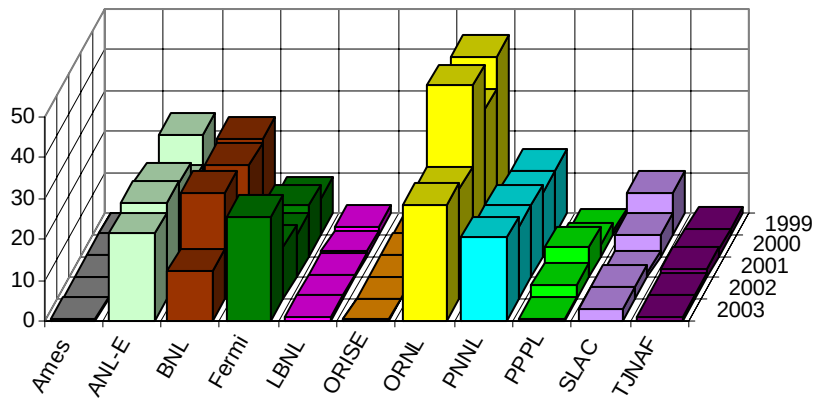
Radiological Control Profile for the Office of Science Laboratories 1999-2003

Collective Dose at SC Laboratories (Person-Rem)



Office of Laboratory Policy and Infrastructure (SC-80)
Office of Science
U.S. Department of Energy

Executive Summary

Looking back at the trend over the past five years, the collective dose from all Office of Science (SC) laboratories has dropped about 12 percent overall, from 130 person-rem in 1999 to 115 person-rem in 2003. By comparison, the collective dose at all Department of Energy (DOE) laboratories increased by about 12 percent in the same period, from 1,295 to 1,445 person-rem.

During 2003, the largest decrease in collective dose was at Brookhaven National Laboratory (BNL), from 26 person-rem in 2002 to 12 person-rem in 2003. The decrease was attributable to changes in the experimental program at the Alternating Gradient Synchrotron.

The largest increase in collective dose was at Fermi National Accelerator Laboratory (Fermilab), rising from 13 person-rem in 2002 to 26 person-rem in 2003. The increase was largely attributable to two shutdowns of the accelerators for upgrades, maintenance, and repair work. The primary goals of these shutdowns were improved accelerator performance and the reduction of future radiation exposures through better component design and improved reliability.

The number of workers with an annual dose exceeding 1,000 millirem dropped from six in 2002 to one in 2003. The single worker in this category was a radiological control technician at Oak Ridge National Laboratory (ORNL), and the dose was largely attributable to clean up efforts associated with a spill of liquid radioactive waste at Building 2026 in October 2003.

Most workers who were monitored for radiation exposure at SC laboratories received no measurable dose at all. Of those who did, approximately 85 percent received less than 100 millirem per year (the threshold for when a dosimeter must be issued). More than 98 percent of those with a measurable dose received an annual dose under 500 millirem, which is one-tenth of the DOE annual limit of 5,000 millirem (5 rem).

Reportable occurrences for radiation exposure, personnel contamination, and loss of control of radioactive material do not show any clear trend, although they generally correspond to the amount of work performed. Off-site doses to members of the public from releases of radionuclides to the environment are all well within regulatory limits. Some SC laboratories have issues with legacy contamination in groundwater and soils from historical releases of radionuclides, but there are no issues of non-compliance with applicable standards for protection of the public.

Introduction

This is a current assessment of the performance of SC laboratories with respect to radiological control. It provides a five-year retrospective look at occupational radiation exposures and radionuclide releases to the environment at all SC laboratories, including results for all DOE employees, contractors, subcontractors, and visitors. The scope of the report includes occupational doses for all workers at each facility and is not limited to just those funded by SC.

The occupational exposure data in this report is taken from the DOE Radiation Exposure Monitoring System (REMS), which serves as the central repository of radiation exposure information for DOE Headquarters. The REMS data is available on the web at http://rems.eh.doe.gov/ and is also published annually in the *DOE Occupational Radiation Exposure Report*. Information on radionuclide releases to the environment was taken from the Annual Site Environmental Reports.

Excellence in Radiological Control

The Department strives to maintain radiation exposures to its workers and the public below administrative control levels and regulatory limits and to further reduce these exposures to levels that are "As Low As Reasonably Achievable" (ALARA). The ALARA methodology considers both individual and group doses and involves a cost/benefit analysis that considers social, technical, economic, practical, and public policy aspects of the overall goal of dose reduction.

To evaluate how well ALARA is being implemented for workers at SC laboratories, it is necessary to look at several different measures of occupational dose. The analysis in this report considers the total number of individuals who are monitored for dose, the number of those who actually receive a measurable dose, their average dose, and the group (or total collective) dose for all monitored individuals at all SC laboratories.

One characteristic of a good ALARA program is that the majority of worker dose should be at relatively low levels, with only a small percentage of workers receiving doses approaching administrative control levels. For this reason, this report also includes a frequency distribution for the total number of exposed workers at selected ranges of dose.

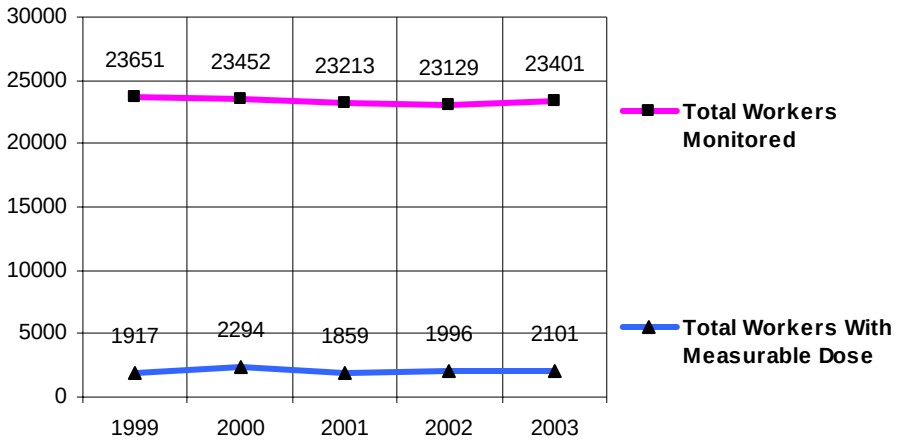
Another characteristic of a robust radiological safety program is that, for a constant workload, both individual and group doses should drop over time, as experience and lessons learned combine to improve radiological work practices. This analysis provides a five-year retrospective of occupational and environmental radiation exposures to evaluate where reductions have occurred. It is important to note that an increase in dose does not necessarily indicate a problem if it can be attributed to increased work activity rather than a decrease in radiation control practices.

