SEC Petition Evaluation Report
Petition SEC-00113

Report Rev #: 0 Report Submittal Date: September 29, 2009

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Site Expert(s):	N/A

Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Petition Qualification Date	DOE/AWE Facility Name
SEC-00113	83.13	June 27, 2008	Brookhaven National Laboratory

Petitioner Class Definition

All employees who worked in any area at the Brookhaven National Laboratory from January 1, 1947 through December 31, 2007.

Class Evaluated by NIOSH

All employees who worked in any area at the Brookhaven National Laboratory from January 1, 1947 through December 31, 2007.

NIOSH-Proposed Class(es) to be Added to the SEC

All employees of the Department of Energy, its predecessor agencies, and its contractors and subcontractors who worked at Brookhaven National Laboratory in Upton, New York, from January 1, 1947 to December 31, 1979, for a number of work days aggregating at least 250 work days, occurring either solely under this employment, or in combination with work days within the parameters established for one or more other classes of employees in the Special Exposure Cohort.

Related Petition Summary Information

SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
None			

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
None	

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Evaluation Report Summary: SEC-00113
Brookhaven National Laboratory

This evaluation report by the National Institute for Occupational Safety and Health (NIOSH) addresses a class of employees proposed for addition to the Special Exposure Cohort (SEC) per the *Energy Employees Occupational Illness Compensation Program Act of 2000*, as amended, 42 U.S.C. § 7384 *et seq.* (EEOICPA) and 42 C.F.R. pt. 83, *Procedures for Designating Classes of Employees as Members of the Special Exposure Cohort under the Energy Employees Occupational Illness Compensation Program Act of 2000*.

Petitioner-Requested Class Definition

Petition SEC-00113, qualified on June 27, 2008, requested that NIOSH consider the following class: *All employees who worked in any area at the Brookhaven National Laboratory from January 1, 1947 through December 31, 2007.*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH accepted the petitioner-requested class. NIOSH evaluated the following class: All employees who worked in any area at the Brookhaven National Laboratory from January 1, 1947 through December 31, 2007.

NIOSH-Proposed Class(es) to be Added to the SEC

Based on its full research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all employees of the Department of Energy, its predecessor agencies, and its contractors and subcontractors who worked at Brookhaven National Laboratory in Upton, New York, from January 1, 1947 to December 31, 1979, for a number of work days aggregating at least 250 work days, occurring either solely under this employment, or in combination with work days within the parameters established for one or more other classes of employees in the Special Exposure Cohort. The class under evaluation was reduced (see Section 3.0 below) because sufficient monitoring data are available to estimate exposures with sufficient accuracy for all workers employed beginning January 1, 1980.

Feasibility of Dose Reconstruction

NIOSH finds it is not feasible to estimate internal exposures with sufficient accuracy for all workers at the site from January 1, 1947 through December 31, 1979. Though NIOSH has found documentation indicating that the appropriate monitoring practices were conducted during the specified time period, historical data management and data retention practices prevent NIOSH from confirming the current retrievability of the data necessary to estimate doses for members of the class. With the exception of this class, per EEOICPA and 42 C.F.R. § 83.13(c)(1), NIOSH has established that it has access to sufficient information to: (1) estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class; or (2) estimate radiation doses of members of the class more precisely than an estimate of maximum dose. Information available from the site profile and additional resources is sufficient to document or estimate the maximum internal and external potential exposure to members of the proposed class under plausible circumstances beginning January 1, 1980.

Health Endangerment Determination

Per EEOICPA and 42 C.F.R. § 83.13(c)(3), a health endangerment determination is required because NIOSH has determined that it does not have sufficient information to estimate dose for the members of the proposed class from January 1, 1947 through December 31, 1979.

NIOSH did not identify any evidence supplied by the petitioners or from other resources that would establish that the proposed class was exposed to radiation during a discrete incident likely to have involved exceptionally high-level exposures. However, evidence indicates that some workers in the proposed class may have accumulated substantial chronic exposures through episodic intakes of radionuclides, combined with external exposures to gamma, beta, and neutron radiation. Consequently, NIOSH has determined that health was endangered for those workers covered by this evaluation who were employed for at least 250 aggregated work days either solely under their employment or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

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SEC Petition Evaluation Report for SEC-00113

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all employees who worked in any area at the Brookhaven National Laboratory from January 1, 1947 through December 31, 2007. It provides information and analyses germane to considering a petition for adding a class of employees to the congressionally-created SEC.

This report does not make any determinations concerning the feasibility of dose reconstruction that necessarily apply to any individual energy employee who might require a dose reconstruction from NIOSH. This report also does not contain the final determination as to whether the proposed class will be added to the SEC (see Section 2.0).

This evaluation was conducted in accordance with the requirements of EEOICPA, 42 C.F.R. pt. 83, and the guidance contained in the Office of Compensation Analysis and Support's (OCAS) *Internal Procedures for the Evaluation of Special Exposure Cohort Petitions*, OCAS-PR-004.

2.0 Introduction

Both EEOICPA and 42 C.F.R. pt. 83 require NIOSH to evaluate qualified petitions requesting that the Department of Health and Human Services (HHS) add a class of employees to the SEC. The evaluation is intended to provide a fair, science-based determination of whether it is feasible to estimate with sufficient accuracy the radiation doses of the class of employees through NIOSH dose reconstructions.[1]

42 C.F.R. § 83.13(c)(1) states: *Radiation doses can be estimated with sufficient accuracy if NIOSH has established that it has access to sufficient information to estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class, or if NIOSH has established that it has access to sufficient information to estimate the radiation doses of members of the class more precisely than an estimate of the maximum radiation dose.*

Under 42 C.F.R. § 83.13(c)(3), if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, then NIOSH must determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class The regulation requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an

[1] NIOSH dose reconstructions under EEOICPA are performed using the methods promulgated under 42 C.F.R. pt. 82 and the detailed implementation guidelines available at http://www.cdc.gov/niosh/ocas.

exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for at least 250 aggregated work days within the parameters established for the class or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

NIOSH is required to document its evaluation in a report, and to do so, relies upon both its own dose reconstruction expertise as well as technical support from its contractor, Oak Ridge Associated Universities (ORAU). Once completed, NIOSH provides the report to both the petitioner(s) and to the Advisory Board on Radiation and Worker Health (Board). The Board will consider the NIOSH evaluation report, together with the petition, petitioner(s) comments, and other information the Board considers appropriate, in order to make recommendations to the Secretary of HHS on whether or not to add one or more classes of employees to the SEC. Once NIOSH has received and considered the advice of the Board, the Director of NIOSH will propose a decision on behalf of HHS. The Secretary of HHS will make the final decision, taking into account the NIOSH evaluation, the advice of the Board, and the proposed decision issued by NIOSH. As part of this decision process, petitioners may seek a review of certain types of final decisions issued by the Secretary of HHS.[2]

3.0 SEC-00113 Brookhaven National Laboratory Class Definitions

The following subsections address the evolution of the class definition for SEC-00113, Brookhaven National Laboratory (BNL). When a petition is submitted, the requested class definition is reviewed as submitted. Based on its review of the available site information and data, NIOSH will make a determination whether to qualify for full evaluation all, some, or no part of the petitioner-proposed class. If some portion of the petitioner-proposed class is qualified, NIOSH will specify that class along with a justification for any modification of the petitioner's class. After a full evaluation of the qualified class, NIOSH will determine whether to propose a class for addition to the SEC and will specify that proposed class definition.

3.1 Petitioner-Requested Class Definition and Basis

Petition SEC-00113, qualified on June 27, 2008, requested that NIOSH consider the following class for addition to the SEC: All employees who worked in any area at the Brookhaven National Laboratory from January 1, 1947 through December 31, 2007.

The petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the BNL workers in question. NIOSH deemed the following information and affidavit statements sufficient to qualify SEC-00113 for evaluation:

[2] See 42 C.F.R. pt. 83 for a full description of the procedures summarized here. Additional internal procedures are available at http://www.cdc.gov/niosh/ocas.

> "To the best of my knowledge there was no internal monitoring for some individuals at Brookhaven National Laboratory and insufficient internal monitoring for the class in the early 1980's."

Based on its BNL research and data capture efforts, NIOSH determined that it has access to internal and external monitoring data for BNL workers during the time period under evaluation. However, NIOSH could not establish that internal records are available for all time periods. NIOSH concluded that there is sufficient documentation to support, for at least part of the proposed time period, the petition basis that internal personal monitoring or area monitoring radiation dose records may have been lost or were otherwise not retrievable from BNL, supporting an F2 petition basis. The information and statements provided by the petitioner qualified the petition for further consideration by NIOSH, the Board, and HHS. The details of the petition basis are addressed in Section 7.4.

3.2 Class Evaluated by NIOSH

Based on its preliminary research, NIOSH accepted the petitioner-proposed class. Therefore, NIOSH defined the following class for further evaluation: All employees who worked in any area at the Brookhaven National Laboratory from January 1, 1947 through December 31, 2007.

3.3 NIOSH-Proposed Class(es) to be Added to the SEC

Based on its research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class to be added to the SEC includes all employees of the Department of Energy, its predecessor agencies, and its contractors and subcontractors who worked at Brookhaven National Laboratory in Upton, New York, from January 1, 1947 to December 31, 1979, for a number of work days aggregating at least 250 work days, occurring either solely under this employment, or in combination with work days within the parameters established for one or more other classes of employees in the Special Exposure Cohort.

4.0 Data Sources Reviewed by NIOSH to Evaluate the Class

NIOSH identified and reviewed numerous data sources to determine information relevant to determining the feasibility of dose reconstruction for the class of employees under evaluation. This included determining the availability of information on personal monitoring, area monitoring, industrial processes, and radiation source materials. The following subsections summarize the data sources identified and reviewed by NIOSH.

4.1 Site Profile Technical Basis Documents (TBDs)

A Site Profile provides specific information concerning the documentation of historical practices at the specified site. Dose reconstructors can use the Site Profile to evaluate internal and external dosimetry data for monitored and unmonitored workers, and to supplement, or substitute for, individual monitoring data. A Site Profile can consist of an Introduction and five Technical Basis Documents (TBDs) that provide process history information, information on personal and area monitoring, radiation source descriptions, and references to primary documents relevant to the radiological operations at the site. The BNL Site Profile consists of a single document. As part of NIOSH's evaluation detailed herein, it examined the following TBD for insights into BNL operations or related topics/operations at other sites:

- *Summary Site Profile Document for the Brookhaven National Laboratory,* ORAUT-TKBS-0048; Rev. 00; August 30, 2006; SRDB Ref ID: 30090.

4.2 ORAU Technical Information Bulletins (OTIBs) and Procedures

An ORAU Technical Information Bulletin (OTIB) is a general working document that provides guidance for preparing dose reconstructions at particular sites or categories of sites. An ORAU Procedure provides specific requirements and guidance regarding EEOICPA project-level activities, including preparation of dose reconstructions at particular sites or categories of sites. NIOSH reviewed the following OTIBs and procedures as part of its evaluation:

- *OTIB: Interpretation of Dosimetry Data for Assignment of Shallow Dose*, ORAUT-OTIB-0017, Rev. 01; October 11, 2005; SRDB Ref ID: 19434

- *OTIB: Analysis of Coworker Bioassay Data for Internal Dose Assignment*, ORAUT-OTIB-0019, Rev. 00; December 29, 2004; SRDB Ref ID: 19439

- *OTIB: Estimating Doses for Plutonium Strongly Retained in the Lung*, ORAUT-OTIB-0049, Rev. 00; February 6, 2007; SRDB Ref ID: 29975

- *OTIB: Internal Dose Reconstruction*, ORAUT-OTIB-0060, Rev. 00; February 6, 2007; SRDB Ref ID: 29984

- *PROC: Occupational Onsite Ambient Dose Reconstruction for DOE Sites*, ORAUT-PROC-0060, Rev. 01; June 28, 2006; SRDB Ref ID: 29986

- *PROC: Occupational X-Ray Dose Reconstruction for DOE Sites*, ORAUT-PROC-0061, Rev. 02; January 2, 2008; SRDB Ref ID: 39338

4.3 Facility Employees and Experts

To obtain additional information, NIOSH interviewed nine current or former BNL employees. SC&A, Inc., a contractor for the EEOICPA Advisory Board on Radiation and Worker Health, also conducted interviews.

- Personal Communication, 2008a, *Personal Communication with Health Physics Manager*, Telephone Interview by ORAU Team; November 21, 2008; SRDB Ref ID: 65829
- Personal Communication, 2008b, *Personal Communication with Health Physics Group Leader*, Telephone Interview by ORAU Team; November 21, 2008; SRDB Ref ID: 65836
- Personal Communication, 2008c, *Personal Communication with Health Physics Manager*, Telephone Interview by ORAU Team; December 11, 2008; SRDB Ref ID: 65827
- Personal Communication, 2008d, *Personal Communication with Health Physics Manager*, Telephone Interview by ORAU Team; December 12, 2008; SRDB Ref ID: 65831
- Personal Communication, 2008e, *Personal Communication with Health Physics Manager*, Telephone Interview by ORAU Team; December 12, 2008; SRDB Ref ID: 65832
- Personal Communication, 2009a, *Personal Communication with Custodian*, Telephone Interview by ORAU Team; January 15, 2009; SRDB Ref ID: 65826
- Personal Communication, 2009b, *Personal Communication with Carpenter*, Telephone Interview by ORAU Team; January 21, 2009; SRDB Ref ID: 65825
- Personal Communication, 2009c, *Personal Communication with Machinist, Pile Operator, Reactor Operator*, Telephone Interview by ORAU Team; January 29, 2009; SRDB Ref ID: 65844
- Personal Communication, 2009d, *Personal Communication with Plumber, Superintendent*, Telephone Interview by ORAU Team; February 5, 2009; SRDB Ref ID: 65840
- Personal Communication, 2009e, *Personal Communication with Three Former BNL Employees*; Interview by SC&A; May 19, 2009; SRDB Ref ID: 71451

4.4 Previous Dose Reconstructions

NIOSH reviewed its NIOSH OCAS Claims Tracking System (NOCTS) to locate EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. Table 4-1 summarizes the results of this review. (NOCTS data available as of September 10, 2009)

Table 4-1: No. of BNL Claims Submitted Under the Dose Reconstruction Rule	
Description	**Totals**
Total number of claims submitted for dose reconstruction	92
Total number of claims submitted for energy employees who meet the definition criteria for the class under evaluation (January 1, 1947 through December 31, 2007).	92
Number of dose reconstructions completed for energy employees who meet the definition criteria for the class under evaluation (i.e., the number of such claims completed by NIOSH and submitted to the Department of Labor for final approval).	28
Number of claims for which internal dosimetry records were obtained for the identified years in the evaluated class definition	21
Number of claims for which external dosimetry records were obtained for the identified years in the evaluated class definition	43

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. NIOSH has been able to obtain monitoring data for some of the claims that meet the class definition. Of the total of 92 claims submitted for energy employees who meet the class definition under evaluation, BNL/DOE has responded to 64. Of these 64 claims, BNL/DOE has indicated that “there is no record of [internal] measurements having been made” for 61 claimants. The remaining three have tritium dose data from the Landauer records during the 1985-1995 time frame. As of this writing, an additional 18 claimant’s files now contain some internal dosimetry data. Internal data found for these 18 claimants resulted from NIOSH data capture efforts conducted during the course of this evaluation. Five of these 18 are for cases not yet responded to by BNL.

Of the 64 claims receiving BNL/DOE responses, 43 (67%) contain external monitoring data. The other 21 responses specifically state that no records exist for the claimant. These 21 were in job categories that would not have been expected to have been monitored, such as secretary, ground water scientist, environmental survey sampler, design engineer, helicopter pilot, and iron worker.

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database (SRDB) to locate documents supporting the evaluation of the proposed class. As of September 10, 2009, there are over 2800 documents in this database pertaining to BNL. These documents were evaluated for their relevance to this petition. The documents include historical background on external and internal dosimetry programs and evaluations, monitoring summary reports, annual environmental reports, reviews and assessments of BNL, evaluations of specific buildings, site surveys, and facility and process descriptions.

4.6 Documentation and/or Affidavits Provided by Petitioners

In qualifying and evaluating the petition, NIOSH reviewed the following documents submitted by the petitioners:

- *SEC Petition Form B*; [name redacted]; May 6, 2008; OSA Ref ID: 105908
- *Affidavit from Survivor*; May 6, 2008; OSA Ref ID: 105908

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

The following subsections summarize both radiological operations at BNL from January 1947 to December 2007 and the information available to NIOSH to characterize particular processes and radioactive source materials. From available sources NIOSH has gathered information regarding the identity and quantities of each radionuclide of concern, and information describing processes through which radiation exposures may have occurred and the physical environment in which they may have occurred. The information included within this evaluation report is intended only to be a summary of the available information.

5.1 BNL Plant and Process Descriptions

ATTRIBUTION: Section 5.1 and its related subsections were completed by Lori Arent, M. H. Chew & Associates, Inc. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

BNL was founded in 1947 at Upton, Long Island, New York, under a contract between the U.S. Atomic Energy Commission (AEC) and Associated Universities, Inc. (AUI). BNL was established to provide facilities for scientific research and remains in operation (see Figure 5-1). The site was formerly Camp Upton and was used by the Army during World Wars I and II.

BNL's early research focused on advanced physics, but expanded into its current suite of research in the fields of medicine, biology, chemistry, physics, materials science, nuclear engineering, and environmental research. BNL was organized into departments that provided research nuclear reactors, particle accelerators, and engineering facilities in support of the Biology, Chemistry, Physics, Medical, Applied Science, Accelerator, and Applied Mathematics Departments (ORAUT-TKBS-0048). BNL activities have been well-documented over the years and detailed descriptions are generally available in the public domain. As of September 10, 2009, NIOSH has gathered and reviewed over 2800 documents pertaining to BNL from a variety of sources. Due to the large amount of information available for the sixty years of BNL work under evaluation, only brief summaries of the available information are provided within this report.

Figure 5-1: Aerial view of Brookhaven National Laboratory.

Research Reactors

BNL's reactor operations began in 1950 with the Brookhaven Graphite Research Reactor (BGRR), a research reactor used for peaceful scientific exploration in the fields of medicine, biology, chemistry, physics, and nuclear engineering. The BGRR operated until 1968. In 1965, its capacity was surpassed by the High Flux Beam Reactor (HFBR). The higher thermal neutron fluence of the HFBR permitted shorter irradiation times and expanded support for researchers of all disciplines, from solid state physics to art history. The HFBR ceased operations in December

1996. BNL also designed and built critical assemblies (i.e., equipment and fissionable material engineered to achieve very low-power self-sustaining barely-critical nuclear chain reactions).

