned releases. Also, a separate HEPA-filtered ventilation system will be installed in the Duct Service Building (Bldg.708-T) and a fixative will be applied to the filter surfaces to further minimize emissions to the environment and potential dose to members of the public.

8.2.4 Dose from Point Sources

Point source descriptions are given in Chapter 4, but an update on BLIP emissions is appropriate here because the BLIP is the only point source with the potential to contribute dose to members of the public. In 2002, the BLIP operated over a period of 21 weeks. The proton beam average current was 86.2 microamperes. During this period, 1,410 Ci of carbon-11 and 4,270 Ci of oxygen-15 gases were released. Tritium produced from activation of the target cooling water was also released, but in very small quantities. The decrease in oxygen-15 emissions, compared to 2001, (7,400 Ci) was primarily due to a decrease in operational period (35 weeks in 2001 compared to 21 weeks in 2002). The modeling program estimated the EDE to the MEI was 8.60E-02 mrem.

Although a comparison to the previous year's emissions shows that total emissions decreased in 2002, further reductions in emissions to the ambient air are being pursued as an objective for the BLIP facility. Moisture is the primary source of emissions (humidity from the hot cell's cooling water). Therefore, a shroud seal was installed to enclose components of the assembly, which includes the cooling water surface (a 16-in. diameter shaft), the transfer cases for the target holder, the chain drive assembly (with motor supports), and any other associated appurtenances. The shroud seal should result in a significant decrease (about 28 percent) in gaseous emissions. When enough operational data have been collected, its efficiency will be assessed.

8.3 INGESTION PATHWAY

Deer and fish at or near BNL have the potential to accumulate radioactivity attributable to BNL operations. As discussed in Chapter 6, deer meat samples collected on the BNL site and less than 1 mile beyond the BNL site boundary were used to assess the potential dose impact to the MEI. To estimate the dose impact, it was assumed that the MEI consumed 15 pounds of fish and about 64 pounds of venison per year (NYSDOH 1999).

Thirty-eight samples of deer meat (flesh) were considered for dose calculations. Potassium-40 (K-40) and cesium-137 (Cs-137) were the two radionuclides detected in these samples. Potassium-40 is a naturally occurring radionuclide and is not related to BNL operations. The average K-40 concentrations were 3.0 ± 0.4 pCi/g in the flesh and 2.4 ± 0.4 pCi/g (wet weight) in the liver. The average Cs-137 concentrations were 1.5 ± 0.4 pCi/g in the flesh and 0.4 ± 0.08 pCi/g (wet weight) in the liver (average on BNL site and less than 1 mile radius). The potential

dose from consuming deer meat with the average C-137 concentration was estimated as 2.2 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 site because years of fish sampling had depleted the population of larger fish. As a result, it would be necessary to take many smaller fish to obtain a sample sufficiently large to complete all analyses desired. The sample size (minimum 1 kg) for fish samples plays a critical role in sensitivities for the detection of specific radionucides. BNL will continue with the suspension for up to three years to allow the on-site fish populations to recover and mature. 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. The only on-site sampling in 2001 was performed by New York State in the stretch of river immediately east of the last gauging station on BNL property to Schultz Road, and in Ice Pond just off the Peconic River east of BNL. In 2002, Chain Pickerel samples collected by NYSDEC at Donahue's Pond had the highest concentration of Cs-137, so these values were used to estimate EDE to the MEI (assuming consumption of 15 pounds of fish). The potential dose from consuming fish was estimated at 0.25 mrem (2.5 μSv) per year. It is highly unlikely that an individual would consume fish with the highest concentration and from this location, but these data were used to estimate dose as a worst-case scenario.

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 2.54 mrem (25 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 within normal background levels. 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 chest x-ray results in 5 to 20 mrem per exposure. Using natural gas in homes yields about 9 mrem per year, cosmic radiation gives 26 mrem to humans, and natural potassium in the body gives about 39 mrem of internal dose. Even with conservative (overstated) estimates of dose from air pathways and the 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.

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 the 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 dose was evaluated based on 410 pCi/kg of Cs-137 in soil at the P7 sampling location. The surface water concentrations used to evaluate biota dose were based on effluent readings taken just upstream of the Sewage Treatment Plant: 1.4 pCi/L for Cs-137, 640 pCi/L (maximum) for tritium, and 1.09 pCi/L for strontium-90. For the dose to aquatic animals, the highest Cs-137 concentration (800 pCi/kg, at Lower Lake, Carmens River) was used. The sum of aquatic animal dose was estimated to be 1.37E-3 rad and the sum of riparian animal dose was 3.24E-3 rad. Therefore, dose to aquatic animals was well below the 1-rad (10 mGy) limit. The doses to terrestrial animals and plants were estimated to be 3.78E-4 and

Table 8-5. BNL Site Dose Summary.

Pathway	Dose to Maximally Exposed Individual	Percent of DOE 100 mrem/year Limit	Estimated Population Dose
Air	0.086 mrem (0.86 micro Sv)	<1%	0.33 person-rem
Water	None	None	None
Ingestion (fish)	0.25 mrem (2 micro Sv)	<1%	Not tracked
Ingestion (deer meat)	2.20 mrem (22 micro Sv)	2.2%	Not tracked
All pathways	2.54 mrem (25 micro Sv)	2.5%	0.33 person-rem

1.86E-4 rad, respectively, well below the biota dose limit of 0.1 rad (1 mGy).

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