Number of Monitored Workers

Personnel dosimetry is required for DOE workers who are likely to receive a dose greater than 100 millirem per year. Also, visitors are monitored at half that limit (50 millirem per year) if they are members of the public and not employees.

In practice, most sites prudently provide dosimetry in excess of this requirement, for reasons of administrative convenience, legal liability, and security. While the total number of monitored workers gives a good indication of the overall scope of the dosimetry program, it is not necessarily a good indicator of the actual exposed work force.

Figure 1: Number of Monitored Workers at SC Laboratories



The total number of monitored workers at all SC laboratories has changed very little, from 23,651 in 1999 to 23,401 in 2003 (see Figure 1). However, only a fraction of those monitored actually received a measurable dose. The number of workers with a measurable dose increased slightly from 1,917 in 1999 to 2,101 in 2003.

Collective Occupational Dose

The collective dose, or total radiation dose, is the sum of all annual doses received by every individual with a measurable dose. It is typically measured in units of person-rem, and it includes doses to visitors, as well as DOE employees, contractors, and subcontractors. The collective dose is monitored by DOE as one measure of the overall performance of radiation protection programs.

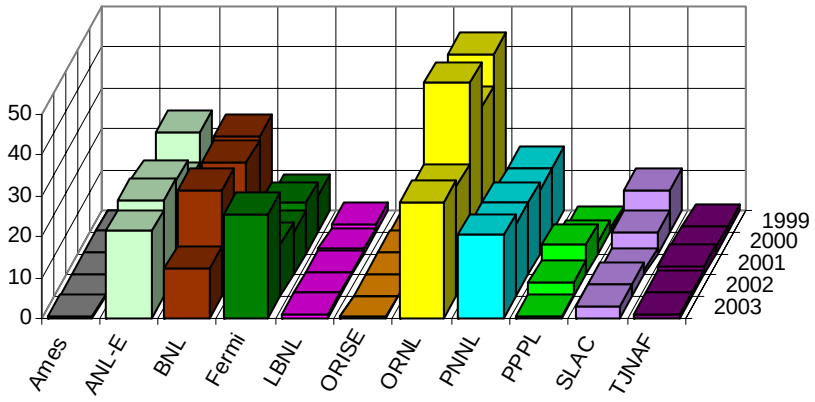
Looking back at the trend over the past five years, the collective dose from SC laboratories has dropped about 12 percent overall, from 130 person-rem in 1999 to 115 person-rem in 2003. By comparison, the collective dose at all DOE laboratories increased by about 12 percent in the same period, from 1,295 to 1,445 person-rem.

During 2003, the majority of the collective dose was at five SC laboratories – Argonne National Laboratory-East (ANL-E), Brookhaven National Laboratory (BNL), Fermi National Accelerator Laboratory (Fermilab), Oak Ridge National Laboratory (ORNL)

and Pacific Northwest National Laboratory (PNNL). Taken together, these five laboratories accounted for over 94 percent of the total collective dose for all of SC.

The collective dose at ANL-E dropped approximately 10 percent in 2003, compared to the previous year. Also, the number of workers with an annual dose exceeding 1,000 millirem dropped from six in 2002 to zero in 2003. The principal dose contributor was the Intense Pulsed Neutron Source (IPNS), with 40 percent of the total collective dose. The Alpha Gamma Hot Cell Facility (AGHCF) improved the shielding on many of their gloveboxes by adding leaded glass to the work areas, which resulted in a 50 percent reduction in dose for manipulator repairs. Also, the AGHCF was in a limited operations mode for approximately four months, due to the work to improve shielding, further reducing the collective dose. Overall AGHCF dose was 15 percent of the ANL-E total; however, this may be expected to increase somewhat in 2004 due to resumption of normal operations, maintenance, and replacement of manipulators.

Figure 2: Collective Dose at SC Laboratories (Person-Rem)



Year	Ames	ANL-E	BNL	Fermi	LBNL	ORISE	ORNL	PNNL	PPPL	SLAC	TJNAF
1999	0.230	24.583	23.371	8.740	1.822	0.042	43.740	15.569	0.817	10.192	1.370
2000	0.311	17.244	22.384	12.340	1.114	0.299	35.848	15.378	2.941	5.464	1.616
2001	0.174	23.033	14.627	10.650	0.682	0.327	47.039	17.639	7.420	1.368	2.317
2002	0.076	23.560	26.244	12.790	0.895	0.274	27.046	17.690	3.707	3.075	1.113
2003	0.448	21.379	12.183	25.670	1.037	0.289	28.591	20.407	0.593	3.127	0.992

At BNL, the collective dose decreased from 26 person-rem in 2002 to 12 person-rem in 2003. The decrease was attributable to changes in the experimental program at the Alternating Gradient Synchrotron. In 2002, both high intensity protons for fixed target experiments and polarized protons and heavy ions were accelerated. In 2003, only heavy ions were accelerated for injection into the Relativistic Heavy Ion Collider. Also, in 2003 there were fewer major refit projects which involved entry into the higher radiation areas in the accelerator ring.

The largest increase in collective dose was at Fermilab, rising from 13 person-rem in 2002 to 26 person-rem in 2003. The increase was largely attributable to two shutdowns

of the accelerators for upgrades, maintenance, and repair work. The primary goals of these shutdowns were improved accelerator performance and the reduction of future radiation exposures through better component design and improved reliability. For example, work at the Booster synchrotron was aimed at reducing beam losses, which will reduce radioactivation of components, residual radiation in the enclosures, and subsequently personnel exposures for those who must maintain the accelerators in the future.