Medical Research Center

Medical research at BNL began in 1950 with the opening of one of the first hospitals devoted to nuclear medicine. It was followed by the Medical Research Center (MRC) in 1958 and the Brookhaven Medical Research Reactor (BMRR) in 1959. The first nuclear reactor built exclusively for medical and biological research, the BMRR came on line on March 15, 1959 and operated until October 2000.

The Radiation Therapy Facility (RTF)

The Radiation Therapy Facility (RTF) is operated jointly by the BNL Medical Department and the State University of New York at Stony Brook. The RTF is a high-energy dual X-ray mode linear accelerator (LINAC) used for the radiation therapy of cancer patients. This accelerator was designed to deliver therapeutic beams of X-rays and electrons for conventional and advanced radiotherapy techniques. This facility began providing therapy in 1991 and is currently operational.

Particle Accelerators

High-energy particle physics research began in 1952 with the Cosmotron, the first particle physics accelerator to achieve billion-electron-volt energies. The Cosmotron operated from 1953 to 1966. In 1960, the Alternating Gradient Synchrotron (AGS), a large accelerator, was built to surpass the Cosmotron's capabilities. The AGS is capable of accelerating protons to energies up to 30 GeV and heavy ion beams to 15 GeV/amu. The AGS achieved full energy in 1960 and is still in use.

Between 1967 and 1970, the Tandem Van de Graaff, 60-inch Cyclotron, and Vertical Accelerator were used for medium-energy physics investigations and for special isotope production. The heavy ions from the Tandem Van de Graaff can also be injected into the AGS for physics experiments. The Tandem Van de Graaff began operating in 1970 and continues to the present.

The Heavy Ion Transfer tunnel connects the coupled Tandem Van de Graaff and the AGS. The interconnection of these two facilities permits intermediate mass ions to be injected into the AGS where they can be accelerated to an energy of 15 GeV/amu. These ions then are extracted and sent to the AGS experimental area for physics research. The AGS Booster is a circular accelerator with a circumference of 200 meters that receives either a proton beam from LINAC or heavy ions from the Tandem Van de Graaff. The Booster accelerates proton particles and heavy ions before injecting them into the AGS ring. The Booster receives protons and heavy ions from the LINAC and Tandem Van de Graaff Facilities to increase their intensity for delivery to the AGS.

The Brookhaven LINAC Isotope Producer (BLIP) became operational in 1973. Protons from the LINAC are sent via an underground beam tunnel to the BLIP facility where they strike various target metals. These metals, which become activated by the proton beam, are then processed at the Target Processing Laboratory for use in radiopharmaceutical development and production. The targets are cooled by a continuously-recirculating water system. The BLIP facility underwent significant upgrades in 1996 in support of the Brookhaven Isotope Research Center (BIRC) program. The 200 MeV Proton Linear Accelerator serves as a proton injector for the AGS and also supplies a continuous beam of protons for radionuclide production by spallation reactions in the BLIP.

In 1982, the National Synchrotron Light Source (NSLS) began operation. The NSLS guides charged particles in an orbit. As the electrons spin inside a hollow donut-shaped tube called an electron storage ring, they give off light called synchrotron light. This light, which can be detected by specialized instruments, is used to study the properties of matter. The NSLS utilizes a linear accelerator and booster synchrotron as an injection system for two electron storage rings that operate at energies of 750 MeV vacuum ultraviolet (VUV), and 2.5 GeV (X-ray). The synchrotron radiation produced by their stored electrons is used for VUV spectroscopy and for X-ray diffraction studies.

Brookhaven's newest accelerator facility is the Relativistic Heavy Ion Collider (RHIC), completed in 1999. The RHIC is designed to recreate a state of matter that scientists believe existed moments after the universe was formed.

Department of Applied Science/Nuclear Energy

The Target Processing Laboratory (also called the Hot Laboratory in 1993) officially opened on January 15, 1951, and is still in use today. The original purpose of the central facility was to provide appropriately shielded areas for research with large amounts of radioactive material. The "hot" area of the Hot Laboratory included five hot cells, three chemical-processing hot cells, and three high-level hot cells for handling and processing radioactivity in gaseous, liquid, or solid form.

The High Intensity Radiation Development Laboratory (HIRDL), which contained (in the early 1970s) a million-curie range of Co-60 and Cs-137 sources, was used for source development and experimental process irradiations. A Co-60 pool in the HIRDL facility operated at lower activity levels into the 1990s. Currently, very little mission-specific work is occurring within the HIRDL.

Waste Management

Waste management has been intrinsic to BNL from the beginning of operations. In late 1949, the Health Physics & Safety Summary Monthly reports began to include a section titled "Waste Disposal" or "Waste Disposal and Reclamation," and later, "Waste Management." The group was composed of Safety and Environmental Protection (S&EP) personnel assisted by personnel from the Maintenance Department. The S&EP personnel remained quite constant over time as seen in organizational charts captured from the site (BNL, 1960-1966). This reference shows the same six individuals employed in this group from 1960-66, with a seventh individual added in

1963. Several of these individuals were still apparently working in waste management decades later.

The group began with monitoring the liquid waste discharges. The Waste Disposal Group operated an incinerator in 1949 and then added a hot laundry operation. Building T-430 was replaced with a new building (Building 167) in 1955. Decontamination activities were added to the group's activities, both liquid chemical decontamination and sand blasting, followed by shot blasting and vapor blasting capability. The group operated a mercury still that decontaminated and purified to a high level many tons of mercury. The group also decontaminated lead so it could be returned to service. The group conducted sizing operations (involving some explosive work) on items that were too large to fit into the normal container for disposal. They also conducted a temporary radioactive waste storage operation wherein highly-activated or highly-contaminated items were stored in trenches or buried containers until they could be disposed of properly. The group also containerized the radioactive material into drums for sea disposal until the early 1960s when they switched over to concrete container vaults that were shipped to Oak Ridge National Laboratory (ORNL) or West Valley for land burial. Another significant activity was disposing of evaporator bottom slurry or other liquid waste by mixing it with concrete and placing it in the above-mentioned containers, either alone or as a means of encasing other radioactive items already in the drums or vaults to provide some degree of shielding. The group reported monthly on the liquid and gaseous releases from BNL until 1971, at which time this reporting responsibility was moved to the environmental group. This group also periodically reported radioactive waste that was dispositioned by BNL (quarterly when required by AEC).

A new Waste Management Facility (WMF) was opened in December 1997. The WMF replaced the original Hazardous Waste Management Facility in its entirety and consolidates several waste management operations into functional buildings. The WMF also provides for significant expansion within a dedicated site suitable for handling and storing hazardous and radioactive wastes generated at BNL.

5.2 Radiological Exposure Sources from BNL Operations

The following subsections provide an overview of the internal and external exposure sources for the BNL class under evaluation.

5.2.1 Internal Radiological Exposure Sources from BNL Operations

ATTRIBUTION: Section 5.2.1 and its related subsections were completed by Eugene Potter, M. H. Chew & Associates, Inc.; Paul Ruhter M. H. Chew & Associates, Inc.; Lori Arent, M. H. Chew & Associates, Inc. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

Many of the radioactive source materials handled at BNL were alpha-particle emitters. Although alpha particles do not present an external exposure hazard, prevention of internal exposures to alpha-emitters was recognized from the onset of site operations as the most significant radiological internal hazard protection challenge (BNL, 1947, pdf p. 2).

There were also a variety of beta- and beta-gamma-emitting radionuclides that were potential internal dose hazards at BNL. Table 5-1 provides a summary of radionuclides that are recognized as potentially contributing to internal dose to BNL workers. This list is not all-inclusive, but it does include all of the most significant sources of internal radiation dose. Radionuclides that emit both alpha and beta(-gamma) are simply listed as alpha-emitters, since the alpha emission will be the predominant component of the internal dose. Likewise, beta-gamma emitters are simply listed as beta emitters.

Table 5-1: Potential Contributors to BNL Internal Dose and Their Primary Modes of Decay

Radionuclide	Primary Mode of Decay
H-3	Beta
Mixed Fission Products (MFP)	Beta
Mixed Activation Products (MAP)	Beta
Th-232	Alpha
Uranium	Alpha
Plutonium	Alpha
Am-241	Alpha
Po-210	Alpha

5.2.1.1 Uranium

Depleted and natural uranium compounds were commonly used in ton quantities at BNL. Uranium in various enrichments, including highly-enriched, was used in critical assemblies and reactors.

Approximately 110 tons of natural uranium fuel slugs were fabricated into aluminum-clad fuel rods by the BNL metallurgy group. During the operation of the BGRR (1950-1958), there were 28 reported ruptures of BGRR fuel and one rupture of a uranium oxide (U_3O_8) sample that was being irradiated for the radioiodine-production program (ORAUT-TKBS-0048, pdf p. 20). Leaking or spent fuel elements were moved to a pool-type underwater storage area (“canal”) where they were chopped up for shipping for off-site disposal. Corrosion and oxidation of the natural fuel slugs occurred in the fuel transfer and storage canal. Over 2414 fuel elements generated during a 12-year period were shipped from the canal. The contaminated water, filter media, and back-flush from the ion exchange columns were pumped to the storage tanks at the Waste Concentration Facility, Building 811. In 1959, the natural uranium was replaced with a smaller enriched uranium core. The BGRR was partially decommissioned in 1972. The exhaust ducts from the reactor and to the stack have been sealed from the fans. The fans remain in their cells. The intake duct, exhaust duct, and fans are grossly contaminated from the fuel failures (ORAUT-TKBS-0048, pdf p. 21). The HFBR and MRR were operated with enriched uranium fuel. Both facilities have now been closed and the spent fuel sent off site. Un-irradiated fuel for the three reactor facilities was stored in secure vaults (DOE, 1996, pdf p. 39).

In about 1950, BNL started investigating the feasibility of processing spent fuel elements by dissolving them in fluorine-based interhalide compounds. After a laboratory study, a distillation plant was constructed in 1951; an engineering test facility was designed in 1953. On May 15, 1957, a series of explosions of liquid bromine trifluoride, uranium hexafluoride, and uranium metal occurred in Building 801. One worker was seriously burned and several others were treated and released. Approximately 50 pounds of natural, un-irradiated uranium were released to the atmosphere (Volatility, 1957).

Uranium was also used in critical assemblies for nuclear reactor research. Research and development on Liquid Metal Fuel Reactor (LMFR) technology took place in Building 820 from 1957-75. A simulated reactor with a core of uranium dissolved in bismuth was studied (ORAUT-TKBS-0048, pdf p. 36). Radiation and Chemical Technology Buildings 526-527 contained unknown quantities of uranium of various enrichments. This area originally housed a criticality facility for reactor physics (ERDA, 1977, pdf p. 48; Liverman 1977). U-233 was used in the Th-U-233 Fuel Rod Development Program in 1962. ORNL was to fabricate and send 1000 rods to BNL for study in its critical experiments facility. A total of approximately 30 kg of U-233 was in the uranium-thorium mixture (Special Nuclear, 1963). The U-233 generally contains U-232 as an unavoidable contaminant. In 1974, U-233 targets were irradiated at the cyclotron using alpha particles, but only in milligram amounts (Progress Report, September 1974).

Uranium was fabricated into targets for irradiation in reactors and accelerators. The uranium was machined in the Hot Machine Shop (Building 530, replaced by Building 462). Uranium targets were reprocessed. For example, from March of 1952 to June of 1960 there was a program at the Hot Laboratory to produce I-131 by acid-dissolution of irradiated uranium samples. U-234 foils (100 μg) were irradiated with deuterons to produce Pu-234 in 1975 (Hull, 1977a).

Depleted uranium (DU) was used in target areas of the AGS (ORAUT-TKBS-0048, pdf p. 25). A muon shield consisting of over 15 tons of DU was set up for a 1966 AGS experiment (HP Summary, May 1966). DU was cleaned for an experiment at CERN (Conseil Européen pour la Recherche Nucléaire, or European Council for Nuclear Research) in 1985-86.

Building 1008 was the Uranium Calorimeter Factory in 1988. One calorimeter module housed fifty 102-inch by 25-inch uranium plates. There were enough plates to construct 20 modules (Lazo, 1988b). NIOSH has obtained no further information about what went on in this factory.

In 1995, an inventory showed that DU was present in eleven buildings in quantities from a few grams to nearly 27,000 kilograms. Natural uranium was located in four buildings in quantities from 10s of grams to nearly 85 kilograms (Miltenberger, 1995).

5.2.1.2 Fission and Activation Products

Fission and activation products were present at BNL from the earliest days to the present. Some fission and activation products were the intended products of the BNL reactors and accelerators. For example, targets were irradiated to produce materials for basic research, medical research, or source manufacture. Other fission and activation products were produced as unintended byproducts of these operations; for example, activation of facilities and equipment, cooling air activation, or activation of contaminants in targets. BNL also imported fission and activation products from other AEC/DOE facilities and commercial sources.

By 1948, 25 different isotopes were already in use, well before the start of operations at the BGRR (Cowan, 1948). From March 1952 to June 1960, there was a program at the Hot Laboratory to produce I-131 by acid-dissolution of irradiated uranium samples. During the late 1950s and early 1960s, a number of radioisotopes were in development and/or production at what was known then as LEAF (Low Energy Accelerator Facility) which included the cyclotrons and the Van de Graaff accelerator (Flood, 1982). The major purpose of these isotopes was medical research. In the 1970s, the BLIP was set up to utilize the excess capacity of the 200 MeV Linac to produce radionuclides to be used in the development of new radiopharmaceuticals, mostly for diagnostic purposes. The Chemistry Linac Irradiation Facility (CLIF) operated in a similar way, but it was used for irradiations of a few hours or less (ERDA, 1977). The Hot Laboratory and other locations were used to process targets (ORAUT-TKBS-0048, p. 40). In 1971-1972, the High Intensity Radiation Development Laboratory (HIRDL), which contained million-curie range Co-60 and Cs-137 sources, was used for source development and experimental process irradiations (ORAUT-TKBS-0048).

The above are just some examples of the many uses of fission and activation products used or produced at BNL. They ranged from small quantities of short-lived isotopes to significant quantities of long-lived material. Many of these activities only involved a few researchers in close contact with the materials. In addition, the isotopes produced for diagnostic medical use had short half-lives to reduce the dose to the patients. After discontinuation of the research, only the longer-lived material remained as residual contamination. Much of the equipment used was decontaminated or disposed of as waste. The primary exception was at the BGRR. In 2000, there were an estimated 1,400 Ci of Fe-55, 0.7 Ci of Co-60, 13 Ci of Sr-90, and 15.5 Ci of Cs-137 remaining in the BGRR complex due to operations with failed fuel (Musolino, 2000).

5.2.1.3 Tritium

Tritium was encountered in several forms: tritiated water (HTO), tritiated gas (HT), organically-bound tritium (OBT), and metal tritide (MT). H-3 appears to have been widely used in medical and biological research. Medical research involving OBTs started in the 1950s. Tritiated thymidine was injected into patients and animals in the mid-1960s (Flood, 1967). In 1967, bean plants were grown in 2 Ci/liter of HTO at Medical/Biology (HP Summary, April 1967). In 1969, after gross H-3 contamination of one of the organic chemistry labs, a reference states that urine samples and CAMs indicated that the form was H-3-labeled benzoic acid (HP Summary, April 1969). There was a long-running experiment with mice in the 1970s and disposal of large quantities of contaminated mouse litter was reported monthly (Progress Reports, 1974). In 1972, H-3-contaminated vacuum pump oils were a problem, especially at the 3.5 MeV Physics/Chemistry Van de Graaff (Flood, 1972). When tritium ions were accelerated, approximately 200 Ci/month of HT was used (ERDA, 1977). The Hot Laboratory fabricated H-3 into accelerator targets. The tritium targets were used at the 18-inch cyclotron, the 50 MeV AGS LINAC, the 3.5 MeV Van de Graaff, the Tandem Van de Graaff, and the 200 MeV LINAC. Accelerator targets were in the form of SMTs, such as zirconium tritide. At Building 919 in 1973, the 80-inch bubble chamber facility had a 250 mCi gas chromatograph source, as well as other sources up to 100 mCi (Bubble Chamber, 1973). Cooling water at the AGS became tritiated, especially at the target stations. The levels ranged from 1,000 pCi/L to 400,000 pCi/L. These were closed systems that were drained prior to 2009 (Lessard, 2009).

The amount of H-3 on site increased dramatically with the start-up of the HFBR in 1965. The HFBR was a 30-60 MW thermal heavy-water-moderated nuclear research reactor. Heavy water flowing in the core was exposed to a dense neutron field which activated the deuterium atoms in the water to produce tritium. The typical concentration was about 2 mCi of H-3 per cm^3 of heavy water. The form was HTO, and this was the most important source of H-3 exposure at BNL from 1965 to 1999. The second most important was probably the 3.5 MeV Van de Graaff where H-3 tritium beams and targets were frequently used. High beam currents of proton or deuterons would cause the H-3 to diffuse out of the zirconium targets and into the beam pipe and the surrounding area. Substantial build-up of contamination was noted in 1970 (HP Summary, February 1970). During the change-out of a leaking H-3 source bottle in 1971, levels reached 2000 MPC in the area of leak. However, the highest exposure to the workers involved was only 24 mrem (HP Summary, October 1971).

5.2.1.4 Thorium

Thorium was present at BNL starting in the 1950s, and was used primarily in nuclear engineering research. All references to thorium at BNL are to natural thorium (Th-232-series). Control and accountability procedures were set up indicating that thorium was to be handled as a source material like uranium (BNL, 1948; Fox, 1950). In 1959, a study was made of ThO_2 hazards as a result of the increased use of this material in the Nuclear Engineering Laboratory (HP Summary, May 1959). The MPC was taken from a proposed revision of NBS Handbook 52 as $4x10^{-12}$ $\mu Ci/cm^2$, making it “very hazardous,” and appropriate arrangements were being made for containment and monitoring. Various chemical compounds and physical forms (including dispersible powders) were present (BNL, October 1957; BNL, December 1957; HP Summary, February 1959; Progress Report, March 1952; Progress Report, April 1952; Progress Report, May 1952; Progress Report, October 1952; Progress Report, November 1953; Progress Report, December 1953; Progress Report, June 1954; Progress Report, August 1954; Rice, 1966). There is evidence that thorium operations were monitored by health physics staff. For example, in 1969, among the operations monitored was the change-out of filters in line with a Th-228 molecular beam apparatus in Chemistry (HP Summary, October 1969). In 1971, thorium foils were used in studies for a fission track personnel dosimeter (HP Summary, September 1971). In the mid-1970s, a “thorium cow” was in use at Bldg. 510. This is a device that concentrates the daughter products from thoron (notably Pb-212) by precipitation on a charged electrode. This device was used to produce calibration sources and at the Tandem Van de Graaff (Progress Report, January 1974; Progress Report, November 1975; Progress Report, December 1975). In

1986, five workers in the Department of Applied Science working with "thorium series (magma)" were identified for whole body counts (Lukas, 1986), indicating that a small program still existed (magma apparently referred to geothermal-research-related samples containing trace amounts of thorium). An inventory of dispersible radioactive material in 1997 indicated that only microcurie amounts were still on site (Flores, 1998).

5.2.1.5 Plutonium

Plutonium was among the first safety concerns at BNL, probably because its hazards were well known by the time BNL was established. Its early uses are not well described, but seemed to involve studying its various properties. Due to the activation of uranium, plutonium was present in the fuel of the operating reactors; however, BNL fuel was sent to other sites for reprocessing (Van Horn, 1962-1963). Nevertheless, plutonium was present in the residual contamination of some facilities, particularly the BGRR which had a history of operations with failed natural uranium fuel elements. There was also Pu in the fission product mixture processed by the waste handlers (HP Summary, March 1949). Plutonium was also contained in neutron sources at Medical, Chemistry, and the calibration facility (ORAUT-TKBS-0048, pdf p. 94).

The following text briefly summarizes known occurrences involving Pu at BNL. In January 1963, a leaking glass carboy containing gold in a solution contaminated with plutonium was received at BNL (AEC, 1963, pdf p. 68). In December 1963, plans were being prepared for the conversion of a gamma facility in the Hot Lab to a plutonium metallurgy laboratory to perform physical and chemical tests on cold and irradiated plutonium carbide fuels (Progress Report, December 1963). In 1966, a lathe contaminated with U-235 and Pu-239, which originally came from Mallinckrodt, appears to have been used in the shops at BNL, (HP Summary, January 1966). In 1966, plutonium was also used in nuclear engineering research in the critical assembly area; plans were designed to prevent surface or airborne contamination or damage to the encapsulated source material (HP Summary, March 1966). In March 1967, four grams of Pu-239 in the forms of oxide and carbide were introduced into one of the glove boxes at the Hot Lab. The experiment consisted of vaporization of oxide in a closed system. The operation was reviewed and covered by health physics (Progress Report, February 1967). In 1970, three Pu vaporization experiments were conducted in the alpha-gamma facility (HP Summary, February 1970). In June 1971, 61 PuO_2-UO_2 pellets containing 439 grams of Pu were encapsulated by the Hot Lab health physics personnel in a new glove box facility set up for this purpose (HP Summary, June 1971). By September 1971, plutonium work at the Hot Lab appears to have ended since some of the equipment was being converted to use in the chemical processing of BLIP targets at the Hot Lab (HP Summary, September 1971). In 1996, there were still gram quantities of plutonium stored in an SNM vault (DOE, 1996, pdf p. 40). In 2000, a total of 1.22 Ci plutonium isotopes were estimated to remain in the BGRR complex (Musolino, 2000).

5.2.1.6 Americium

Americium is generally present at BNL as a by-product of plutonium production/irradiation. There is also evidence that operations involving purified Am-241 took place on site during the time period under evaluation. In 1959, an Am-241-contaminated dry box from the criticality facility was partially cleaned prior to storage (HP Summary, May 1959). Americium sources were also used for calibrations (HP Summary, October 1964; HP Summary, April 1965; HP Summary, June 1965) and X-ray fluorescence studies (Progress Report, Oct-Nov 1983). In 1966, americium “in sizable amounts” was to be used in the critical assembly area; plans were designed to prevent surface or airborne contamination or damage to the encapsulated source material (HP Summary, March 1966). There is no subsequent mention of this material, which is likely an indication that no problems were experienced. Site interviews indicate that since 1989 Am-241 has only been present in μCi amounts for research projects (Personal Communication, 2008c). An inventory of dispersible radioactive material in 1997 indicated that only microcurie amounts were still on site (Flores, 1998). However, it may still be present in residual contamination with plutonium isotopes. In 2000, a total of 0.072 Ci of Am-241 was estimated to remain in the BGRR complex (Musolino, 2000).

5.2.1.7 Polonium

Polonium was among the first radionuclides received at BNL. Apparently polonium sources were initially used due to security issues associated with using plutonium sources (HP Summary, October 1949). The two most common uses appear to have been as an alpha source for basic research and as a Po-Be neutron source for calibrations and other purposes. The hazards of polonium were recognized early on, and in 1947 safety precautions were published by groups using polonium sources (Salant, 1947).

A Po-Be source was requested as early as 1947 (Hayner, 1947). There was a 1949 request for a replacement polonium source to be used in a spectrometer (Lancaster, 1949). Initially, the sources were constructed using a thin nickel plating which could allow the polonium to diffuse through it, and some of these sources leaked (Cowan, 1947; Progress Report, April 1965). Two individuals acquired 20% of the maximum permissible body burden (MPBB) from an incident in August 1960 (Haworth, 1960; HP Summary, January 1961). In 1963, the Chemo Nuclear group worked with 10-Ci polonium sources. The operations manual for this work was reviewed by health physics and emergency instructions were brought up-to-date prior to use. Instrumentation for monitoring these experiments was checked and found to be in working order (Progress Report, September 1963). A Po-210 contamination incident also occurred on December 21, 1964 (Progress Report, January 1965). A physics experiment which involved 297 mCi of Po-210 was planned in 1966 (HP Summary, March 1966). The material was to be dissolved in hydrofluoric acid, placed in a sealed container in the alpha dry box at the Hot Lab, and then transferred to the Physics lab in a sealed bag. Documentation has not been located that indicates whether the experiment took place. An inventory of dispersible radioactive material in 1997 indicated that only microcurie amounts were still on site (Flores, 1998).

5.2.2 External Radiological Exposure Sources from BNL Operations

Given the broad scope of BNL activities involving ionizing radiation, workers were potentially exposed to external photon, beta and/or neutron radiation from a variety of sources. Potential sources included radioactive materials, nuclear reactors, particle accelerators, and X-ray-generating equipment.

5.2.2.1 Photon

Many BNL radiological operations involved gamma and X-ray photon radiation fields. Potential photon exposure sources to workers would have been associated with the following:

- Gamma-emitting fission and/or activation products resulting from reactor and accelerator operations.
- Production and use of high-intensity gamma sources, typically Co-60 and Cs-137.
- Radioisotopes used in medical research and treatment.
- X-ray-generating machines.
- Calibration sources of americium, thorium, radium, cobalt, cesium, and other miscellaneous radionuclides.

The very high-intensity sources were handled in a shielded configuration or shielded facility. Highly-contaminated or activated equipment was handled using standard health physics controls of time, distance, and shielding.

5.2.2.2 Beta

BNL research and operations did not focus on activities with beta-particle-emitting source terms. However, beta radiation over a broad range of energies could have been encountered from: activation and fission products from reactor and accelerator operations; and other radionuclides such as those used as calibration sources and for medical treatment and research.

Whether a beta source is considered an internal hazard or both an internal and external hazard depends on the maximum energy of the beta emission for a given radionuclide, the shielding employed, and the use of protective clothing. Higher-energy beta-emitters present both an external hazard (to the skin) and an internal hazard. In many cases, beta-emitting radionuclides also emit characteristic photons.

5.2.2.3 Neutron

There were many sources of potential neutron radiation exposure associated with BNL operations. The source of the neutron emissions from these activities and potential worker exposure would have been associated with the following:

- Accelerators
- Operating reactors, especially those designed to create neutron beams
- Neutron-generating sources, either via the α,n reaction (PuBe, RaBe, PoBe) or via spontaneous fission sources (Cf-252)

The broad scope of BNL neutron-generating activities resulted in a correspondingly extensive neutron energy spectrum. The spectrum ranged from the thermal energy region of 0.025 eV through the fission spectrum of 0.1 to 6.0 MeV (predominant energy of 0.7 to 1.0 MeV), and included high-energy, accelerator-produced neutrons greater than 14 MeV. Additional information is available in ORAUT-TKBS-0048.

5.2.3 Incidents

Incidents that occurred at BNL were documented and worker exposures were assessed when the event involved radioactive sources. Incident reports are maintained at BNL and copies of many of these reports have been obtained through NIOSH data capture efforts and are now in the SRDB.

BNL reportedly maintains an unofficial spreadsheet with information on historical spills and other contamination incidents as part of the "Radiological Footprint Project." The purpose of the spreadsheet is to assist with D&D activities. This spreadsheet was not made available to NIOSH, but was mentioned in one of the SC&A interviews (Personal Communication, 2009e).

Table 5-2 summarizes nine major BNL incidents that occurred during the evaluation time frame and that might have significant potential for internal or external personnel exposure.

Table 5-2: Major BNL Incidents (This table spans two pages)		
Facility/Building	**Year**	**Description**
BGRR, Building 701	1952-57	During the early years of BGRR operation, fuel failures occurred that resulted in radioactive materials being released to the air stream that cooled the reactor. There were 28 reported ruptures of BGRR fuel during the period 1952-1957. All occurred with natural uranium. There was one rupture of a uranium oxide (U_3O_8) sample that was being irradiated for the radioiodine production program. Aside from Ar-41, I-131 was the most important radionuclide discharged to the atmosphere from the BGRR that would contribute to a potential dose. Br-82 and I-133 were released in somewhat larger concentrations. (BGRR History, 1997)
Hot Laboratory, Building 801	5/15/1957	There was a serious incident involving the Volatility Project where uranium reprocessing was the objective. There was a series of explosions of UF_6/BrF_3 and a few people were injured, one hospitalized. There was a release of about 50 lbs of natural, un-irradiated uranium to the local environment. Apparently, the UF_6 readily combines with moisture to form an oxide. The BrF_3 is very corrosive and damaged equipment in the building, nearby trees, and automobiles. Eight workers with the highest inhalation received uranium urine bioassay; the highest concentration was 0.54 mg/l uranium. (Volatility, 1957)
Inner Alpha Laboratory Building T-137	8/2/1960	Alpha contamination occurred during experiments conducted with a 10-Ci Po-210 source that was supposedly sealed. Two individuals acquired internal body burdens from this incident; the highest result was 14% of the 0.03 microcurie body burden permissible by NBS Handbook 69 (Haworth, 1960 ; Cowan, 1961).
Physics Lab Building 510	10/30/1962	Exposure from a Physics Department x-ray diffraction apparatus was investigated. The estimated exposure to the operator was 10 rad to the left hand and 260 rad to part of the right hand. Audible and electrical interlocks were specified to avoid future incident (Distenfeld, 1962).
Laboratory W-9 Building 703	12/19/1975	Contamination from a sample transfer process was investigated. The original sample contained approximately 0.5 of Ci Ce-14l and 80 mCi of Ce-143. Three workers were evaluated and one was assigned 330 mrad following fecal and WBC analyses (Roesler, 1976; Tony, 1976).
BLIP Facility and Hot Lab (Bldg 801)	5/16/1978 7/31/1978	Two I-126 iodine exposure incidents occurred in 1978 affecting BLIP and Hot Lab workers. At BLIP, a target vaporized and at the Hot Lab, there was visible contamination on a needle used for nuclide extraction from BLIP-irradiated targets. Eight workers were potentially exposed and they received whole body and thyroid counts. The highest exposure was 1.35 rem to the thyroid (Miltenberger, 1978b; Miltenberger, 1978c).
Calibration Facility Building T-348	4/10/1978	An investigation was performed due to an external exposure incident involving a Cs-137 source that became stuck in its irradiation tube. The source was rated at 3.8 R/hr at 50 cm (4/13/78). Initially a gamma exposure of 4.3 rem was assigned, which was subsequently refined to 2 rem after further evaluation (White, 1978; Flood, 1978).

Table 5-2: Major BNL Incidents (This table spans two pages)		
Facility/Building	**Year**	**Description**
HFBR Building 750	March and April 1990	At HFBR, there was a contamination incident that resulted in a formal investigation. Workers were installing a new valve in the reactor vessel in preparation for start-up. A new portal monitoring had been installed and workers began experiencing alarms upon exit and entry. After contamination was found in two personal vehicles, on- and off-site surveys were conducted determine the extent of the contamination. Low-level spots of contamination were found off-site in four additional personal vehicles and in two homes; contamination was easily removed in each case. A total of 108 residences were surveyed. Whole body counts were performed for 60 HFBR workers and three were found to have very low internal depositions. The general public was not affected (DOE, 1990).

6.0 Summary of Available Monitoring Data for the Class Evaluated by NIOSH

ATTRIBUTION: Section 6.0 and its related subsections were completed by Tim Adler, Oak Ridge Associated Universities; Eugene Potter, M. H. Chew & Associates, Inc.; Paul Ruhter, M. H. Chew & Associates, Inc. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The following subsections provide an overview of the state of the available internal and external monitoring data for the Brookhaven National Laboratory (BNL) class under evaluation. The personnel monitoring program at BNL has always been officially organized under a health and safety-oriented department. Various names and organizational structures have existed. The administrative chronology of BNL's personal monitoring programs is summarized in Section 7.1.

Despite the existence of organized occupational monitoring departments at BNL, some aspects of the personnel monitoring programs have been decentralized for much of the site's history. This decentralization is particularly applicable to internal exposure monitoring record maintenance. Monitoring requirements were determined primarily within specific departments or divisions (e.g., Reactor Division) on work area and activity-specific bases. This was accomplished through the assignment of health physicists to specific BNL work areas. The health physicists decided monitoring requirements for workers under their purview based on their judgment of exposure potential. After analysis, personal monitoring results were returned to the area health physicists for comparison to standards in existence at the time, to assess safety adequacy, and guide future monitoring. Internal monitoring results were frequently stored only in files located at the various site work areas. Records have also been stored in individual workers' files, medical files, or vendor files that, in turn, may exist in several different locations on site or in off-site archives. These personnel data management practices (i.e., lack of centralized databases) preclude the summarization and presentation of total internal monitoring data availability. In addition to complicating the data availability assessment, BNL's data management practices have apparently adversely affected the ultimate retrievability of internal monitoring data collected prior to 1980. This latter determination is discussed in more detail in Section 7.1.

It is noteworthy that external radiation monitoring and the associated records have historically been more centralized. This may be due in part to the relatively low internal exposure potential for most work performed at BNL. From the beginning an entity known as the "Personal Monitoring Group" collected and compiled all site external monitoring data for inclusion into external exposure summary reports as required by DOE (initially AEC). Detailed further in Section 6.2, this group maintained a more centralized reporting and monitoring data record system. As time passed increased centralization of both internal and external monitoring requirements and data management has occurred.

Consolidation of BNL monitoring records is an ongoing effort at BNL. Data storage technology, in particular, has improved since the first data were collected in 1947. The launch of the Health Physics Record System (HPRS) can be considered the most significant technology change to the program thus far. The HPRS was launched in 1996 with a phased implementation between March 1995 and January 1996. Prior to that time, data were kept on hard copy or in vendor files. Table 6-1 briefly summarizes the sources for historical monitoring data relative to availability within the HPRS.

Table 6-1: Sources for Monitoring Data		
Type of Data	**Date Range**	**Where Found**
Internal Monitoring Data	1949 - 2001	Individual/detailed data are not in HPRS. Results are available in hard copy stored in individual personal monitoring files and/or medical files. Some results from 1995 - 2000 are stored electronically, but not in HPRS.
Internal Monitoring Data	After 2001	Data are in the HPRS. This 2001 date reflects the current status but will keep moving back as BNL continues to migrate older monitoring data into HPRS.
Film badges	Prior to 1985	BNL data are in hard copy/reports, personnel cards. Summary data are in HPRS.
Film badges/CR-39/Lexan	1985 – 1996	Landauer database and microfiche. Some electronic data are available on disk. Paper copy is available in bound books.
TLD/CR-39/Lexan*	After Jan 1996*	HPRS

* Lexan was not used after June 1997; therefore, Lexan dose results are not stored in HPRS after that time.

Because the majority of the available internal monitoring data applicable to the evaluation time frame still exists in hard copy form, in multiple locations, primarily sorted into individual employee files, a definitive assessment of total monitoring data availability would only be possible through the perusal and tallying of each file's contents. Constraints on the retrievability of the data from the site, especially for internal monitoring data prior to 1980, precluded NIOSH's accomplishment of this task. However, NIOSH has extracted and electronically entered monitoring data found within the approximately 2300 documents that were captured from the site and other sources as of May 2009. Furthermore, NIOSH conducted two additional data capture exercises focused specifically on retrieving monitoring data from individual worker files; and data available within those captured files has been summarized in this evaluation.

The results of the NIOSH data capture efforts provide the basis for the observed data availability summaries presented in the following subsections. It is important to remember that the data presented do not represent the actual total available monitoring data, but rather, a subset that was available within the documents retrieved. Presentation of the captured results therefore expectably indicates the presence of temporal and data quantity gaps. Nevertheless, when coupled with numerous captured documents describing health and safety practices at BNL, the data obtained thus far provide additional support for the existence of a comprehensive and conscientious worker monitoring program appropriately based on exposure potential. However, personnel monitoring data retrievability issues, which are compounded by the site's record-keeping practices over the years, present the most significant issues affecting this report's evaluation. It is apparent that there was a turning point in the BNL radiological program and record-keeping requirements at the beginning of 1980 (following a 1979 site assessment). Based on this information, the assessment of NIOSH's ability to bound dose for the class under evaluation is primarily focused on the ability of the site (or other applicable entity) to identify, retrieve, and provide (to NIOSH) the applicable BNL personnel internal and external monitoring data.

6.1 Available BNL Internal Monitoring Data

For much of the site's operational history, department/division health physics representatives designated personnel for participation in the internal dosimetry program (WBCs and/or urinalysis) using professional judgment. This judgment could also have included monitoring frequency (BNL, 1995; Holeman, 1999). Table 6-2 summarizes *in vivo* and *in vitro* monitoring practices and data storage media for the evaluation period. In general, *in vivo* and *in vitro* dosimetry was performed for initial employment checks, annual physicals, for employees engaged in higher-exposure-potential work, and incidents. Details regarding the various analyses used and the associated minimum detectable activities are presented in the BNL TBD for Occupational Internal Dose (ORAUT-TKBS-0048).