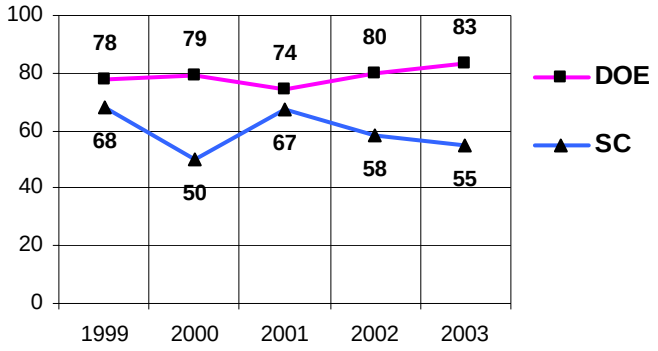
The collective dose at ORNL increased slightly, from 27 person-rem in 2002 to 29 person-rem in 2003. The increase in dose was attributable to clean up efforts associated with a spill of liquid radioactive waste in Building 2026 in October 2003. That incident resulted in a dose of 312 mrem to a facility supervisor and 1320 mrem to a radiological control technician.

At PNNL, the collective dose increased from 18 person-rem in 2002 to 20 person-rem in 2003. Nearly all of the increase in dose was from projects at the Radiochemical Processing Laboratory involving decontamination of nuclear power reactor control rod drive mechanisms and Hanford Site cleanup activities.

Average Measurable Occupational Dose

The average measurable dose is calculated by dividing the collective dose by the total number of individuals with a measurable dose. The average dose for all SC facilities has ranged between 50 to 68 millirem during the last five years (see Figure 3).

Figure 3: Average Measurable Dose at SC Laboratories (mrem/yr)



While the average measurable dose is one useful indicator for dose to workers (and visitors) at SC laboratories, it can be misunderstood if taken out of context. For example, the average dose can drop if there is an overall increase in the number of workers who receive very low levels of measurable dose. This may give a mistaken impression that doses are dropping, when in fact they are rising.

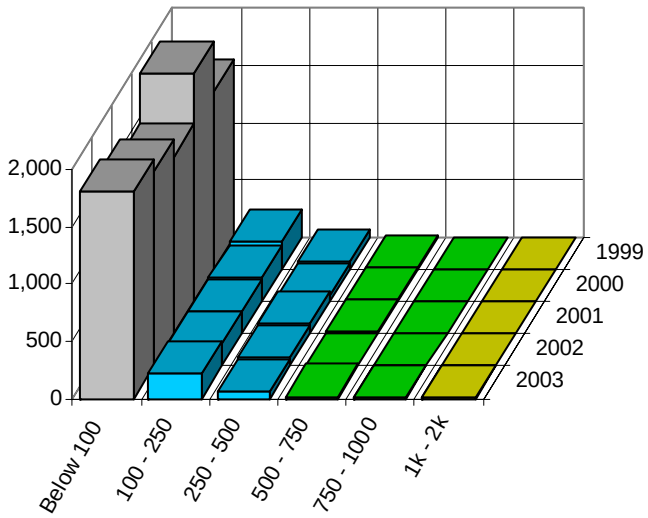
Also, since the average is calculated by dividing by the total number of workers with a measurable dose, the average may not be very sensitive to increases in dose to small numbers of workers, which may be of concern. In order to provide a more complete picture of radiation exposures, the following section presents exposure data as a

frequency distribution showing the number of workers at selected intervals of annual dose with trends over the past five years.

Occupational Dose Distribution

Of all SC laboratory workers who receive a measurable dose, the majority received an annual dose of less than 100 millirem, which is the DOE threshold for requiring dosimetry (see Figure 4). For the last five years, at least 80 percent of all workers at SC laboratories fell into this category. Also, for this same time period, more than 98 percent of all workers had a dose of less than 500 millirem per year, which is one-tenth of the annual limit of 5,000 millirem in 10 CFR 835.

Figure 4: Dose Distribution for SC Laboratories: Total Number of Workers in Each Dose Range



Dose Range (millirem/year)

Total Workers In Each Dose Range (mrem) >

Year	Below 100	100 - 250	250 - 500	500 - 750	750 - 1000	1k - 2k
1999	1,560	252	73	22	5	5
2000	1,997	212	62	19	1	3
2001	1,549	191	88	19	5	7
2002	1,698	201	73	12	6	6
2003	1,802	212	65	17	4	1

The number of workers who received an annual dose exceeding 1,000 millirem decreased from six in 2002 to one in 2003. The single worker in this category was a radiological control technician at ORNL, who received a dose of 1320 millirem as a result of clean up efforts associated with a spill of radioactive liquid in Building 2026.

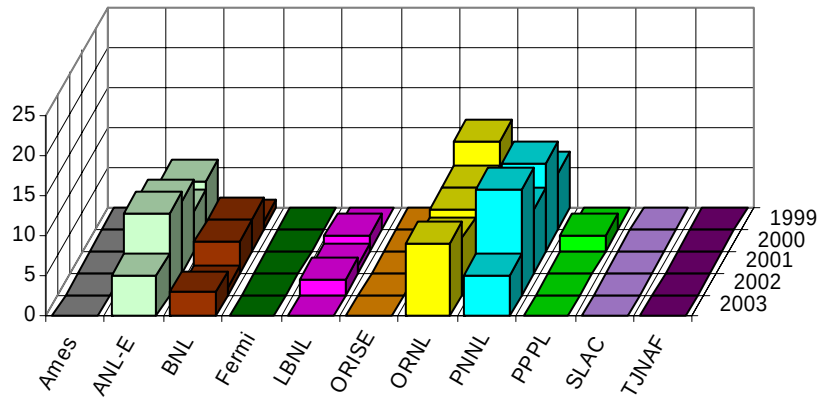
Unplanned Radiation Exposures

During the past five years, there were four occurrences of unplanned radiation exposures at SC laboratories. During the same time, a total of 81 of these kinds of occurrences were reported DOE-wide. There was one occurrence of this kind in 2003, at ORNL.