Table 6-2: Internal Dosimetry Timelines and Data Source Descriptions

Type	Dates	Description
In vivo	1960 - 1991	Outputs are available from the whole-body counting system that was in place at the time (several whole-body counting systems were in place during this time period). This hard copy output is kept in personnel dose history files, some log books, and some medical records.
	1992-present	*In vivo* bioassay performed routinely for Reactor Division personnel, Waste Management personnel, BLIP, Facility Support personnel, and Environmental Restoration personnel. These data are all available as hard copy reports from the PM Whole Body Counter.
	1999-present	*In vivo* bioassay data are also available electronically on the workstation of the Whole Body Counting System. The data have been exported and provided to NIOSH ("ABACOS2K" files). The data indicate that 2815 counts were performed on 963 individuals.
In vitro	1947- 1984	Results were manually kept in hard copy in different formats. This hard copy is kept in personnel dose history files.
	1984- 2003	*In vitro* bioassay performed for RD personnel. 1984-1995 tritium dose data were sent to Landauer and recorded in the Landauer System. Data are available on microfiche and have been entered into a spreadsheet by NIOSH. Many tritium monthly summaries from 1992 - 1999 are available in hard copy reports. The tritium data primarily are in terms of dose. Urinalysis data consisting of over 11,000 tritium results and a few gamma scans from the on-site Analytical Services Laboratory ("ASL" Access database) have been captured for the period 1995-2003.
	1999- present	After 1999, hard copy records of all *in vitro* bioassay results are maintained in the whole body counter office. After 2000, electronic versions are also available and have been captured by NIOSH.
Other	1998-present	Doses from intakes are recorded in HPRS. Doses could be the result of either *in vivo* or *in vitro* bioassay or assigned from air samples.

Attachment 1 presents a summary of whole body counts and urinalysis monitoring data pulled from documents NIOSH captured during the initial general-evaluation data capture events (as of May 1, 2009) plus results obtained from two data-pedigree-focused efforts that occurred later. Results in Attachment 1 have been presented in terms of the number of employees monitored per year. Extraction and entry of individual analytical results was performed only for data found in documents captured prior to May 1, 2009 (over 2,300 documents at that time). These individual analytical results are presented and discussed the following two subsections. More-recently collected data (captured after May 1, 2009), which includes data from the 1990s forward, are included in the summary contained in Table 6-2, but have not been included in the Table 6-3 assessment.

6.1.1 Urinalysis Monitoring Data

As mentioned above, Attachment 1 contains a compilation of the available *in vitro* bioassay results from the SRDB documents collected and posted by NIOSH as of May 1, 2009. The raw data compilation contains just under 9100 individual urinalysis sample results from 1049 individuals. Table 6-3 below summarizes the total number of *in vitro* results currently captured by year and by individual radionuclide. Though many documents were used as data sources, a large portion of the internal data captured have come from two sets of urinalysis records from 1952-1975 (Urinalysis Records, 1952-1975a; Urinalysis Records, 1952-1975b). These documents contain handwritten bioassay records for individual employees that were terminated. The records appear to include all bioassay results for each employee listed within the documents, not just their termination results. Of the results collected, 87% were surveys, 7% were incidents, 5% were unknown, and 1% were re-checks.

In general, results include the employee's name and at least one identifier such as "BNL Life Number," division/department, and/or a location indicator. Major work groups identified included:

- Accelerator
- Biology, Chemistry, and Physics
- Critical Assembly, Department of Applied Science, and Nuclear Engineering
- Health Physics, Safety & Environmental Protection, and Waste Management
- Hot Lab and Medical
- Plant Maintenance and Shops
- Pile and Reactor

The "BNL Bioassay Record" (Form 1720) was used from 1951 to 1967 and includes MFP, Sr-90, H-3, and alpha column headers. The other form used from 1952 to 1976 is titled "Urinalysis Record" and includes gross (gamma), Sr-90, and Po-210 column headers. There is also a "Gross Activity" form (BN-945), a "BNL H-3 Exposure Evaluation" form, and memos that detail incident follow-ups. Other radionuclides that were monitored for specific incidents included:

- Ag-110
- Am-241
- Au-198
- Ce-141/143 (urine and fecal)
- Co-60
- Hf-181
- Na-24
- P-32
- Ra-226
- Ru-106
- U-233
- Zn-65

Table 6-3: Total No. of *In Vitro* Results/Yr and No. of Individual Radionuclide Results/Yr*
Note: A single sample may include more than one result (multiple analyses per sample.)
(This table spans three pages)

Year	Count of Samples	Count of Gross (d/m/d)	Count of MFP (d/m/d)	Count of Sr-90 (d/m/d)	Count of H-3 (µc/l)	Count of U/Total U (ug/l)	Count of "U" (d/m/d)	Count of Nat U (µg/l)	Count of Nat U (d/m/d)	Count of U-238 (µg/l)	Count of EU/U-235 (d/m/d)	Count of Gross alpha (d/m/d)	Count of Po-210 (d/m/d)	Count of Pu/Pu-239 (d/m/d)	Count of I-131 (d/m/d)	Count of I-131 (µc/d)	Count of Gamma (d/m/d)	Count of Cs-137 (µc/d)	Count of Cs-137 (d/m/d)	Count of Other RA	Count of Individual RA Results
1949	17			5										12							17
1950	52	1	3	4										44							52
1951	81	1	3											76						1	81
1952	93	43	48											2							93
1953	77	51	26																		77
1954	172	104	45	4									21								174
1955	278	192	48	75		1				2			29								347
1956	244	149	68	53									38							2	311
1957	295	157	65	19		1				44			9							22	317
1958	189	90	91	13						2	1		5				1			1	206
1959	221	60	103	19	2	7		3		33		6	4	7	2					1	247
1960	293	104	116	29	2	12		5		28	2	12	56								366
1961	250	111	119	87	3	1		1		7	5	18	8		2						362
1962	309	120	160	100	4	6	1	7		14	4	8	1			2			7	1	435
1963	355	91	195	130	3	15	14	17		35	15	13	1	6	1			2		2	540
1964	222	59	140	59	12	4	1	6		2	1		5	1	12	2	1	2	11	3	321
1965	263	40	99	9	101	6	4	5	1		11	2	1	6	4	5		57		1	352
1966	410	37	112	5	231		4	7	19	6	2		2	4		1		54		2	486

Table 6-3: Total No. of *In Vitro* Results/Yr and No. of Individual Radionuclide Results/Yr*
Note: A single sample may include more than one result (multiple analyses per sample.)
(This table spans three pages)

Year	Count of Samples	Count of Gross (d/m/d)	Count of MFP (d/m/d)	Count of Sr-90 (d/m/d)	Count of H-3 (µc/l)	Count of U/Total U (ug/l)	Count of "U" (d/m/d)	Count of Nat U (µg/l)	Count of Nat U (d/m/d)	Count of U-238 (µg/l)	Count of EU/U-235 (d/m/d)	Count of Gross alpha (d/m/d)	Count of Po-210 (d/m/d)	Count of Pu/Pu-239 (d/m/d)	Count of I-131 (d/m/d)	Count of I-131 (µc/d)	Count of Gamma (d/m/d)	Count of Cs-137 (µc/d)	Count of Cs-137 (d/m/d)	Count of Other RA	Count of Individual RA Results
1967	959	5	105	11	804	5	26	2	1	5	1		1	10	1		5	39			1021
1968	713	1	74		624	1	12		1	4		3					63	2			785
1969	695		57		623	6	25	1		5	1			1		3	47				769
1970	566	2	38		531									9			33			3	616
1971	271	1	16		270									1			19				307
1972	220	1	6		219												9			1	236
1973	262	1	13		262												14				290
1974	341		6		341												6				353
1975	254	1	10		246							3					12			5	277
1976	70		1		70												1				72
1977	103				103																103
1978	116				109															7	116
1979	98				98												1				99
1980	95				91													1		3	95
1981	131				92												45				137
1982	102				102																102
1983	76				76												1				77
1984	102				54												1			48	103

Table 6-3: Total No. of *In Vitro* Results/Yr and No. of Individual Radionuclide Results/Yr*
Note: A single sample may include more than one result (multiple analyses per sample.)
(This table spans three pages)

Year	Count of Samples	Count of Gross (d/m/d)	Count of MFP (d/m/d)	Count of Sr-90 (d/m/d)	Count of H-3 (µc/l)	Count of U/Total U (ug/l)	Count of "U" (d/m/d)	Count of Nat U (µg/l)	Count of Nat U (d/m/d)	Count of U-238 (µg/l)	Count of EU/U-235 (d/m/d)	Count of Gross alpha (d/m/d)	Count of Po-210 (d/m/d)	Count of Pu/Pu-239 (d/m/d)	Count of I-131 (d/m/d)	Count of I-131 (µc/d)	Count of Gamma (d/m/d)	Count of Cs-137 (µc/d)	Count of Cs-137 (d/m/d)	Count of Other RA	Count of Individual RA Results
1985	50				50												1				51
1986	41				38																38
1987	8				4					3							4			1	12
1989	1																			1	1
Grand Total	9095	1422	1767	622	5165	65	87	54	22	190	43	65	181	179	22	13	264	157	18	105	10444

* Includes only the data available to NIOSH from data captured prior to May 1, 2009.

6.1.2 Whole Body Counting Data

Table 6-4 below summarizes the *in vivo* analytical results by year and by individual radionuclide extracted from SRDB documents captured as of May 1, 2009. During this evaluation process, NIOSH captured and entered over 1900 individual WBC results from 686 individuals. The data ranges from 1960 (the start of whole body counting at BNL) to 2000, after which the data are kept in the HPRS. The majority of the captured data are from the 1980s; currently, data gaps exist for the years 1963, 1965-69, 1971, and 1991.

The data came primarily from several sets of whole-body results (WBC Summaries, 1987; Whole-Body Results, 1973-1981; Whole-Body Results, 1975-1981; Whole-Body Results, 1979-1986; Whole-Body Results, 1988-1994; Whole-Body/Thyroid Results, 1983-1984). Much of the data was compiled from memos written from WBC program managers to S&EP representatives when they forwarded the WBC results for employees working in their respective areas.

Typical radionuclides measured included: Cs-137, Co-58/60, Zn-65, Fe-59, Mn-54, and Be-7. There are also results for Cs-134, Ce-141/144, Ba/La-140, and the radioiodines. Results for lung and thyroid dose were also captured.

In general, results include the employee's name and at least one identifier such as "BNL Life Number," division/department, and/or a location indicator. There is some uncertainty regarding the WBC identifiers and work locations, but the data were cross-matched with the *in vitro* data or organizational charts when possible. Major work groups identified included:

- Accelerator
- Biology, Chemistry, and Physics
- Critical Assembly, Department of Applied Science, and Nuclear Engineering
- Health Physics, Safety & Environmental Protection, and Waste Management
- Hot Lab and Medical
- Plant Maintenance and Shops
- Pile and Reactor

Table 6-4: Total No. of *In Vivo* Results/Yr and No. of Individual Radionuclide Results/Yr
(This tables spans two pages)

Year	Total Analyses	Cs-137 (nCi)	Cs-134 (nCi)	Co-60 (nCi)	Co-58 (nCi)	Zn-65 (nCi)	Fe-59 (nCi)	Ce-41/144 (nCi)	Ba/La-140 (nCi)	Mn-54 (nCi)	Be-7 (nCi)	I-133 (nCi)	I-125 (nCi)	I-126 (nCi)	I-131 (nCi)
1960	29	29				27									
1961	2	1				1									1
1962	2	2													
1964	3			3											
1970	1	1													
1972	8	8				1									
1973	48	48			2	10					3				
1974	83	82				71	1				1				6
1975	47	47						3							
1976	14	13													
1977	36	33													
1978	36	21				7				10	4			8	
1979	33	31	1			3					1		1		
1980	107	99		95		79	31			46	45		35		
1981	137	124	1	117		17				3	15		6		
1982	19	12		12						12					
1983	21	15	2	12	14	2	4			3	2	1	4		
1984	223	177	60	154	172	161	57	7	7	109	46	9	15		7
1985	117	101	1	79	79	80	25	1	1	9	28	52	9		5
1986	171	137	123	117	128	136	137	1		95	28		59		61
1987	165	140	59	104	114	113	134			70	59		33	2	28
1988	167	156	1	144	105	149	105			109	92	13	16		7
1989	238	219	1	177	3	100	4			67	142	60	15		7
1990	2	2		2											
1992	1														
1993	114	111		111		111	7	2		110	110				110
1994	85	84	83	84	80	84	80			84	1				1

Table 6-4: Total No. of *In Vivo* Results/Yr and No. of Individual Radionuclide Results/Yr
(This tables spans two pages)

Year	Total Analyses	Cs-137 (nCi)	Cs-134 (nCi)	Co-60 (nCi)	Co-58 (nCi)	Zn-65 (nCi)	Fe-59 (nCi)	Ce-41/144 (nCi)	Ba/La-140 (nCi)	Mn-54 (nCi)	Be-7 (nCi)	I-133 (nCi)	I-125 (nCi)	I-126 (nCi)	I-131 (nCi)
1995	4	1													
1996	2														
1997	1														
1998	2														
1999	2														
2000	1														
Total	1921	1694	332	1211	697	1152	585	14	8	727	577	135	193	10	233

6.1.3 Air Monitoring Data

As a part of BNL's radiation protection program, it is evident that extensive monitoring of airborne radioactive dust has been regularly performed. In addition, air monitoring for tritium was performed and charcoal cartridges were used to sample for iodines. Information supporting these conclusions can be found in many captured documents. For example:

- *Health Physics Summary for 1954* describes air monitoring activities in the canal area of the reactor in 1954 (HP Summary, December 1954).
- *Airborne Contamination at the Hot Laundry* is an extensive study of airborne contamination in the Hot Laundry in 1956 (Bergin, 1956).
- *Monthly Hot Lab Reports and Progress Reports January-December 1963* is an analysis of continuous air samples at the Waste Concentration Plant in 1963 (Progress Reports, 1963)
- *Appendix on Radiation Safety for Particle Accelerators* includes air sampling as one of the exposure control methods (BNL, 1969).
- *Monthly Reports for 1973* describes air monitoring results for Building 650 (Monthly Reports, 1973).
- *Air Samples* provides results for air samples taken during an operation that welded percussion pins onto uranium plates (Lazo, 1988a).
- *Respirator Use by RCG Personnel* discusses air samples taken to verify that respiratory protection was not required (Reciniello, 1992).

Several appraisals of the air monitoring program have also been captured. A November 1961 assessment by HASL for the AEC found the air sampling records at the Pile Health Physics office were lacking in that very little air sampling information is contained in the logbooks. Few air samples were taken and only the significant results were recorded. BNL apparently agreed to address the situation, and by January 1962, it was remedied (Breslin, 1961; Breslin, 1962a). In May 1962, the air sampling program during a shutdown at the BGRR was again criticized, stating that health physics relied too much on past experience with similar operations, nose swipes, and urine samples (Breslin, 1962b). Burns & Roe was contracted by BNL to conduct an appraisal of airborne monitoring in 1991. The appraisal identified where airborne monitoring was satisfactory, where some improvements were desirable, and where airborne monitoring was not required because only small amounts of radioactivity were being used in the operations (BNL, 1990-1991a; BNL, 1990-1991b).

Although evidence of an extensive air monitoring program has been found, very few monitoring results from this program have been located. As indicated in the references above, results for a few isolated situations have been located, but data that reflect the daily air sampling results that would be needed to reconstruct potential worker exposure have not been located. This same observation was made in the HASL reviews discussed above. The evidence suggests that, in general, airborne issues at the reactors, labs, and accelerators were very infrequent, thus resulting in a casual approach to record-keeping. The inability to locate comprehensive results limits the viability of using air monitoring results in the dose reconstruction process. Therefore, further assessment of potential internal dose using air sample data will not be included in this evaluation report.

6.2 Available BNL External Monitoring Data

From the beginning of operations that may have involved radioactive material (in 1947), exposure to external radiation was monitored. Table 6-5 summarizes the period of use, type of dosimeter, MDL, and exchange period.

Table 6-5: Minimum Detectable Levels for Photon, Beta, and Neutron Dose (mrem)

Period of Use	Dosimeter	MDL (mrem)[a]	Exchange Frequency
Start-up through 1954	Multi-element film + NTA	40	Weekly Monthly
1955 through 1995	Multi-element film +NTA	30	Monthly
1996 to present	Harshaw 8814 and 8806 TLD + CR-39	10	Monthly
Start-up through 1995	NTA film[b]	~50	Weekly Monthly
1996 to present	CR-39[b]	~20	Monthly

[a] Estimated MDLs for each dosimeter in the workplace even though many doses were reported at less than the MDL.
[b] Processing done by R. S. Landauer.

Table 6-6 provides a more specific listing of the types of monitoring performed at various times throughout BNL's history, the methods/materials used, how the data were recorded, and in what manner the data are available for retrieval for creating a worker's exposure history. The table shows that BNL periodically changed the monitoring methods to adopt better technologies for performing personnel monitoring.

Table 6-6: External Dosimetry Timelines and Data Source Descriptions

Type	Dates	Description
Whole Body Badges	1947- 1965	BNL Film badges: BNL read its own data and recorded data on personnel cards.
	1965- 1984	BNL Film Badges: BNL read its own data and recorded data in a computer. These data are now available only in hard copy.
	1985- 1995	Landauer read Landauer Film Badges and stored data on their system. These data are now available on microfiche and paper monthly reports. Summary data for lifetime Dose of Record for personnel has been entered in HPRS.
	1996 –present	BNL implements TLDs, reads its own badges, and stores data in HPRS.
Ring Dosimetry	1947- 1965	BNL Ring Badges: BNL read its own data and recorded it on personnel cards.
	1965- 1984	BNL Ring Badges: BNL read its own data and recorded it in a computer. These data are available only in hard copy.
	1985- 1995	Landauer read Landauer Rings and stored data on their own system. These data are now available on microfiche.
	1996 –present	Landauer read Landauer Rings and transmitted the data to BNL. These data are stored in HPRS.
Environmental Monitoring	1947 – mid 1998	4 TLD-200 (calcium fluoride) 1cm x 1cm chips placed in a brass sphere which was then placed in a small plastic bottle with string attached.
	Mid 1998 – present	Harshaw 8807 with TLD 2211 cards.
Area Monitoring	1947- 1965	BNL Film badges: BNL read its own data and recorded it on personnel cards.
	1965- 1984	BNL Film Badges: BNL read its own data and recorded it in a computer. These data are now available only in hard copy. Landauer read Landauer Badges and stored data on their own system; these data are now available on microfiche. Summary data for personnel have been entered in HPRS.
	1996 –present	BNL implements TLDs, reads its own badges, and stores the data in HPRS.
Neutron Dosimetry	Pre-1984	BNL whole-body film badges used NTA films for neutron measurement.
	1985 - 1995	Landauer whole-body badges used combinations of NTA films, CR39, and Lexan for neutron monitoring.
	1996 - present	BNL Harshaw 8806 TLD badges used a TLD-600 element in all badges with the addition of Landauer-supplied CR39 and Lexan (discontinued after June 1997) when high-energy neutron monitoring at the Alternating Gradient Synchrotron (AGS) was desired.