Personnel Contamination

In addition to unplanned radiation exposures, sites are also required to report occurrences of personnel contamination. Although these kinds of occurrences do not cause any significant dose, they are tracked as a performance indicator for conduct of operations. An increase in the number of contaminations may indicate a degradation in radiological control practices, if not otherwise attributable to a change in work activities.

Figure 5: Occurrences at SC Laboratories for Personnel Contamination



Year	Ames	ANL-E	BNL	Fermi	LBNL	ORISE	ORNL	PNNL	PPPL	SLAC	TJNAF
1999	0	6	1	0	0	0	11	7	0	0	0
2000	0	5	4	0	2	0	8	11	2	0	0
2001	0	9	4	0	1	0	8	8	0	0	0
2002	0	10	1	0	2	0	7	13	0	0	0
2003	0	5	3	0	0	0	9	5	0	0	0
Total	0	35	13	0	5	0	43	44	2	0	0

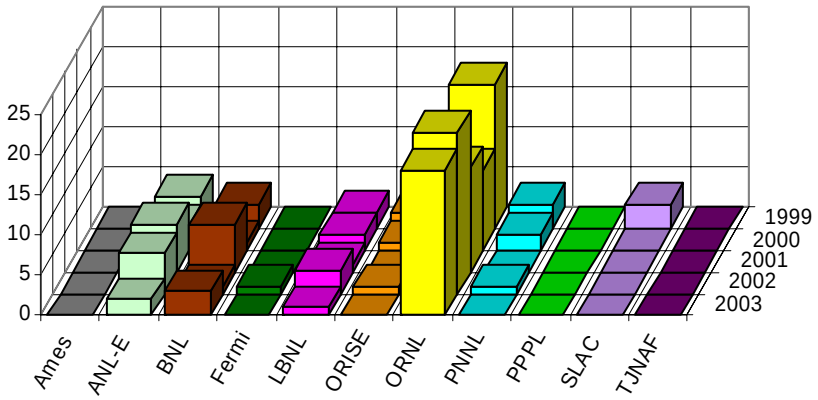
There were 142 occurrences of personnel contamination for SC during the past five years, as compared to 1,317 for all of DOE. These occurrences were predominately at the multi-program laboratories (see Figure 5). These occurrences do not show any clear trend, although they generally correspond to the amount of work performed.

Loss of Control of Radioactive Material and Spread of Contamination

In addition to personnel contamination, sites also report occurrences of loss of control of radioactive material, and/or spread of contamination. Like personnel contamination, these occurrences do not cause significant dose, but are used as a performance indicator for conduct of operations.

There were 136 reported occurrences for this category during the past five years at SC laboratories, as compared to 1,101 reported DOE-wide. These occurrences were predominately at ORNL (see Figure 6), which are mostly due to the legacy contamination found from movement of personnel from old buildings to newer facilities.

Figure 6: Occurrences at SC Laboratories for Loss of Control of Radioactive Material & Spread of Contamination



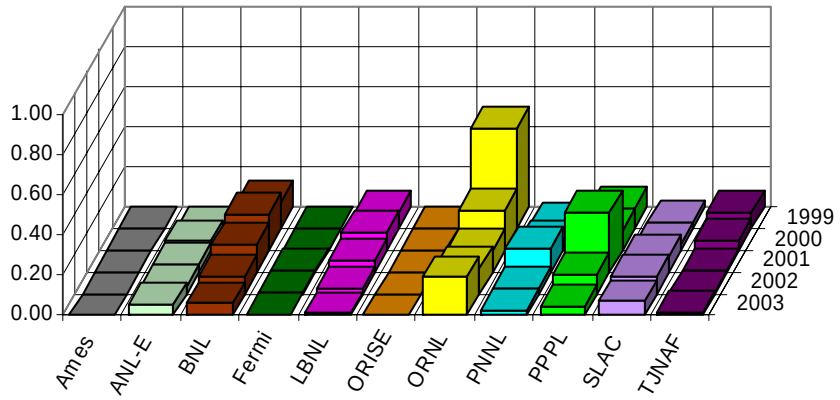
Year	Ames	ANL-E	BNL	Fermi	LBNL	ORISE	ORNL	PNNL	PPPL	SLAC	TJNAF
1999	0	4	3	0	2	2	18	3	0	3	0
2000	0	3	1	0	2	1	10	2	0	0	0
2001	0	6	6	0	1	0	13	0	0	0	0
2002	0	5	1	1	3	1	20	1	0	0	0
2003	0	2	3	0	1	0	18	0	0	0	0
Total	0	20	14	1	9	4	79	6	0	3	0

Environmental Releases of Radionuclides

All DOE facilities are required to demonstrate to the Environmental Protection Agency (EPA) that radionuclides released to air do not cause a dose greater than 10 millirem per year to any member of the public. This standard is found in the National Emission Standards for Hazardous Air Pollutants (NESHAPS) standard 40 CFR 61, Subpart H. This dose of 10 millirem per year is too small to measure because of the much higher natural background radiation (around 300 millirem per year) and must be calculated annually, using EPA-approved computer codes.

Over the past five years the dose to the maximally exposed individual has remained substantially less than one millirem per year at all SC laboratories (see Figure 7). In 2003, the largest dose was at ORNL (0.189 millirem, or about 2 percent of the limit).