Though the generally un-centralized nature of BNL's radiation monitoring program has resulted in difficulty obtaining complete historical internal monitoring data sets, external monitoring summary data are available for the entire evaluation time period with the exception of the summary report for 1971. External results for individual employees are available for 1971, but the annual summary report was not captured.

Radiation exposure data were submitted annually to the AEC/ERDA/DOE in accordance with reporting requirements. Attachment 2 displays these data (except for 1971 as noted above) and demonstrates that a significant number of workers were monitored every year. These data (from 1974 to 2007) were collected from the Annual Reports available on the DOE REMS website, and from similar annual reports found among BNL records (prior to 1974) (AEC, 1970; AEC, 1972; AEC, 1973; WBC Summary, 1960; WBC Summary, 1961; WBC Summary, 1964; Whole-Body Results, 1965-1969).

Figure 6-1 shows the dose distribution in the monitored population, indicating the maximum exposure range measured each year as well as the average exposure received by individuals with measureable exposure. Average dose data were not available in the summary reports for the years 1958-65 and 1971-73. Figure 6-1 shows that the maximum exposure range went from around 7-9 rem in the late 1950s down to around 4-5 rem from 1963 through the 1970s, and then slowly ramped down through the 1980s (2-4 rem) and 1990s (0-2 rem). Since 1990, the maximum exposure range has been 0-1 rem. For those years for which average dose data are available, the values were around 1-2 rem until 1980, after which the averages were generally below 1 rem.

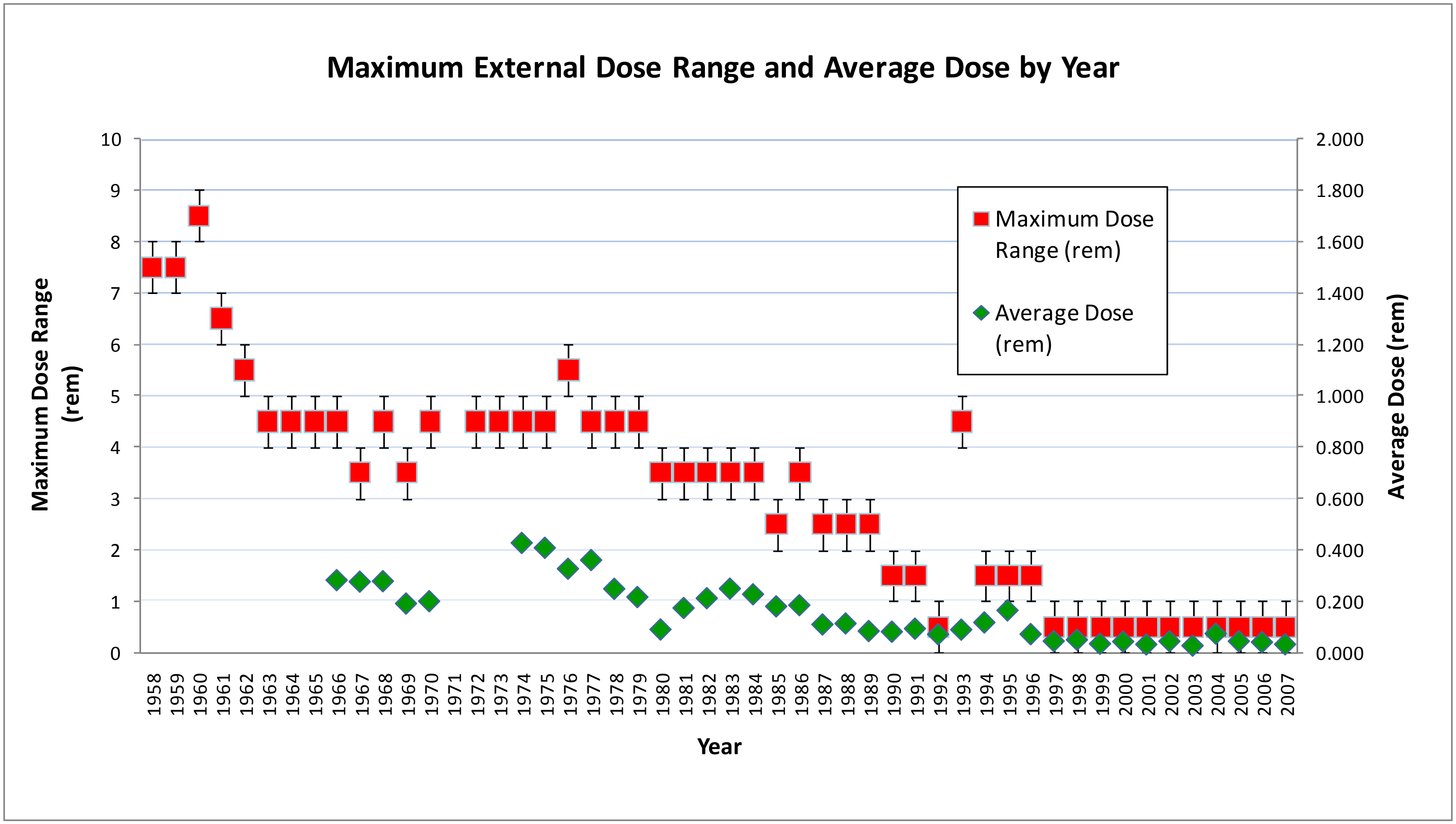

Figure 6-1: Maximum External Dose Range and Average Dose by Year

The Personnel Monitoring Policy was to provide a radiation dosimeter to all workers who had the potential to receive external exposure (HP Procedures, 1948; Personnel Monitoring, 1948; Personnel Monitoring, unknown date; Pocket Chambers, 1952; Safety Manual, 1948; Use of Dosimetry, 1995). This was implemented by designating those facilities that used radioactive materials or created radiation sources as “radiation areas” and requiring that all who entered must have a radiation dosimeter. The available records clearly indicate that this policy was being implemented throughout the operating history. However, this resulted in a segment of workers who were not externally monitored and for whom no radiation exposure records are available. This is consistent with industry practice, as there would have been workers whose duties did not require that they be near a source of radiation and would not have been expected to have received radiation exposure in the location of their normal work assignment. It should be noted that AEC/ERDA/DOE requirements specified that only those individuals expected to exceed 10% of the annual dose limit (or later, exceed 100 mrem/y) were required to be monitored. Some examples of the types of workers who may not have been monitored include: those in administrative positions whose normal work location was not in one of the facilities with radiation areas; construction trade workers whose projects were located in non-radiation areas; and engineers or scientific personnel whose duties did not require that they enter a radiation area. Personnel dosimeter monitoring data will not be available for such types of workers.

NIOSH has identified that personnel dosimeter monitoring data for reconstructing external doses are available for the entire time that BNL has been operational. The data include extensive external monitoring results, including neutron exposure data.

7.0 Feasibility of Dose Reconstruction for the Class Evaluated by NIOSH

The feasibility determination for the class of employees under evaluation in this report is governed by both EEOICPA and 42 C.F.R. § 83.13(c)(1). Under that Act and rule, NIOSH must establish whether or not it has access to sufficient information either to estimate the maximum radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class, or to estimate the radiation doses to members of the class more precisely than a maximum dose estimate. If NIOSH has access to sufficient information for either case, NIOSH would then determine that it would be feasible to conduct dose reconstructions.

In determining feasibility, NIOSH begins by evaluating whether current or completed NIOSH dose reconstructions demonstrate the feasibility of estimating with sufficient accuracy the potential radiation exposures of the class. If the conclusion is one of infeasibility, NIOSH systematically evaluates the sufficiency of different types of monitoring data, process and source or source term data, which together or individually might assure that NIOSH can estimate either the maximum doses that members of the class might have incurred, or more precise quantities that reflect the variability of exposures experienced by groups or individual members of the class as summarized in Section 7.5. This approach is discussed in OCAS’s SEC Petition Evaluation Internal Procedures which are available at http://www.cdc.gov/niosh/ocas.

The next four major subsections of this Evaluation Report examine:

- The sufficiency and reliability of the available data. (Section 7.1)
- The feasibility of reconstructing internal radiation doses. (Section 7.2)
- The feasibility of reconstructing external radiation doses. (Section 7.3)
- The bases for petition SEC-00113 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of BNL Data

ATTRIBUTION: Section 7.1 and its related subsections were completed by Tim Adler, Oak Ridge Associated Universities. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

This subsection answers questions that need to be asked before performing a feasibility evaluation. Data Pedigree addresses the background, history, and origin of the data. It requires looking at site methodologies that may have changed over time; primary versus secondary data sources and whether they match; and whether data are internally consistent. All these issues form the bedrock of the researcher's confidence and later conclusions about the data's quality, credibility, reliability, representativeness, and sufficiency for determining the feasibility of dose reconstruction. The feasibility evaluation presupposes that data pedigree issues have been settled.

Personnel monitoring oversight organization at BNL has changed several times during the period under evaluation. The following is a brief summary of oversight history; additional details are available within captured documents, including some organization charts. Initially, the Health Physics Division was responsible for providing general monitoring guidance and health physicist oversight personnel. Within the division, this was accomplished by the "Personal Monitoring Group" which, through its dedicated health physicists, had responsibility for determining monitoring requirements, and data evaluation, reporting, and maintenance. Monitoring sample analysis has been performed by both off site services and also on site by Analytical Services (a group within the Health Physics Division). Later, the Health Physics Division became the Safety and Environmental Protection Division (S&EP) and then finally into the Radiological Control Division (RadCon). Whole-body counting services were provided by the Medical Division until 1980 when that function was consolidated with other personnel monitoring under the S&EP Division. The transition was in part a result of criticisms from S&EP personnel that whole-body counting was not occurring as requested, records were seemingly getting misplaced, and that the Medical Division "does not specifically provide for diagnostics or the follow-up of positives" (Hull, 1979; Cohn, 1980).

Hundreds of documents retrieved from the site indicate the presence of a skilled and dedicated health and safety work force at BNL for the period under evaluation. Based on interviews and review of captured documents, it is apparent that workers dealing with known sources of potential exposures were monitored commensurate with the identified significance of the exposure. Unfortunately, sufficient data may not be retrievable to demonstrate that this was the case for all employment periods. Captured documents provide examples of how new potential exposure sources were characterized prior to determining monitoring/shielding requirements, and show that incidents were addressed with appropriate follow-up measurements. Extensive documentation of incidents also appears to have been an integral part of BNL's culture for the evaluation time frame. Additionally, monitoring-data-report consistency checks, where possible, have indicated no consistency problems. It is noteworthy that, for the majority of BNL's operating history, available monitoring records exist primarily in hard copy form only. The potential for inconsistencies between original and succeeding record storage media is therefore minimized.

Despite evidence supporting adequate BNL worker monitoring practices, NIOSH identified two aspects of BNL data pedigree that have potential to impact data sufficiency for bounding doses for the class under evaluation: (1) the determination of the total quantity and type of internal monitoring data actually collected over the years (data availability); and (2) the current retrievability of that data. Difficulty in assessing these two pedigree characteristics result from trends in BNL data collection and storage during the period evaluated in this report. Specifically, difficulties result from the decentralized nature of internal monitoring data storage, and the lack of centralized electronic databases until the incorporation of the Health Physics Record System beginning in 1996 (see Section 6.0). Data still reside in several different locations at BNL, including individual workers' monitoring files and medical files, log books, microfiche, and in memos and other miscellaneous documents that have been collected from many on-site locations and then indexed to applicable workers by name and BNL "Life Number." Most of the collection and indexing work has been completed, but some of this work is still ongoing.

Per interviews conducted with current BNL Personnel Monitoring Group staff, radiation exposure record storage can be broken into three general time periods. From 1947-1970s, BNL maintained an individual file folder by name for each monitored employee for the purpose of storing hard copies of monitoring results. Interviewees noted that during this time frame, in some cases, records indicating bioassay sample collection may have been filed without including the actual bioassay results. From the 1970s-1980s, limited electronic record keeping was started for some BNL monitoring datasets. BNL's decision to leave the electronically-reported data stored as such resulted in a somewhat reduced use (and completeness) of the individual file folders. That is, though the electronically reported data are available, hard copies of this information were not typically placed within the individual file folders during this period. From the 1990s to the present, record maintenance has become more systematic and more electronically-based. This is most evident from 1996 forward with the initiation of the HPRS record-keeping system.

It is apparent that the inconsistency and timeliness with which hard copy internal monitoring results were placed directly into respective personnel monitoring files created a potential compromise of the currency and ultimate completeness of at least some employees' internal monitoring records. This evaluation, as well as information provided by BNL interviewees, indicates that BNL's historical handling of hard copy internal records could potentially have some effect on older data retrievability as recently as the early 1980s. Focused data capture work performed by NIOSH (described below) indicates that the effects from 1980 forward are likely minimal; however, the effects on pre-1980 data retrievability may be significant.

NIOSH addressed the inability to readily obtain comprehensive historical monitoring data availability summaries by conducting much more extensive data capture and data entry activities than is typically necessary for DOE-operated facility evaluations (see Table 7-1, *BNL Data Capture Summary*). To date, NIOSH has captured and reviewed over 2800 documents from BNL and other sources. From these captured documents, NIOSH has extracted and electronically recorded over 9,000 urinalysis results, almost 2,000 whole-body counting results, 5,900 tritium doses, and whole-body counter channel-by-channel printouts for 3,000 measurements located in log books. Whenever noted in the documents, employee work group information was also recorded to best assess the appropriateness of monitoring being performed. In addition, NIOSH performed two data capture events focused specifically on retrieving selected workers' monitoring data to further define data availability and retrievability. These efforts and the resulting conclusions are described in more detail below.

Table 7-1: BNL Data Capture Summary

Dates of Visit*	Brief Summary of Captured Information Types
7/6/2009 – 7/9/2009	Medical and personnel monitoring files for selected past and present employees. Files included whole body counts, exposure investigations, tritium bioassay data, personnel contamination reports, and external exposure with some neutron data.
6/29/2009 - 7/2/2009 (Kansas City Records Center)	HP and exposure investigations, urinalysis, and external exposure information for various employees (from within employee medical files).
5/18/2009 - 5/21/2009 (Kansas City Records Center)	Whole-body counts, urinalysis, and external exposure information for various employees (from within employee medical files).
5/11/2009 - 5/15/2009	Internal dosimetry information from members of the Evaluation Team's sample group, tritium exposure reports, liquid scintillation counter printouts with chains of custody for tritium bioassay samples, tritium monthly dose input sheets from 1979 to 1986.
2/17/2009 - 2/20/2009	Bioassay data for selected employees, tritium report with bioassay data and calculated doses, reactor operations monthly reports, Landauer tritium dose summary, High Flux Beam Reactor (HFBR) operational history and brief history, HFBR tritium and heavy water losses, the HFBR hazard category reduction justification, Alternating Gradient Synchrotron (AGS) operational history and bioassay Technical Basis Document (TBD), and the site annual technical reports from 1949-1970.
1/12/2009 - 1/23/2009	Station monitoring worksheets (1949-1969), whole-body count logbooks, visitors' bioassay, tritium documents, whole-body counts results, and whole-body count histories.
11/12/2008 - 11/21/2008	Whole-body counting protocol, environmental and bioassay results, memos regarding thorium powder metallurgy, current and historical BNL Personnel Monitoring procedures and supporting memos.

Table 7-1: BNL Data Capture Summary	
Dates of Visit*	**Brief Summary of Captured Information Types**
10/19/2008 - 10/31/2008	Whole-body counting, urinalysis, bioassay records, exposure records, medical injury reports, radiological investigations. Data capture included inventory of Brookhaven's Safety and Environmental Protection Group records.
9/15/2008 - 9/26/2008	Radiological control procedures, exposure reports, radiological incidents, whole-body counts, neutron/proton information, glove box surveys, environmental monitoring procedures, hot laundry review, X-ray exposure information, HP/Chemistry monthly progress reports, urinalysis data, neutron surveys and data sheets. Data capture included inventory of Brookhaven's Safety and Environmental Protection Group records.
8/10/2008 - 8/23/2008	Urine sample results (1952 through 1975), whole-body count results (1970s to 1980s), monthly reports (HP, IH, environmental protection, building safety), radiation surveys, bonnersphere measurements/neutron calculations, 5480.11 implementation, RadCon manual implementation plans and reports of noncompliance, air monitoring, dose summaries, effluent releases. Data capture included inventory of Brookhaven's Safety and Environmental Protection Group records.
3/27/2006 - 3/30/2006	Various employees were questioned by reviewers and documents were provided to be scanned.
2/27/2006 – 2/4/2006	Various employees were questioned by reviewers and documents were provided to be scanned.

* Unless noted otherwise, data capture events took place at Brookhaven National Laboratory.

7.1.1 Internal Monitoring Data Pedigree Review

Only brief assessments of data availability and pedigree were possible for the electronically-stored internal monitoring data associated with the 1990s forward (see Sections 6.1 and 6.2). As of the date of this evaluation, recently-retrieved datasets from BNL continue to be reviewed by NIOSH. As with earlier years, BNL's post-1980s monitoring was based on exposure potential and overseen by health physics professionals. In addition, BNL adopted DOE's RadCon Manual monitoring requirements in 1992. Continued centralization of data management and retention was also still occurring. Interviews with BNL data management personnel noted little likelihood of data retention/retrievability problems with this later era.

Based on its assessment, as documented in this report, NIOSH has identified sporadic issues with obtaining personnel monitoring data over all BNL years; however, NIOSH has identified a significant deficiency in BNL internal data availability/retrievability for the years prior to 1980. As discussed in this report, 1980 corresponds with a period when monitoring program records-management changes were implemented at the site.

<u>Assessing Data Availability from Captured BNL Documents</u>

As noted, BNL's varied methods of maintaining hard copy internal monitoring records prior to the 1990s have complicated pedigree determination for this era. To initially assess data availability, internal monitoring analytical data were extracted during the review of over 2,300 documents captured by May 2009. These data summaries have been presented in Tables 6-3 and 6-4 in this report. To better determine data availability, two additional data capture efforts were performed (yielding over 400 more documents). The resultant captured data were summarized only in terms of numbers of people/monitoring type/year. These latter data summaries are presented individually in succeeding subsections. They were also combined with earlier data capture information and presented in Attachment 1.

The summarized results can at best provide an indication of total BNL monitoring data availability. The only way to determine the actual total hard copy data availability would be to access and compile data from each and every employee's files as well as from other hard copy repositories BNL has used over the years; that level of effort has not been performed as part of this evaluation. Evaluation time constraints precluded this level of effort. Despite the limitations, the data captured are sufficient to provide support of some basic BNL monitoring program characteristics noted above and to give some insight into potential data availability for the class under evaluation. Although NIOSH cannot confirm the ability to consistently retrieve BNL personnel internal monitoring data prior to 1980, the data summarized in Attachment 1 indicate that:

- BNL workers have been monitored for internal exposures since at least 1949 forward.
- Monitoring results were documented and reported to oversight personnel.
- Workers engaged in higher internal-exposure-potential jobs (Reactors, BLIP, Hot Lab, Waste Disposal) appear to have been monitored more frequently than those in lower-exposure-potential positions
- Uranium and mixed fission product urinalysis drops off after the BGRR shuts down and the HFBR starts up (with resultant increased H-3 analysis for HFBR workers)
- Over time there has been a trend towards an increased use of whole-body counting versus urinalysis to monitor BNL workers.

<u>Two-Hundred-Person Monitoring Data Capture Exercise</u>

NIOSH performed additional data capture focused specifically on obtaining employee monitoring data from BNL personnel files. This was done to expand the data availability knowledge that resulted from the general document capture work described above. Additionally, efforts were made to assess BNL data storage practices over time and also to gauge BNL's progress in its ongoing effort to collect and file hard copy personnel monitoring information that is not currently stored in employee-specific files. Preferably, a random sampling of names would have been chosen from the BNL's Human Resources Database. NIOSH access to this database was denied by BNL due to Privacy Act concerns; therefore, NIOSH selected 200 BNL employees' names from over 2300 names identified in previously-captured documents for this BNL data capture and retrievability exercise/assessment. The sample size reflected the maximum deemed possible for a single data-capture event and was developed to include people from various workgroups and apparent employment times represented in the evaluation period.

All data available for the selected employees were captured from BNL's two primary hard copy data repositories: (1) employees' personal monitoring (PM) files; and (2) employees' medical files. Comparisons were made to data that already existed for some of the selected 200 workers in NIOSH's existing Excel spreadsheet. Comparisons were also made to BNL's "Historical Bioassay Index." This index is used to link a growing collection of miscellaneous hard copy data being recovered from various on-site locations (i.e., other than employees' PM and medical files). The captured monitoring data were assessed and reviewed to compile data availability summaries for the 200-person sample group.

Attachment 3 presents the 200-person data availability summary in terms of number of people monitored/year/analysis. Data from employees in the same work groups were totaled. To reduce the table size, selected work groups were also compiled. As with the previous work, the results are still just an indicator of total data availability and are limited by not having access to precise individual employment time frames and/or changes in work groups over time. Results shown in Attachment 3 generally reflect the trends seen in the summary of data initially compiled from the documents captured prior to May 2009. It is evident that at least some additional internal monitoring data are available within workers' monitoring and medical files and that higher-exposure-potential activities were monitored.

Attachments 4, 5, and 6 present data type captured versus the storage repository in which it can be found by year. The purpose of these plots was to get an indication of historical data storage techniques and the relative presence of data in "expected" locations such as PM or medical files versus the amount of data obtained from less-secure locations, such as those being searched for compilation into the Historical Bioassay Index. It is important to note that identical results can be and often are found in more than one repository. An additional purpose of these plots was to assess BNL progress towards collection of miscellaneous hard copy records into the more retrievable and secure Historical Bioassay Index. To this end, data extracted from NIOSH's initial document capture work was compared to data found during the 200-person exercise. Results of the numbers of employees with data found by NIOSH and not yet located in that employees' PM files, medical files, or Historical Bioassay Index were plotted. These latter results are denoted in the Attachments as *"[data type]* NIOSH Captured Documents not Matched to Index, Medical or PM files."

As seen in the Attachments, tritium data storage seems to be much more consistently stored in the PM and medical files after the late 1960s. Trends in the storage of other urinalysis and whole-body counting data are not as clear. It is apparent, however, that most data are found stored in the PM and medical files from 1970 forward regardless of data type. Plots of data captured by NIOSH that have not yet been assimilated into BNL's primary storage repositories shows at least some collection and filing work remains to be performed by BNL. Peaks observed for this latter data type are most often attributed to individual documents containing multiple employees' results.

Sixty-Nine-Person Requested Monitoring Data Retrieval Test

NIOSH performed a final focused data capture to assess BNL's historical monitoring program performance based on specific documented monitoring requests. The goal was to perform a test that would provide an indication of the program's ability to execute requested monitoring, document the results, and preserve the results in a readily-retrievable manner over time. To this end, NIOSH again used captured documents to identify specific names and requested monitoring that spanned the years 1948-1992 (the time frame most likely to exhibit record retention problems). After selection, NIOSH searched for monitoring results responsive to the specific monitoring requests in the workers' personal monitoring files, medical files, and the "Historical Bioassay Index." Though this exercise was straightforward by design, unknown variables can still exist. Examples include the possibility of worker assignment changes or undocumented request modifications or cancellations made by BNL staff.

The results of this exercise are summarized in Table 7-2. Results indicate a trend towards more consistent data collection and maintenance apparent in the 1970s which continues into a high data retrieval rate by 1980. This trend may be related to the general trend towards better monitoring data storage practices seen in the 200-person exercise. It is also likely evidence that shifting the whole-body counting responsibilities from the Medical Division to the S&EP division contributed to the improved record maintenance practices sought by BNL at that time. Centralization and improved control over personnel monitoring sample collection, analyses, follow-up work, and records maintenance were all goals of this reorganization (Hull, 1979; Cohn, 1980).

Table 7-2: Sixty-Nine-Person Requested Monitoring Data Retrieval Test

Request Time Span	Data Available in BNL files?		Percent Success	Comments
	Yes	No		
1992	11	0	100	All requests were WBC.
1980 - 1989	12	1	92	One WBC request counted as not found because data that were found were 18 months after the request date. Five requests included urinalysis along with WBC and the urinalysis results were not found (see discussion below).
1973 - 1979	12	4	75	All requests were WBC.
1968	0	12	0	All requests were WBC.
1950	2	9	18	Pre-WBC; all requests were for urinalysis.
1948, 1949	0	6	0	Pre-WBC; all requests were for urinalysis.

Results of this exercise indicate that data collection and retention in readily-accessible storage locations has been very good from 1980 forward. The only "missing" whole-body count was from 1980. It was counted as missing because the closest result was 18 months after the request. Also noteworthy are five urinalysis results from the 1980s that were not found. Follow-up discussions with BNL data management personnel indicated that four out of the five requests were likely in error as whole-body counting would have been the analysis of choice for the listed isotopes of interest during the 1980s. The fifth request was for Pu. It is possible that the likelihood of exposure may have been revisited due to a lack of research with Pu during this time frame. Exposure to Pu was possible during remedial work associated with sealing the BGRR vents and ductwork, but this work was completed many years prior. It is also possible that the missing sample result exists but is still awaiting incorporation into the worker's file. Whether or not this sample was ever collected or analyzed is unknown.

NIOSH concludes that the BNL internal monitoring data pedigree is sufficient to bound doses for the evaluated class from January 1, 1980 through December 31, 2007. This conclusion is based on the results of extensive data capture, document reviews, interviews, and extra data availability and retrieval investigations performed. Prior to 1980, less-centralized control of sample analyses and record maintenance have apparently comprised the retrievability of BNL internal monitoring records.

7.1.2 External Monitoring Data Pedigree Review

External radiation exposure was performed by a single organization (generally called Personnel Monitoring) throughout BNL's operating history. This group was responsible for processing the dosimeters and maintaining the records of personnel radiation exposure. Consequently, there is continuity to these records and they are still retrievable. The records are maintained in hard copy for the period prior to 1986, on microfiche for the period 1986-1995 (when an off-site vendor processed the dosimeters), and on the BNL HPRS database from 1996 to the present.

The adequacy of the dosimeter to monitor the radiations encountered in BNL operations was well documented, particularly for the NTA film during the early accelerator operations with very unusual radiation energies. Film was used as the dosimetry medium until 1996. An off-site vendor was used to process the film from 1986-1995. That off-site vendor continues to process the CR-39 used for higher-energy neutrons. BNL processed the TLDs that were used from 1996 to the present. BNL achieved dosimetry DOELAP accreditation in 1995 and has subsequently maintained accreditation through the present day, which is a demonstration of the satisfactory external dosimetry program at the site.

All workers with a significant potential for workplace radiation exposure were issued dosimeters. Workers who entered a radiation area were required to wear a radiation dosimeter. A radiation area was defined as any area where a worker could receive more than 10 mrem in a day. Workers who used radioactive materials in areas where the exposure was expected to be less than 10 mrem in a day were also recommended to wear a radiation dosimeter. With this set of procedures in place, there would have been a population of workers that did not enter radiation areas or work with radioactive materials who would not have been monitored.

There has been continuity in the external radiation exposure monitoring program throughout BNL's operating history. The appropriate workers were monitored with an appropriate dosimeter and their records are retrievable for the entire evaluation time frame. External monitoring records requested for monitored BNL claimants have consistently been supplied. Based on NIOSH's assessment of BNL external dosimetry, the results of its extensive data captures and document reviews, and interviews with BNL personnel, NIOSH concludes that the BNL external monitoring data pedigree is sufficient to bound doses for the class under evaluation over the entire covered period.

7.2 Evaluation of Bounding Internal Radiation Doses at BNL

ATTRIBUTION: Section 7.2 and its related subsections were completed by Eugene Potter, M.H. Chew & Associates. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The principal sources of internal radiation doses for members of the class under evaluation were:

- Operation and maintenance of nuclear reactors and accelerators
- Production of radioactive isotopes in reactors and accelerators
- Chemical separations of radioactive isotopes
- Research activities with radioactive isotopes
- Medical diagnosis and treatment with radioactive isotopes
- Fabrication, maintenance, and repair of ancillary equipment
- Waste management activities

The potential internal sources were dependent on the operational area and activities. The major sources of intakes have been fission products, activation products, and tritium. The records list a wide spectrum of radionuclides that were monitored, including transuranics. Many of the radionuclides apply to a small set of workers on a research project or to workers (e.g., radiation monitoring technicians) whose tasks could have exposed them to many different sources (ORAUT-TKBS-0048, Section 2.0).

The following subsections address the ability to bound internal doses, methods for bounding doses, and the feasibility of internal dose reconstruction.

7.2.1 Evaluation of Bounding Process-Related Internal Dose Data

The following subsections summarize the extent and limitations of information available for reconstructing the process-related internal doses of members of the class under evaluation.

The primary sources of internal radiation doses for members of the class under evaluation were inhalation of fission products, activation products, and tritium. There is no electronic database of bioassay records for most of BNL's history. Unlike the external monitoring records, bioassay records were not collected in a single location at the BNL site. The hard copy records recovered by NIOSH include urine bioassay data analyzed for fission products, strontium, tritium, uranium, plutonium, polonium, iodine, and cesium. There are also some gross alpha and gross gamma results.

Multiple data capture efforts have taken place to support this evaluation. These efforts have gathered data from BNL, DOE Germantown, Lee's Summit, DOE Grand Junction, Kansas City Federal Records Center, and Atlanta NARA. Hundreds of boxes of health physics records have been found pertaining to the BNL covered time period. Records include: monthly progress/status reports, environmental monitoring reports, investigation and incident reports, dose rate and contamination surveys, exposure/dose reports, whole body/thyroid counting results, urinalysis reports, and employee termination bioassay reports.

It is clear from these efforts that comprehensive health physics programs were in effect at BNL during the 1947-2007 time period. From BNL's onset, a Radiation Safety Committee (RSC) was formed to establish rules for the safe handling of radioactive materials (BNL, 1947). A Safety Manual was published and changed as necessary to promulgate the rules presented in the health physics chapter. The RSC recognized that urine bioassay procedures that had previously been used at other AEC sites would be necessary as soon as the site began receiving radioactive materials (i.e., before the operation of the first reactor or accelerator). By the end of 1948, the site had already received approximately 2.5 curies distributed among 25 isotopes, and the BNL Health Physics and Instrumentation Division had supported the machining of uranium for the BGRR at Chapman Valve (Cowan, 1948).

The intention of the BNL radiological protection program was to avoid radioactive material intakes through the use of ventilation, enclosure in glove boxes and hoods, and respirators and supplied air masks. However, BNL realized that potential intakes could occur through upset conditions, such as spills, breakage of containers, or ventilation failure. Initially, contamination surveys and air samples were used to trigger the need for bioassay follow-up. For example, on December 2, 1949, two workers were sent to Medical for treatment following an incident with Sr-90. The urine samples were sent to Oak Ridge National Laboratory (ORNL) (SR-90, 1949).

During most of the site's existence, it appears that department/division safety representatives or managers designated personnel for participation in the internal dosimetry program (WBCs and/or urinalysis) based on potential exposure. Historically, lists of workers to be sampled or whole-body counted were produced. Therefore, it may be difficult to determine if monitoring should have occurred by job title. After the DOE RADCON manual was published in 1992, BNL introduced more formality into the designation of workers for participation in the bioassay program (BNL, 1991; BNL, 1992a; BNL, 1992b; BNL, 1992c).

7.2.1.1 Urinalysis Information and Available Data

In May 1949, the BNL Medical Department arranged for three plutonium urine samples per week to be sent to ORNL for analysis (HP Summary, May 1949). However, it appears that the RSC did not establish a policy of routine ("survey") bioassay until February 1950 (HP Summary, 1950). In 1959, the Medical Department's protocol was described as "People working with significant amounts of isotopes have 24 hour urinalysis for strontium mixed fission products or whatever material they are working with" (Love, 1959). Urinalyses were also done as a part of separation physical examinations (Cowan, 1949; Williams, 1963).

Initially, support was obtained from Oak Ridge National Laboratory to perform urinalysis for plutonium, polonium, mixed fission products, barium-lanthanum, yttrium, and strontium (Urinalysis Records, 1950; Urinalysis Records, January-September 1951; Urinalysis Records, February-December 1952; Urinalysis Records, 1953-1954). Bioassay services were also received from the chemistry laboratory organized under the New York Operations Office (NYOO) of the AEC (Sample Records, 1962-1963; Urinalysis Records, 1955-1964; Urinalysis Records, June 1955; Urinalysis Results, 1964; Urinalysis Records, September-November 1965). This laboratory had developed methods for dealing with the hazards arising from NYOO facilities (e.g., uranium, beryllium, fluorine, thorium, and radium) (NYOO Reports, 1949).

In the early 1950s, BNL developed its own analytical capabilities that were refined and expanded over the years. However, some types of urinalyses continued to be obtained from outside laboratories (Urinalysis Records, September-November 1965; Urinalysis Records, May 1968; Urinalysis Records, July 1968; Urinalysis Records, October 1968; Urinalysis Records, March 1969; Urinalysis Records, June 1969; Urinalysis Records, June 1987; Urinalysis Records, April 1988). In the late 1990s, BNL established a contract with Eberline for all bioassay analyses except for H-3 which remained in-house until April 2004. Eberline was replaced by the Severn-Trent (ST) Laboratory in December 2001. ST also started to do the H-3 analyses when they were discontinued on site. The ST lab has since been renamed Test America. The current BNL bioassay program is accredited by the DOE Laboratory Accreditation Program (ORAUT-TKBS-0048, Section 5.5.2).

Initially, urinalysis records were maintained with the medical records, since they were part of the "treatment" of workers as a follow-up to positive nasal swabs, contamination events, or were done as a part of physical examinations. Later, these results were collected in individual Personnel Monitoring (PM) files that also contained the external dosimetry results. Data from at least as far back as 1952 appear to have been transferred to the PM files around 1967. However, some early bioassay records may still only be located in the medical records. Some additional results may have been forwarded to the employee's group (e.g., Reactor, Accelerator) and not filed in the PM file. BNL has just within the last few years developed an index of some of this historical bioassay data. BNL now checks all three sources for information when an EEOICPA request is received. Since 2000, urine results from the contract laboratories have been stored electronically at BNL and hard copy back-ups are maintained in the site's Whole Body Counter office.

For this evaluation report, over 9,000 results were captured from various hard copy reports (termination reports, incident reports, etc.). This collection provides information on the types of urinalyses that were done over the site's history. Radionuclides routinely measured included: gross gamma, Sr-90, mixed fission products, tritium, uranium (total, natural, enriched), gross alpha, and gamma spectroscopy (primarily Cs-137 and I-131). There are also Pu-239 results, including some associated with incidents. Additional data are located in the PM files; NIOSH has captured and analyzed data for approximately 200 people from this source. The NIOSH assessment of the specific urinalysis data is discussed in the following sections.

Uranium

BNL realized that a bioassay technique for uranium would be needed as early as 1949 (Cowan, 1949). The first uranium analyses captured during this evaluation are from 1955, and were performed by NYOO. Thus, it appears that at least by 1955 uranium bioassay was a part of the bioassay program. It is not clear when an in-house capability was developed, but it appears that a fluorometric method with a detection limit of 5 μg/L was in place by 1982 (Urinalysis Records, August 1982). A "workgroup monitoring" program for uranium was proposed by Lessard in 1987 (Lessard, 1987a) where only representative workers for a work group would be sampled. NIOSH has only recovered about 464 results for a period of about 32 years (1955-1987). The majority of the samples (251) were marked routine or survey, 64 were incident samples, and 147 were not designated. The samples were collected from over 20 different work groups or locations, with the Hot Lab and Nuclear Engineering having the most. Only 46 of the samples recovered were designated specifically as EU or U-235. The following is a summary of the dates of uranium samples recovered from SRDB Documents:

- U/Total U (ug/L) 12/26/55 to 4/17/69 65 results
- U (dpm/d) 6/5/62 to 11/20/69 87 results
- Nat U (ug/L) 5/4/59 to 7/25/69 54 results
- Nat U (dpm/d) 12/16/65 to 4/23/68 22 results
- U-238 (ug/L) 4/23/55 to 2/1/87 190 results
- EU/U-235 (dpm/d) 4/9/58 to 5/6/69 43 results
- U-233 (dpm/L) 4/9/58 3 results

It is clear that many additional results may be located in the individual PM records. As some of the site's older facilities have undergone decontamination and decommissioning (D&D) starting in 2000, D&D workers were sampled for U-234, U-235, and U-238 (ORAUT-TKBS-0048, p. 75).