Figure 7: NESHAPS dose at SC Laboratories (mrem/yr)



Year	Ames	ANL-E	BNL	Fermi	LBNL	ORISE	ORNL	PNNL	PPPL	SLAC	TJNAF
1999	0.000	0.004	0.130	0.003	0.080	0.000	0.500	0.028	0.100	0.032	0.080
2000	0.000	0.046	0.180	0.005	0.090	0.000	0.200	0.045	0.098	0.032	0.048
2001	0.000	0.036	0.137	0.006	0.060	0.000	0.110	0.120	0.300	0.080	0.011
2002	0.000	0.039	0.086	0.008	0.030	0.000	0.130	0.023	0.100	0.085	0.007
2003	0.000	0.057	0.060	0.007	0.010	0.000	0.189	0.021	0.047	0.070	0.013

In addition to complying with the NESHAPS standard for releases to air, DOE facilities must also comply with the DOE dose limit of 100 millirem per year for members of the public from all pathways (DOE O 5400.5, *Radiation Protection of the Public and the Environment*). Important pathways which are evaluated include releases to both groundwater and surface waters (e.g., drinking water, eating fish, swimming, wading, and shoreline use). Some SC laboratories have outdoor radiological soil contamination from legacy releases which can contribute to the water pathways if the radionuclides migrate from the soil.

Ames Laboratory has not reported any radionuclide releases to groundwater or surface water, or any legacy contamination in soil.

At ANL-E, the only significant location where radionuclides attributable to operations (primarily tritium and strontium-90) have been found in off-site water was Sawmill Creek, below the wastewater outfall. Although this water is not used for drinking purposes, a 50-year effective dose equivalent of 0.022 millirem was calculated in 2003 for a hypothetical individual ingesting all drinking water at the radionuclide concentrations measured at that location.

There are several groundwater tritium plumes at BNL where concentrations exceed the 20,000 picoCuries per liter (pCi/L) drinking water standard. One is associated with the

inactive High Flux Beam Reactor (HFBR), and several others are associated with BNL's accelerator facilities. The portion of the HFBR plume with concentrations exceeding 20,000 pCi/L extends from the HFBR approximately 2,500 feet to the south. Activated soils containing tritium and sodium-22 have been created near a number of BNL's accelerator facilities as the result of secondary particles (primarily neutrons) produced at beam targets and beam stops. Tritium (and lesser amounts of sodium-22) has leached into the groundwater in several of these areas where rainwater had infiltrated into the activated soils. Engineered controls have been put in place to prevent continued rainwater infiltration. There are also several strontium-90 plumes where concentrations exceed the 8 pCi/L drinking water standard. Two are associated with the Waste Concentration Facility and the Brookhaven Graphite Research Reactor (BGRR), which is no longer in operation. Strontium-90 is also routinely detected in groundwater in the former Animal/Chemical Pits/Glass Holes area. There is no radiological dose risk from drinking water because residents adjacent to BNL site get their water from Suffolk County Water Authority. The effective dose equivalent from the air pathway was calculated as 5.96E-2 mrem (0.6 mSv) to the maximally exposed individual. The ingestion pathway dose was estimated as 2.18 mrem from venison consumption and 0.19 mrem from consumption of fish caught at Swan Pond. The total annual dose to the maximally exposed individual from all pathways was estimated as 2.43 mrem for 2003.

Surface water monitoring at Fermilab shows tritium concentrations to be well within the DOE Derived Concentration Guides (DCGs) for allowable radionuclide releases to surface waters, and no radionuclides were detected in samples taken at the site boundary.

Although tritium has been found in the groundwater below Lawrence Berkeley National Laboratory (LBNL), it does not extend offsite and does not contribute to the public dose because there is no exposure pathway.

Oak Ridge Institute for Science and Education (ORISE) has not reported any radionuclide releases to groundwater or surface water or any legacy contamination in soil.

There are large areas of outdoor radiological soil contamination at ORNL from legacy releases. The majority of these releases are from legacy waste disposal and aging underground process waste lines. The major radionuclides are strontium-89, strontium-90, cesium-137, and tritium. Weekly surveys are conducted to measure the dose rate at these outdoor areas. The measured dose rates are typically less than 0.001 mrem/hour, with a maximum around 0.3 mrem/hour. In 2003, the worst-case analysis of public exposure to waterborne radionuclides from ORNL gave a maximum possible individual dose of about 0.0007 millirem for all pathways combined (e.g., drinking water, eating fish, swimming, wading, and shoreline use).

There have not been any known releases of radionuclides to groundwater or surface waters from PNNL that resulted in a significant off-site dose to members of the public. The Hanford Site has legacy soil and groundwater contamination, some of which is located at or near PNNL facilities. However, this contamination is primarily the result of historical Hanford weapons production activities, not PNNL activities.

There had been a substantial tritium inventory at Princeton Plasma Physics Laboratory (PPPL) from 1994-97 for fusion research on the Tokamak Fusion Test Reactor (TFTR). In August 1995, PPPL began to monitor tritium levels in on-site groundwater more comprehensively; all measurements have been well below the EPA drinking water standard and have continued to decrease since the dismantlement of TFTR was completed in 2002.

Tritium exists in minor concentrations in some groundwater at the Stanford Linear Accelerator Center (SLAC). There is no indication that the inventory of tritium in the groundwater exceeds any regulatory limits or is migrating offsite, based on routine monitoring of groundwater wells. Consequently, the groundwater tritium poses negligible potential to affect worker and public environmental doses. Both groundwater and wastewater are regularly monitored and remain well within regulatory limits.

Groundwater samples have been monitored at the Thomas Jefferson National Accelerator Facility (TJNAF) since 1987, and no accelerator-produced activity has been detected.

Laboratory Profile Sheets

The following section is one-page synopses for each of the SC laboratories, briefly discussing their radiological operations and a summary of the occupational radiation exposures for the past five years. Contractual performance measures for radiological control are also noted, including both dose and contamination control, as applicable.

The dose distribution tables are highlighted in color for easier reading and to help facilitate comparison of one laboratory with another. The highlight colors are the same as those used in Figure 4, “Dose Distribution for SC Laboratories” (0-100 mrem is gray, 100-500 mrem is blue, 500-1000 mrem is green, and 1000-2000 mrem is yellow).