Fission and Activation Products

Fission product urinalyses were initially obtained from outside laboratories. By June 1951, preliminary work started on development of an in-house MFP urine procedure (HP Summary, June 1951). During the operation of the BGRR, many workers were routinely sampled for mixed fission products (Urinalysis Records, 1952-1975a; Urinalysis Records, 1952-1975b). Sampling frequency varied from as short as monthly to as long as annually. During the operation of the HFBR, the concentrations of radionuclides other than tritium were not considered to be significant. The rationale was that the concentration of tritium in the primary cooling water was several million times its "tolerance limit" whereas fission products from fuel uranium surface contamination and activated coolant impurities, such as Na-24, were present at less than 100 times tolerance (ORAUT-TKBS-0048, Section 5.5.2).

- Approximately 3200 mixed fission and activation product samples were located for the period 1950-1976. The majority of the samples are for Reactor and Hot Lab personnel. However, samples were also obtained from other groups, including (but not limited to) Health Physics, Plant Maintenance, Nuclear Engineering, Physics, and Accelerator.

- Some samples were specifically analyzed for Sr-90 (nearly all in conjunction with a fission product analysis). NIOSH has recovered over 600 Sr-90 results for the period 1949-1967. The majority of the samples are for the Reactor, Hot Lab, and Heath Physics groups.

- Urine results for Cs-137 were also recovered. These results were essentially all from the 1960s. Of the 175 results recovered, 140 were for the Hot Lab, with no other group having more than 10 results.

- Thirty-five urine results for I-131 were recovered for 1959-1969. Nearly all of these were for the Hot Lab and Health Physics groups.

Urine results recovered for other miscellaneous fission and activation products, other than those listed in this section, are summarized in Table 7-3.

Table 7-3: Urine Results Obtained for Fission and Activation Products

Radionuclide	No. of Samples	First Date	Last Date	Reason for Sample(s)
Ag-110	1	8/7/1957	8/7/1957	Incident
Au-198	3	11/19/1970	11/24/1970	Incident
Be-7	1	1/29/1980	1/29/1980	Incident
Ce-141/143	2	12/22/1975	12/22/1975	Incident
Ce-144	1	11/17/1964	11/17/1964	Survey (routine)
Co-60	9	10/10/1956	12/19/1980	1 survey; 1 incident; 7 unknown
Cs-132	2	5/22/1978	6/7/1978	Unknown
Hf/Hf-181	2	8/5/1966	8/5/1966	Incident
I-126	5	5/22/1978	7/28/1980	Unknown
Na-22	1	6/7/1978	6/7/1978	Unknown
Na-24	2	2/26/1963	2/17/1964	Incident
P-32	16	4/23/1957	4/7/1972	9 survey; 7 incident
Ra-226	1	5/18/1964	5/18/1964	Incident
Ru-103	1	4/17/1951	4/17/1951	Incident
Ru-106	1	4/21/1965	4/21/1965	Incident
Sr-82	1	3/16/1987	3/16/1987	Incident
Zn-65	1	3/29/1963	3/29/1963	Incident

Most of the samples in the table are incident-related and were not likely part of a routine program. The information in this section and Table 7-3 illustrates that BNL had the ability to sample and analyze for a great variety of radionuclides when potential intakes occurred.

It is clear that many additional fission or activation product results are located in the individual PM records. After 1960, fission and activation products can be accounted for by whole-body counting, either directly or by using ratios. As some of the site's older facilities have undergone D&D starting in 2000, D&D workers were sampled for Sr-90, (ORAUT-TKBS-0048, p. 75).

Tritium

In 1958, a vibrating reed electrometer and chambers suitable for tritium urinalysis were set up in Building T-145 (Progress Report, April 1958). By October 1959, the equipment was ready for standardization (HP Summary, October 1959). Initially, the analysis was done by combustion and gas counting. Liquid scintillation counting for tritium urinalysis was adopted in the early part of 1964 (Gemmell, 1967).

NIOSH has captured 5165 H-3 results for the period 1959-1987. Over 99 percent of the results were routine (survey) samples. Most of the samples were for the Health Physics (1058) and Reactor (3141) groups. Over 100 samples per year were recovered for 1965-1975, 1977, 1978, and 1982. Over 800 results were recovered for 1967. The data show that the samples were probably collected monthly from the mid-1960s to the early 1970s. From the late 1970s to the early 1980s, samples were collected weekly. NIOSH evaluated the number of samples recovered for HFBR workers against an estimate of the number that were probably analyzed. The references did not consistently report the number of people assigned. Indications are that there were probably up to 150-200 people who worked at or visited the reactor each month. Of these, there was probably a core group of 20-30 people regularly sampled for H-3.

For the period 1992-2000, NIOSH has captured several monthly tritium dose records. A few also have bioassay results (BNL, 1992b; BNL, 1992c; BNL, July-December 1999; Dose Report, April 1992; Dose Report, July 1995; Exposure Summaries, August-December 1992; Exposure Summaries, October 1992; Exposure Summaries, January 1993; Exposure Summaries, February 1993; Exposure Summaries, August 1993; Exposure Summaries, September 1993; Exposure Summaries, October 1993; Exposure Summaries, 1994; Exposure Summaries, November 1994; Exposure Summaries, 1995; Exposure Summaries, January-September 1995; Exposure Summaries, 1996; Exposure Summaries, 1997; Exposure Summaries, January-November 1998; Exposure Summaries, 1998-1999; Tritium Assessments, August 1993; Tritium Assessments, October-November 1993; Tritium Assessments, October-December 1993; Tritium Assessments, January-February 1994; Tritium Assessments, February-March 1994; Tritium Assessments, January-August 1994; Tritium Assessments, December 1994; Tritium Assessments, January-February 1995; Tritium Assessments, January-March 1995; Tritium Assessments, December 1996).

NIOSH has also captured tritium dose records that were maintained for the site by the R. S. Landauer Company. The date range is 1984 to July 1995. Recently, over 11,000 electronic tritium bioassay results were captured from the Analytical Services Laboratory (ASL) database for the period 1995-2003. It is clear that many additional tritium results are located in the individual PM records.

Thorium

No thorium-specific urine bioassay records were recovered. It is not clear whether additional data capture would produce any urine data. It appears that whole-body counting was the method of choice for thorium bioassay after 1959; therefore, assessment of whether sufficient information (represented by whole-body counts) exists to support bounding the thorium dose, is contained in Section 7.2.1.2.

Plutonium

Plutonium urinalyses were among the first samples requested at BNL. In May 1949, Medical arranged for three Pu urine samples/week to be sent to ORNL (HP Summary, May 1949). In 1959, Pu urinalysis services were purchased from Nuclear Science and Engineering Corp., and gross alpha analyses were being done at BNL as a check, while consideration was being given to doing the Pu analyses in-house using the Hanford method (HP Summary, November 1959). NIOSH has recovered 179 results for the period 1949-1971. Most of the results are for routine (survey) samples. The work groups for more than a third of these samples are unknown. Most of the remaining samples are for the Reactor, Hot Lab, and Health Physics groups in the early 1950s. As some of the site's older facilities have undergone D&D starting in 2000, D&D workers were sampled for Pu-238, Pu-239, and Pu-240 (ORAUT-TKBS-0048, p. 75).

Americium

Only a few Am-241 urine results have been recovered. One sample was collected in the Health Physics Group in 1958 and one from the reactor in 1959, indicating that BNL had the ability to analyze urine samples for this radionuclide. The lack of samples recovered to date may indicate that the routine operations involving Am-241 were considered to be well-controlled. However, two gross alpha results were tied to an americium incident on July 28, 1975; the incident involved "HPS students" as opposed to BNL employees. The results for both samples were given as "ND" (not detected). No other information on this incident was located. As some of the site's older facilities have undergone D&D starting in 2000, D&D workers were sampled for Am-241, (ORAUT-TKBS-0048, p. 75).

Polonium

Like plutonium, polonium was one of the earliest urinalyses requested from ORNL by BNL. NIOSH has recovered 181 results for the period 1954-1967. Most of the samples are for the Hot Lab and Nuclear Engineering and most are for the period 1954-1960. The lack of Po-210 urinalyses in later years is probably a reflection of the fact that polonium use fell out of favor across the DOE complex. Furthermore, its short half-life means that there is no residual contamination from earlier operations.

7.2.1.2 Whole Body Counting Information and Available Data

The Medical Division began using a whole-body counter at the end of 1958 (Unknown author, 1958). It was first used as a research tool, but it became evident that it was also of use when someone was potentially involved in an incident. Pile operators were the first group to be routinely counted (Cowan, 1964b, pdf p. 29; Davis, 1970). Like the urine program, facility health physicists were asked to supply lists of individuals whose jobs put them at risk for intakes of radioactive material (Various authors, September-November 1973; Whole Body Counting, 1973). After confirmed intakes, whole-body counting was repeated daily and the results were correlated with daily urine excretion results (Cowan, 1964b). Beginning in 1960, whole-body counts on BNL employees were recorded in periodic physical log books, indicating that the whole-body counter was considered operational. In the 1960s, whole-body counts were also included in the separation physical examinations for reactor operators (Davis, 1970). By 1968, over 1000 individuals had been counted and only Cs-137 and K-40 (both present in background) had been detected, with the exception of Zn-65 in some Pile operators (Cowan, 1968). There were three references located for thorium WBCs for occupational exposures (HP Summary, May 1959; Lukas, 1986; Miltenberger, 1979). An additional reference was found related to its use in medical research (Various authors, 1966).

NIOSH has recovered the logbooks for the WBCs done on approximately 1000 people from 1961-1968 (Cowan, 1968; Whole-Body Results, March-May 1963; Whole-Body Results, May-July 1963). However, data are in the form of counts per channel; they would need to be hand-entered and analyzed before they would be useful for dose reconstruction.

Starting in late 1979, S&EP took over the routine and special whole-body counts (Hull, 1978; Hull, 1979). The same counter was used to support research in the Marshall Islands. When the counter was in the Marshall Islands, the Medical facility's counter was available to support the occupational program (Cohn, 1980; Miltenberger, 1980a). For positive results in the S&EP counter, additional counts could be done with the Medical 54-detector whole-body counter to localize the contamination (Cohn, 1980). In 1987, the S&EP whole-body counter was described as "chair type system" using a 28 cm by 10 cm NaI detector that could be positioned in either a lung/thyroid or a whole-body counting geometry (Miltenberger, 1987a).

Around 1990, the site lost the use of the counter that had supported both the site and the Marshall Island programs. The fixed facility at Medical was still available, but apparently routine counts were not performed. In 1992, a new "standup" counter using high-purity germanium detectors was put into operation and counting resumed for HFBR workers. After the resumption of whole-body counting, workers were designated for counts in accordance with the DOE RADCON Manual (BNL, 1992a; BNL, 1992b). The gap may have extended to 1995 for AGS workers (Murray, 1995) who were considered to be at lower risk. In 1999, the site received DOELAP accreditation in *in vivo* counting. In 2004, the high-purity germanium detectors were replaced with broad-energy germanium detectors.

For this evaluation report, 1921 *in vivo* counts (WBC, lung, and thyroid counts) for about 680 individuals were captured from SRDB documents. Most came from tables attached to memos to S&EP representatives giving the results for employees in their areas. The primary work groups monitored were the AGS, HFBR, and Medical (laboratory) staff working in the medical isotope program, primarily with iodine isotopes. About 20 counts were found from 1960 and 1962 (not including the counts in the log books). Most of the data cover the time period from 1970-1989 and 1993, with none from 1990-92. Electronic data for the period 1999-2009 (ABACOS data) has recently been captured, consisting of over 2,800 counts of BNL personnel.

7.2.1.3 Other Types of Bioassay

No records of information exist to support the routine performance of chest (lung) counts at the BNL site. In 1973, the whole-body counting facility was not considered to be responsive enough to detect uranium and/or plutonium (Whole-Body Results, January-February 1973). However, some counts were performed for an off-site project with an estimated “lower limit of detection” of 1 nCi for U-235. Lung counts were also performed as a result of incidents involving certain gamma or positron emitters (Xe-127, Sr-82, Co-60) (Lessard, 1987b; Miltenberger, 1987c; Miltenberger, 1987d).

Monitoring for radioactive iodines was by urine and whole-body counting in the 1960s (Progress Reports, 1961). Some early thyroid monitoring for iodine may only be in the medical records (Personal Communication, 2008b). Routine as well as incident thyroid counts were performed starting in the 1970s (Atkins, 1974; Carter, 1976; Iodine, 1970s; Iodine Results, 1980s; Lessard, 1984a; Lessard, 1986; Lessard, 1987c; Miltenberger, 1980b; Miltenberger, 1987c; Thyroid Count Results, July-August 1981; Thyroid Count Results, January 1988a; Thyroid Count Results, January 1988b; Thyroid Count Results, January 1988c; Thyroid Count Results, February 1988; Thyroid Count Results, March 1988a; Thyroid Count Results, March 1988b; Thyroid Count Results, October 1988; Whole-Body Results, July-August 1978; Whole-Body/Thyroid Results, 1984-1985; Whole-Body/Thyroid Results, January 1986). Only one person who did iodinations was on a thyroid counting program in 2006 (ORAUT-TKBS-0048, Section 5.6.2).

7.2.1.4 Evaluation of Bounding Process-Related Internal Dose Data Summary

NIOSH’s data capture efforts have revealed that no conclusive evidence exists to support the ability to consistently retrieve BNL personnel bioassay prior to 1980 for uranium, MFP, MAP, plutonium, and americium; however, after January 1, 1980, urinalyses for these radionuclides have been identified in the BNL files and are available to NIOSH to support bounding potential doses for the post-1979 portion of the class under evaluation. NIOSH also has no conclusive evidence that polonium bioassay are sufficiently retrievable prior to 1980. By January 1, 1980, significant research with polonium had ended; therefore, further evaluation of the ability to bound polonium internal dose will not be performed for this report. After January 1, 1965, tritium urinalyses have been identified in the BNL files and are available to support bounding the tritium dose for the post-1964 portion of the class under evaluation.

Retrievability of other types of bioassay data is similar to that determined for urinalyses. No conclusive evidence exists to support the ability to consistently retrieve *in vivo,* chest (lung) counts, or thyroid counts prior to 1980. After 1980, *in vivo* counts are available in BNL files to support bounding assessments for penetrating gamma-emitters (e.g., Cs-137, Co-60), uranium, thorium, and americium/plutonium dose assessment. Chest and thyroid counts are similarly available to support bounding dose for the post-1979 portion of the class under evaluation.

7.2.2 Evaluation of Bounding Ambient Environmental Internal Doses

The BNL ambient air-monitoring program began in 1950. The annual environmental surveillance reports summarize yearly results. Stack release points and principal radionuclides in the airborne effluent are contained in the annual reports. These data are described in detail in ORAUT-TKBS-0048, Section 4.0. For its entire history, BNL monitored workers entering radiological areas with external dosimeters. Workers who were not monitored for external dose would not have received internal dose associated with hazards in the operational areas. NIOSH can assess potential internal doses for these non-radiological workers through the assignment of ambient environmental intakes. Although the ambient environmental internal dose would be accounted for in the available post-1979 operational data and information, sufficient information is available to support evaluating ambient environmental internal dose for the entire covered period for the BNL site.

7.2.3 Methods for Bounding Internal Dose at BNL

ATTRIBUTION: Section 7.2.3 and its related subsections were completed by Eugene W. Potter, M. H. Chew & Associates, Inc. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

7.2.3.1 Methods for Bounding Process-Related Internal Dose

Intakes to monitored workers may be estimated using the available *in vitro* and/or *in vivo* data for the specific radionuclides that were analyzed, which is generally recognized in this report as available starting in 1980. Therefore, these post-1979 intake estimates may then be used to bound post-1979 doses from those radionuclides, using the methodologies described in the BNL TBD (ORAUT-TKBS-0048). Because pre-1980 personnel internal monitoring data cannot be reliably obtained from the site, the assessment of the ability to bound the pre-1980 process-related internal dose is not included here. The following subsections summarize the extent and limitations of information available for reconstructing the process-related internal doses of members of the class under evaluation.

Uranium

Based on NIOSH's assessment of BNL, there are questions concerning the retrievability of the data due to the lack of a centralized records repository at the BNL site and the random nature that data and documentation has been discovered during data captures and site visits to support this SEC. However, from 1980 forward, *in vivo* and *in vitro* data can be used to support bounding uranium dose.

If the isotopic information is not available, NIOSH can bound the doses to uranium by assuming a bounding mass-to-activity conversions for fluorometric urine results, and fully-enriched uranium for radiometric results.

Fission Products and Activation Products

Starting in 1980, it appears that S&EP filed the BNL personnel WBCs counts in the PM files, which includes WBC data for MFP and MAP. ORAUT-OTIB-0054 discusses mixed fission product/mixed activation products ratios and the calculation of intakes based on a single nuclide (e.g., Cs-137). The dose calculation for an organ of interest would take into account the differences in biokinetics between the two radionuclides.

For I-125, the recovered thyroid counts start in 1981. After 1974, workers who were not monitored for radioactive iodine were unlikely to be exposed.

Tritium

For 1965-1999, the most prevalent urine bioassay sampling was tritium for workers employed at the HFBR. During HFBR operation, the concentrations of radionuclides in the moderator other than tritium were not considered to be significant.

For the period 1965-1983, NIOSH has captured from 70 to over 800 results per year from documents along with additional results from PM files. For the Period 1984-1995, NIOSH has obtained the dose reports for every worker monitored for H-3 (Tritium Assessments, 1984-1995). For the period 1992-1999, NIOSH has recovered other dose reports for the HFBR and MRR workers (see Section 7.2.1.1.). Using these data, NIOSH could recover sufficient H-3 data from the individual PM files and the ASL data to bound tritium dose for 1965-1999. For 2000 to present, urine results from the contract laboratory also have been captured.