Ames Laboratory (Ames)

In 2003, Ames had the second lowest collective dose among all SC laboratories. The radiological work at Ames includes use of x-ray devices, remediation of legacy contamination, stewardship of radioactive materials, and intermittent research involving small amounts of radioactive materials. There are currently 17 x-ray systems and approximately 90 trained x-ray workers. Radioactive materials work has been minimal over the past five years, with primary use consisting of sealed source materials and irradiated metals. A minimal amount of radioactive materials research involving irradiated metals was conducted during 2003. Ames Laboratory radiological activities are subject to a readiness review process and ALARA committee review.

Occupational Radiation Dose Distribution (1999-2003)

Ames — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100-250	250-500	500-750	750 - 1000	1k-2k
1999	109	3	230	77	106	1	2	0	0	0	0
2000	122	13	311	24	109	13	0	0	0	0	0
2001	138	13	174	13	125	13	0	0	0	0	0
2002	135	9	76	8	126	9	0	0	0	0	0
2003	138	21	448	21	117	21	0	0	0	0	0

Contractual Performance Measures for Radiological Control:

Ames uses the average total effective dose equivalent (TEDE) to measure the effectiveness of management commitments to ALARA. The rating is based on the average TEDE per person who received a measurable dose, as follows:

Outstanding = less than 30 millirem
Excellent = 30-42 millirem
Good = more than 42 and less than 79 millirem
Marginal = between 79-91 millirem
Unsatisfactory = more than 91 millirem

Argonne National Laboratory – East (ANL-E)

The collective dose at ANL-E dropped approximately 10 percent in 2003, compared to the previous year. Also, the number of workers with an annual dose exceeding 1,000 millirem dropped from six in 2002 to zero in 2003. The principal dose contributor was the Intense Pulsed Neutron Source (IPNS), with 40 percent of the total collective dose. The Alpha Gamma Hot Cell Facility (AGHCF) improved the shielding on many of their gloveboxes by adding leaded glass to the work areas, which resulted in a 50 percent reduction in dose for manipulator repairs. Also, the AGHCF was in a limited operations mode for approximately four months, due to the work to improve shielding, further reducing the collective dose. Overall AGHCF dose was 15 percent of the ANL-E total; however, this may be expected to increase somewhat in 2004 due to resumption of normal operations, maintenance, and replacement of manipulators.

Occupational Radiation Dose Distribution (1999-2003)

ANL-E — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100-250	250-500	500-750	750-1000	1k-2k
1999	2888	187	24583	131	2701	126	34	14	8	3	2
2000	2824	183	17244	94	2641	140	27	8	5	0	3
2001	2819	187	23033	123	2632	136	32	10	1	1	7
2002	2793	233	23560	101	2560	180	35	10	1	1	6
2003	2370	231	21379	93	2139	159	51	18	3	0	0

Contractual Performance Measures for Radiological Control:

Performance expectations for the Laboratory include the collective dose equivalent to monitored individuals, an index based on the number of radioactive contaminations and contaminated individuals, and other radiological measures. The contract provides that a joint committee of Argonne Site Office (ASO) and ANL representatives appointed by the ASO Manager and the ANL Director, respectively, will review the occupational radiation protection performance measures quarterly and agree on adjustments to performance expectations as necessary to account for changes in the scope of radiological work.

Brookhaven National Laboratory (BNL)

In 2003, the collective dose at BNL was 12 person-rem, down from 26 person-rem the previous year. The decrease was attributable to changes in the experimental program at the Alternating Gradient Synchrotron. In 2002, both high intensity protons for fixed target experiments and polarized protons and heavy ions were accelerated. In 2003, only heavy ions were accelerated for injection into the Relativistic Heavy Ion Collider. Also, in 2003 there were fewer major refit projects which involved entry into the higher radiation areas in the accelerator ring.

Occupational Radiation Dose Distribution (1999-2003)

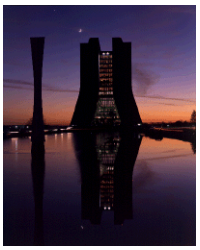
BNL — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100-250	250-500	500-750	750-1000	1k-2k
1999	5653	521	23371	45	5132	453	59	7	2	0	0
2000	5484	430	22384	52	5054	363	57	8	2	0	0
2001	5048	387	14627	38	4661	351	28	8	0	0	0
2002	4672	439	26244	60	4233	368	48	15	5	3	0
2003	4135	306	12183	40	3829	273	29	3	1	0	0

Contractual Performance Measures for Radiological Control:

Performance measures are in place for implementing the site-wide rollout of the radiological source inventory database in FY 2004. There are no specific ALARA collective dose goals in the contract for FY 2004. The draft performance measures for FY 2005 define an effective ALARA program as comprised of dose goals and administrative control levels that are challenging and consider both historical exposures and planned operations, is supportive of changes to those goals when operating assumptions change, communicates ALARA initiatives that help to optimize radiological exposures, and ensures dose is shared among all qualified workers.

Fermi National Accelerator Laboratory (Fermilab)



During 2003, the collective dose at Fermilab increased to approximately 26 person-rem, up from 13 person-rem the previous year. The increase was largely attributable to two shutdowns of the accelerators for upgrades, maintenance, and repair work. The primary goals of these shutdowns were improved accelerator performance and the reduction of future radiation exposures through better component design and improved reliability. For example, work at the Booster synchrotron was aimed at reducing beam losses, which will reduce radioactivation of components, residual radiation in the enclosures, and subsequently personnel exposures for those who must maintain the accelerators in the future.

During the shutdowns, job-specific ALARA planning for each major task was conducted, and some tasks that were "high dose" were deferred to the latter portion of the shutdown in order to take advantage of radioactive decay to reduce the radiation levels. Although these improvement projects raised the collective dose in 2003, the long term benefits include the reduction of exposures in the future because of increased reliability in the Booster's performance.

The Fermilab research program expanded by adding renewed fixed target operations supporting the neutrino physics experiment MiniBooNE as well as a limited scope 120 GeV fixed target physics research program. Also, the luminosity for the Run II Tevatron Collider Program was increased greatly.

Occupational Radiation Dose Distribution (1999-2003)

Fermi — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100-250	250-500	500-750	750-1000	1k-2k
1999	1051	227	8740	39	824	211	13	2	0	0	1
2000	1361	406	12340	30	955	390	14	1	1	0	0
2001	1344	368	10650	29	976	352	13	3	0	0	0
2002	1424	389	12790	33	1035	363	21	5	0	0	0
2003	1879	612	25670	42	1267	556	43	10	3	0	0

Contractual Performance Measures for Radiological Control:

Performance measures are in place with respect to TEDE which are based on the fiscal year and include a time delay to accommodate badge processing. In 2003, an adjectival rating of Excellent was achieved for this measure.

Lawrence Berkeley National Laboratory (LBNL)

In 2003, LBNL continued to have the lowest collective dose among the five SC multi-program laboratories. Radiological work includes research in life sciences and physical sciences involving small amounts of radioactive materials and closure activities at the former Bevatron accelerator. The laboratory has a number of policies within the framework of Integrated Safety Management that contribute to maintaining occupational radiation doses ALARA. Radiation safety professionals perform a "walk down" on any operation that yields a dosimeter reading exceeding 50 millirem to any worker. Also, the LBNL Radiation Safety Committee (RSC) meets quarterly, and the "top 5" worker doses are reviewed to ensure that the doses are commensurate with the work performed. The RSC also evaluates dose trends for each building.

The collective dose from the 88-inch Cyclotron has been reduced from 1.0 person-rem in 1998 to 0.07 person-rem in 2003 and continues to contribute less than 10 percent of the site total. Radiopharmaceutical development and functional imaging with positron emission tomography represent areas of growth in radiological work with increasing numbers of research protocols.

Occupational Radiation Dose Distribution (1999-2003)

LBNL — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100-250	250-500	500-750	750-1000	1k-2k
1999	1781	46	1822	40	1735	41	5	0	0	0	0
2000	1835	44	1114	25	1791	42	2	0	0	0	0
2001	1694	21	682	32	1673	21	0	0	0	0	0
2002	1538	33	895	27	1505	32	1	0	0	0	0
2003	1384	20	1037	52	1364	17	2	1	0	0	0

Contractual Performance Measures for Radiological Control:

An Outstanding rating requires that the number of individual exposures exceeding 100 millirem must be less than or equal to the control level of 10, plus the average individual positive dose is less than the control level of 50 millirem, all without an increase in workload.

The LBNL performance measure for reportable occurrences of personnel contamination provides an Outstanding rating for a weighted number of contaminated individuals less than or equal to 4.0 (with unusual occurrences having a weighting factor of 1.5, and off-normal at 1.0). The performance measure for control of radioactive material and spread of contamination provides an Outstanding rating for 2.0 or less weighted occurrences (with unusual occurrences using a weighted factor of 1.5 and off-normals 1.0).

Oak Ridge Institute for Science and Education (ORISE)

In 2003, ORISE had the lowest number of monitored employees and the lowest collective dose for all SC laboratories. For the last five years, ORISE has never had a worker with a dose exceeding 100 millirem. The only sources of radiological exposure are some sealed sources for calibration and some environmental samples for analysis.

Occupational Radiation Dose Distribution (1999-2003)

ORISE — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100-250	250-500	500-750	750-1000	1k-2k
1999	48	8	42	5	40	8	0	0	0	0	0
2000	94	58	299	5	36	58	0	0	0	0	0
2001	87	55	327	6	32	55	0	0	0	0	0
2002	99	69	274	4	30	69	0	0	0	0	0
2003	89	59	289	5	30	59	0	0	0	0	0

Contractual Performance Measures for Radiological Control:

A performance measure is in place for worker radiation dose to assess the effectiveness of the ORISE personnel exposure program and to document that the ALARA Program is in place and active. The average ORISE employee occupational dose is calculated by dividing the collective total effective dose equivalent for all monitored ORISE employees by the total number of employees with a measurable dose. A rating of Meets Expectation is assessed for the quarter if the average dose falls below 10 millirem, and a rating of Does Not Meet Expectation is assessed if the average exceeds 10 millirem.

Oak Ridge National Laboratory (ORNL)

In 2003, the collective dose at ORNL increased slightly, from 27 person-rem in 2002 to 29 person-rem in 2003. The increase in dose was attributable to clean up efforts associated with a spill of liquid radioactive waste in Building 2026 in October 2003. That incident resulted in a dose of 312 mrem to a facility supervisor and 1320 mrem to a radiological control technician.

The major contribution to the collective dose at ORNL is the work at the Radiochemical Engineering Development Center (REDC) and the HFIR. The collective dose at ORNL will remain a challenge because of future projects and activities, including the return of liquid and gaseous waste operations to ORNL, continued cleanup of legacy radioactive materials, and the operation of the Spallation Neutron Source. There is an ALARA Steering Committee and an ALARA Working Committee which discuss ongoing projects and share lessons learned on dose reductions. The ALARA awards are routinely presented to employees who develop methods of reducing dose for particular jobs.

Occupational Radiation Dose Distribution (1999-2003)

ORNL — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100-250	250-500	500-750	750-1000	1k-2k
1999	6159	506	43740	86	5653	376	89	28	9	2	2
2000	5954	371	35848	97	5583	258	77	27	8	1	0
2001	5345	389	47039	121	4956	255	73	43	14	4	0
2002	5995	354	27046	76	5641	273	55	22	4	0	0
2003	6562	375	28591	76	6187	296	52	22	4	0	1

Contractual Performance Measures for Radiological Control:

Performance measures are in place for both worker radiation dose and radiological operations. The measure for worker radiation dose is based on the average measurable dose; ratings range from Outstanding for 90 millirem or less, to Marginal for more than 110 millirem.

The radiological operations measure is based on five factors:

- the number of radiological workers that exceed their ORNL ALARA goal by five percent
- the number of radiological workers exceeding 30 percent of any dose limit in 10 CFR 835
- the number of occurrences for radiation exposure
- the number of occurrences for personnel contamination
- loss of control of radioactive material or spread of contamination

Pacific Northwest National Laboratory (PNNL)

In 2003, the collective dose at PNNL increased slightly, from 18 person-rem in 2002 to 20 person-rem in 2003. Nearly all of the increase in dose from 2002 to 2003 is from Radiochemical Processing Laboratory (RPL) workers, which represents over 80 percent of the total laboratory dose. The dose increase from the RPL correlates to projects involving decontamination of nuclear power reactor control rod drive mechanisms and Hanford Site cleanup activities. The PNNL collective dose was planned within less than two percent of the PNNL ALARA Committee target for collective dose.

In 2003, there were four staff with doses between 750 and 1000 mrem. The doses for the four staff range between 809 and 877 mrem, each below the PNNL radiological program limit of 2000 mrem, and well below the regulatory limit of 5000 mrem.

Occupational Radiation Dose Distribution (1999-2003)

PNNL — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100-250	250-500	500-750	750-1000	1k-2k
1999	1609	236	15569	66	1373	190	30	15	1	0	0
2000	1396	174	15378	88	1222	133	20	18	3	0	0
2001	1474	207	17639	85	1267	160	29	15	3	0	0
2002	1788	212	17690	83	1576	168	21	19	2	2	0
2003	2067	218	20407	94	1849	166	31	11	6	4	0

Contractual Performance Measures for Radiological Control:

Performance measures were in place in FY 2003 to manage spread of radioactive contamination. There was zero spread of radioactive contamination events during this rating period.

Princeton Plasma Physics Laboratory (PPPL)

The collective dose at PPPL decreased last year, from 3.7 person-rem in 2002 to 0.6 person-rem in 2003. With the completion of the TFTR D&D project (1999-2002), PPPL worker exposures have returned to levels that were typically experienced prior to commencement of the TFTR removal work.

Occupational Radiation Dose Distribution (1999-2003)

PPPL — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100-250	250-500	500-750	750-1000	1k-2k
1999	406	34	817	24	372	33	1	0	0	0	0
2000	466	59	2941	50	407	51	8	0	0	0	0
2001	484	108	7420	69	376	87	11	9	1	0	0
2002	426	145	3707	26	281	130	15	0	0	0	0
2003	348	111	593	5	237	111	0	0	0	0	0

Contractual Performance Measures for Radiological Control:

Performance measures are in place for both collective dose and personnel contamination control. A TEDE of 0-4 person-rem for routine operations and 0-8 person-rem for D&D is rated as Outstanding.

A total of zero contamination events is rated as Outstanding. Contamination events are defined as the number of ORPS-reportable skin or clothing contamination events (excluding protective clothing contamination).

Stanford Linear Accelerator Center (SLAC)

The collective dose at SLAC increased slightly to 3.1 person-rem, up from 3.0 person-rem the previous year. The increase was attributable to an increased beamline power level and operation time, as compared to the previous year. Overall, the dose remains small and well below previous years.

The majority of the worker dose comes from maintenance activities. In 1997, SLAC began replacing original beamline equipment, which was slightly activated after 20 years of use. Replacing the aged, activated equipment has helped reduce radiation exposures overall; the collective dose at SLAC has dropped every year for the last five years.

In 2000, SLAC experienced an unexpectedly large number of small positive doses (most less than 10 millirem) for some workers who normally receive no measurable dose. The results could not be attributed to any known exposures or quality control problems, and a new dosimetry system was instituted. As a result, the number of workers with doses below 100 millirem decreased.

Occupational Radiation Dose Distribution (1999-2003)

SLAC — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100-250	250-500	500-750	750-1000	1k-2k
1999	2493	104	10192	98	2389	78	17	7	2	0	0
2000	2424	489	5464	11	1935	483	6	0	0	0	0
2001	3155	35	1368	39	3120	32	3	0	0	0	0
2002	2676	79	3075	39	2597	76	1	2	0	0	0
2003	3023	109	3127	29	2914	106	3	0	0	0	0

Contractual Performance Measures for Radiological Control:

Performance measures are in place for unplanned radiation exposures and personnel contamination control. An Outstanding rating requires no occurrences of ORPS-reportable radiation doses or contamination. An unplanned radiation exposure includes a dose in excess of 100 millirem/year to nonradiological workers.

Thomas Jefferson National Accelerator Facility (TJNAF)

The collective dose at TJNAF dropped slightly last year, from 1.11 person-rem in 2002 to 0.99 person-rem in 2003. The number of workers with a measurable dose increased from 34 in 2002 to 39 in 2003. It should be noted that the bulk of the collective dose at TJNAF is obtained by performing maintenance in the High Power Beam Dump Enclosures. In 2003, six of the seven highest individual doses were attributable to work performed in these areas. These doses, in turn, accounted for approximately 40 percent of the collective dose total for TJNAF in 2003. Approximately two-thirds of the monitored individuals at TJNAF are visitors.

There is a "Level of Concern" set at 60 millirem per quarter; any individual dose exceeding this level triggers an ALARA review. Additionally, any individual who receives a total dose exceeding 50 mrem in a six month period, either through analysis of supplementary dosimetry used in conjunction with a Radiation Work Permit or through Thermo Luminescent Dosimeter (TLD) badge readings, is placed on a monthly TLD badge frequency for the remainder of the monitoring year. This enables closer monitoring for individuals who may be approaching administrative alert levels.

Occupational Radiation Dose Distribution (1999-2003)

TJNAF — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100-250	250-500	500-750	750-1000	1k-2k
1999	1454	45	1370	30	1409	43	2	0	0	0	0
2000	1492	67	1616	24	1425	66	1	0	0	0	0
2001	1625	89	2317	26	1536	87	2	0	0	0	0
2002	1583	34	1113	33	1549	30	4	0	0	0	0
2003	1406	39	992	25	1367	38	1	0	0	0	0

Contractual Performance Measures for Radiological Control:

Performance measures are in place for the number of reportable and recordable exposures to radiation as off-normal occurrences; this measure weights unusual occurrences by a factor of five.

Another measure requires a peer review of the Radiological Control Program in even-numbered fiscal years.