Exposures to tritiated water and/or vapor (HTO) and gaseous tritium (HT) were the most prevalent forms of tritium exposure at BNL. Organically-bound tritium (OBT) would have been encountered only in locations where biological research with labeled compounds was conducted, primarily Medical and Biology. Exposures to the stable metal tritide (SMT) form of tritium may have been encountered as the result of the storage of tritium adsorbed on rare metals, particularly as accelerator targets. On a case-by-case basis, intakes of OBT and SMT compounds may be bounded using the methodologies outlined in ORAUT-OTIB-0066. For workers at Biology, Medical, and Chemistry, the doses to H-3 can be bounded by assuming the form is either HTO or OBT, whichever results in the highest dose to the organ of interest. Similarly, for workers at the accelerators, H-3 doses can be bounded by assuming the form is either HTO or SMT, whichever results in the highest dose to the organ of interest. Historically zirconium tritide was the compound used in the targets (Progress Report, April 1958, pdf pp.3-4). Workers at the HFBR and the MMR reactors represent the largest population monitored for H-3. The doses to these workers can be bounded by assuming the form is HTO. Workers at the BGRR were unlikely to be exposed to significant concentrations of other H-3 compounds. Therefore, NIOSH concludes that the H-3 dose to all workers can be bound for the period 1965-present.

Thorium

It appears that the remaining post-1980 thorium work at BNL was the 1986 work involving relatively small amounts encountered in geothermal research (thorium in "magma") (Lukas, 1986).

No post-1980 thorium-specific urine bioassay results were captured for this report.

It is unclear whether additional data capture would provide much WBC data for thorium. From the information gathered for this report, NIOSH concludes that the few workers exposed to thorium were monitored by whole-body counting and that, after January 1980 when the S&EP took over the WBC program, the counts were filed in the workers' PM files. Therefore, NIOSH concludes that WBCs can be used to bound the doses for thorium for 1980-1996. An inventory of dispersible radioactive material in 1997 indicated that only microcurie amounts of thorium were still on site (Flores, 1998). Therefore, NIOSH concludes that intakes were unlikely for the period 1997-2007.

Plutonium

Whole-body counting is not an effective method of detecting intakes of plutonium at the levels of interest for internal dosimetry. Although some MDAs were located for the various systems, it was not until the addition of broad-energy germanium detectors to the stand-up whole-body counter in 2004 that *in vivo* counting could detect reasonably low levels of plutonium indirectly by counting Pu-241's daughter, Am-241, in a chest-counting configuration. Therefore, NIOSH concludes that, for most of the site's post-1979 history, doses from plutonium cannot be bounded by whole- body counts.

The lack of plutonium urinalysis results recovered for 1972-1999 is an indication that there was probably very little plutonium research in this time frame. Therefore, NIOSH concludes that plutonium intakes were unlikely for the period 1972-1999. As some of the site's older facilities have undergone D&D starting in 2000, D&D workers were sampled for Pu-238, Pu-239, and Pu-240 (ORAUT-TKBS-0048). After 2000, urine results are available electronically and have been captured. Therefore, NIOSH concludes that, after January 1, 1980, sufficient monitoring data and dose reconstruction methods are available to bound plutonium dose at BNL.

Americium

Whole-body counting with NaI detectors or high-purity germanium detectors is not an effective method of detecting intakes of americium at the levels of interest for internal dosimetry. It was not until the addition of broad-energy germanium detectors to the stand-up whole-body counter in 2004 that *in vivo* counting could detect reasonably low levels of Am-241 in a chest-counting configuration. Therefore, NIOSH concludes that, for most of the site's post-1979 history, doses from americium cannot be bounded by whole- body counts.

As some of the site's older facilities have undergone D&D starting in 2000, D&D workers were sampled for Am-241 (ORAUT-TKBS-0048). After 2000, urine results are available electronically and have been captured. Therefore, NIOSH concludes that, after January, 1980, sufficient monitoring data and dose reconstruction methods are available to bound americium dose at BNL.

Polonium

Whole-body counting cannot be used to detect or bound the doses to polonium.

NIOSH has determined that polonium intakes after 1980 were unlikely. An inventory of dispersible radioactive material in 1997 indicated that only microcurie amounts were still on site (Flores, 1998).

Incidents

Incidents often resulted in requests for special bioassays (see Section 5.2.3 for a summary of the incident-related data). In such cases, these bioassay results may be used to support bounding intake estimates for the exposure situations/conditions associated with the incidents using the internal dose reconstruction methods defined in the BNL TBD (ORAUT-TKBS-0048).

7.2.4 Internal Dose Reconstruction Feasibility Conclusion

Prior to January 1, 1980, the whole-body counts necessary to bound the doses from gamma-emitters were frequently not performed as requested. In addition, the site's system for filing results of WBCs and urinalyses was inconsistent, leading to uncertainty regarding the complete retention and availability of the monitoring records. NIOSH concludes in this evaluation that sufficient *in vitro* and *in vivo* bioassay data are available to support bounding internal dose for members of the proposed class for the period January 1, 1980 to December 31, 2007.

7.3 Evaluation of Bounding External Radiation Doses at BNL

The principal sources of external radiation doses for members of the proposed class were BNL particle accelerators, nuclear reactors, and laboratory facilities (ORAUT-TKBS-0048). Potential radiation exposure to workers included beta particles, X-rays and higher-energy photons, and a wide energy range of neutrons.

The following subsections address the ability to bound external doses, methods for bounding doses, and the feasibility of external dose reconstruction.

7.3.1 Evaluation of Bounding Process-Related External Dose Data

ATTRIBUTION: Section 7.3.1 and its related subsections were completed by Paul Ruhter, M. H. Chew & Associates, Inc. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The following subsections summarize the extent and limitations of information available for reconstructing the process-related external doses of members of the class under evaluation.

7.3.1.1 Personnel Dosimetry Data

From the beginning of BNL operations, the measurement of radiation dose was an integral part of an extensive radiation safety monitoring program intended to assure worker protection. Portable radiation instruments, pocket ionization chambers, and personnel dosimeters were used to evaluate radiation fields, establish appropriate controls to minimize personnel exposures, and monitor and document personnel exposures.

Phillips provides an extensive description of the film badge in use at BNL and its capabilities (Phillips, 1974). The BNL badge was adopted from the Martin Marietta badge used at Oak Ridge National Laboratory. As described in ORAU-TBKS-0048, BNL processed the film badges on site until 1985, at which time they began using a vendor-processed film badge. The DOE Laboratory Accreditation Program accredited a BNL TLD badge in 1995. In 1996, the film badge was replaced by the TLD badge; the TLDs were processed on site (Loesch, 1995). The film and TLD badges were designed to monitor all the radiations types anticipated to exist at BNL (i.e., photon, beta, and neutron).

Attachment 2 presents radiation exposure data was submitted annually to the AEC/ERDA/DOE, as required. These data were collected from the Annual Reports available on the DOE REMS website (from 1974 to 2007), and from similar annual reports found among BNL records (prior to 1974) (AEC, 1970; AEC, 1972; AEC, 1973; Annual Report, 1961; WBC Summary, 1960; WBC Summary, 1964; Whole-Body Results, 1965-1969). The data show the dose distribution in the worker population, indicating the maximum exposure measured each year as well as the average exposure received by the workers with measureable exposure.

Photon

Personnel exposure monitoring data were kept on a separate card for each employee for each year (Cowan, 1964b). As indicated in ORAUT-TKBS-0048, the radiation exposure assigned to each monitored worker was recorded in this fashion until 1995. From 1996 to the present, radiation exposure records have been kept on the Health Physics Record System (HPRS), a computerized database. These records are available, and when adjusted for missed dose and the dosimeter uncertainty correction factor (as defined in ORAUT-TKBS-0048), represent an adequate basis for bounding BNL radiation exposures. Numerous “termination” reports or dose histories can be found in the documents obtained from BNL. In particular, two of these dose histories demonstrate the ability to assemble dose histories in 1981 and 1992 that stretched back throughout the history of BNL (Dosimetry History, 1949-1981; Dosimetry History, 1962-1992). External radiation exposure was monitored and the data were collected in a retrievable manner.

Although a large fraction of the worker population was monitored for external radiation exposure, there clearly was a portion unmonitored. This is to be expected because some portions of the BNL staff would have been assigned to work in areas not associated with radioactive materials or radiation areas, and therefore, they would not have been required to be monitored. The annual statistics for external exposures are presented in Attachment 2.

As of August 11, 2009, 64 EEOICPA claims meeting the class definition under evaluation had been returned from DOE with supporting information. For 43 of those 64 claims, DOE has provided external dose data that essentially cover the period(s) of employment specified by the claimants. Consequently, when compared with the data being provided by DOE, the number of employees with and without external exposure information appears consistent with the historical number of employees who were monitored and unmonitored.

As discussed in ORAUT-TKBS-0048, it also appears that all workers were issued dosimeters from start-up through 1954. However, after 1954, it was the policy that employees who were unlikely to exceed 10% of the annual limit (later, exceed 100 mrem/y), or who did not enter radiation areas, were not monitored. Based on this information, NIOSH concludes that the external photon dose for unmonitored individuals is bounded by the maximum exposure scenario represented by the monitored workers. ORAUT-TKBS-0048 contains the applicable monitored and unmonitored worker dose reconstruction methodology applicable to the completion of individual claims for the BNL site.

Based on the information available on the BNL monitoring program and the available monitoring data, NIOSH concludes that sufficient data are available to bound photon doses for the class under evaluation.

Beta

The preceding general discussion about personnel dosimetry and record-keeping applies equally well to the beta component of the dosimeter data. The beta dosimeters used throughout BNL history were sensitive to, and calibrated to, beta energies likely to be encountered at BNL. Extremity and wrist dosimeters were also used when it was deemed appropriate due to the radiation fields in the working environment. On occasion, special dosimeters were worn to monitor non-routine work that resulted in "significantly non-uniform doses to various areas of the whole body" (Sengupta, 2000). The special dosimeters were worn without the regular dosimeter. The highest dose measured by any of the special dosimeters was the dose of record. All of these dosimeters would have recorded any exposure to beta radiations. Extremity and wrist badge results are also available and can be used to supplement the reported dosimeter skin dose, as applicable.

The monitoring records were retained and should be available in the employee files. The missed dose and bias/uncertainty factors described in ORAUT-TKBD-0048 should be applied. With these adjustments, the data available should be sufficient to establish a bounding beta/shallow dose estimate for the class under evaluation.

Neutron

The preceding general discussion about personnel dosimetry and record-keeping applies equally well to the neutron dosimeter. The neutron doses were measured with NTA film from start-up through 1995, when it was replaced with the TLD. High-energy particles would create spallation products that would produce stars on the NTA film; the total number of prongs on the stars was counted, and the resulting dose, generally using 10 mrem/prong, was added to determine the total neutron dose.

In addition, starting in the mid-1980s, CR-39 and Lexan were also used in neutron dosimetry. The use of CR-39 continued after 1995. The CR-39 and Lexan were analyzed by an outside vendor (Lexan, 1988).

Numerous references attest to the appropriateness of the personnel neutron dosimetry used at BNL. Cowan discussed the adequacy of the dosimeter to radiation fields encountered at the AGS and concluded it was “fail safe” for the radiations typically found at the accelerators (Cowan, 1964a). Throughout BNL history, the evaluation of the film always assumed a QF or RBE of 10. The NTA film was known by BNL to under-respond to the low-energy neutrons that would have been more prevalent at the reactors; this was the best available technology at the time. The Cd-shielded portion of the film badge was also used as an indication of low-energy neutron exposures. The correction factors provided in ORAUT-TKBS-0048, Table 6-7, appropriately account for this known under-response. The dosimetry in place in the mid-90s and later successfully passed the DOELAP Performance Tests, demonstrating its adequacy for personnel monitoring applications.

Unmonitored workers were those who would not have been assigned to work in posted radiation areas. Neutrons do not constitute a significant exposure source in the natural environment; a source is required to generate neutrons, be it a radioactive source, an accelerator, or a reactor. Since these sources were normally well-controlled at BNL (i.e., inside posted radiological control areas), the unmonitored worker would not have been exposed to neutron sources or received neutron exposures. Consequently, neutron exposures are not applicable for unmonitored workers.

NIOSH’s review of the available dosimetry data identified some gaps in the neutron exposure records for some monitored workers. An internal audit of radiation surveys at the Physics Department noted that the NTA film was always "processed," but only "read" (the labor-intensive part of the process) if: (a) the beta-gamma dose was >100 mrem; (b) the Cd area indicated a thermal neutron exposure; or (c) the individual was on the special list (based on neutron exposure potential) prepared by an area HP (Gollon, 1982). The auditor noted that only half a dozen personnel out of 32 actually had neutron doses in the two previous years. Based on NIOSH’s reviews, the criteria used at BNL seem reasonable considering the common dosimetry practices for the time period under evaluation. For the purpose assessing these data gaps in support of bounding neutron doses for applicable members of the class under evaluation, gaps in monitoring records can be assessed as “zero” dose results rather than unmonitored periods.

The monitoring records were retained and are available in the employee files based on DOE-provided records for claims. The missed dose and bias/uncertainty factors described in ORAU-TKBD-0048 should be applied. With these adjustments, the available data should be sufficient to establish a bounding neutron dose estimate for the class under evaluation.

7.3.1.2 Area Monitoring Data

Area monitoring results have been discovered in the BNL data capture process. However, the available documents do not cover all facilities for all time frames. The ready availability of personnel monitoring data obviates the need for area monitoring data.

7.3.2 Evaluation of Bounding Ambient Environmental External Doses

ATTRIBUTION: Section 7.3.2 and its related subsections were completed by Paul Ruhter, M. H. Chew & Associates, Inc. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

ORAUT-TKBS-0048 provides a discussion and method for evaluating the Ambient Environmental External Dose at BNL. This information is sufficient for evaluating potential external dose in the case of dose reconstruction for unmonitored workers. However, for the purpose of the bounding assessment in this evaluation, NIOSH concludes that the ambient environmental dose is included in the available dosimetry data, which represent the bounding external exposure scenario for the BNL class under evaluation. Therefore, further assessment of the ambient environmental dose is not included in this report.

7.3.3 BNL Occupational X-Ray Examinations

The frequency of required X-ray examinations differed over the years. This information should be in the individual worker file provided by DOE along with notations regarding both the date and the purpose of the exam. BNL records also will indicate the exam view (ORAUT-TKBS-0048).

7.3.4 Methods for Bounding External Dose at BNL

ATTRIBUTION: Section 7.3.4 and its related subsections were completed by Paul Ruhter, M. H. Chew & Associates, Inc. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

There is an established protocol for assessing external exposure when performing dose reconstructions (these protocol steps are discussed in the following subsections):

- Photon Dose
- Beta Dose
- Neutron Dose
- Medical X-ray Dose

7.3.4.1 Methods for Bounding Operational Period External Dose

Photon Dose

Photon doses for monitored workers have been measured with sensitive dosimeters throughout BNL's history (see Section 7.3.1.1). BNL workers were required to wear film badges when entering a "radiation area" and to have a neutron film in that badge when a neutron exposure was possible (Personnel Monitoring, 1948). The resultant monitoring data have been retained over the entire course of the class period. With the methods described in ORAUT-TKBS-0048, including the missed dose and bias corrections, these data permit adequate estimation of bounding photon doses for the class under evaluation.

Beta Dose

As with photon doses, beta (electron) doses for monitored workers have also been measured with sensitive dosimeters throughout BNL's history (see Section 7.3.1.1). The monitoring data have been retained over the entire duration of the class under evaluation. With the methods described in ORAUT-TKBS-0048, including the missed dose and bias corrections, these data permit estimation of bounding photon doses for the NIOSH-evaluated class.

Neutron Dose

The dosimetry used to monitor neutron exposures reflected the state-of-the-art technology available during BNL operations. The limitations were known and discussed in the documents collected at BNL. ORAUT-TKBS-0048 provides correction factors that make appropriate adjustments for these limitations. The monitoring data are available for the monitored workers. Neutron exposures should not be included for unmonitored workers.

Medical X-ray Dose

The Medical records discussed in Section 7.3.3 are being made available through the claims process, and therefore, should be sufficient to provide a bounding estimate of any doses associated with medical X-ray procedures. ORAUT-OTIB-006, *Dose Reconstruction from Occupational Related Diagnostic X-Ray Procedures*, provides a bounding approach for those individuals for whom no Medical Records are available.

7.3.5 External Dose Reconstruction Feasibility Conclusion

The data sources for photon, beta, and neutron doses, as well as occupational X-ray examinations and ambient environmental external doses, have been examined and found to be adequate for bounding external doses for monitored BNL workers. The assessment of doses for unmonitored workers can be determined from the ambient environmental external dose methods defined in ORAUT-TKBS-0048. Based on NIOSH's assessment of the available external data and the dose calculation methods available in ORAUT-TKBS-0048, NIOSH concludes that it is feasible to bound external dose for the class under evaluation.

7.4 Evaluation of Petition Basis for SEC-00113

ATTRIBUTION: Section 7.4 and its related subsections were completed by Tim Adler, Oak Ridge Associated Universities. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The following subsections evaluate the assertions made on behalf of petition SEC-00113 for the Brookhaven National Laboratory.

7.4.1 No or Insufficient Internal Monitoring

SEC-00113: *To the best of my knowledge there was no internal monitoring for some individuals at Brookhaven National Laboratory and insufficient internal monitoring for the class in the early 1980's.*

NIOSH has identified information to corroborate the petitioner claim that for some members of the class under evaluation, neither personnel nor area monitoring was performed. It is expected that no internal monitoring would be necessary for work assignments with no internal exposure potential. Strong evidence exists that members of the evaluated class who performed work with internal exposure potential were monitored appropriately and a portion of the resultant data has been captured. Though it is evident that internal monitoring was performed as necessary for the class under evaluation, there is uncertainty regarding the complete retention and availability of radiation monitoring records necessary to bound doses prior to 1980.

7.4.2 Badge Overexposure Incident

SEC-00113: …*was involved in an incident during that time. He came home one day to tell me that a person inspecting the badges wanted to know where he had been because his badge was overexposed. He mentioned that during one of the experiments on the equipment he maintained, the warning light system indicating a radioactive area had not been activated and he was in the area repairing some malfunction. He also mentioned that the equipment that he (was) repairing was still "hot."*

NIOSH obtained and reviewed the claimant's monitoring records, but was unable to locate any records that indicated an overexposure. The available records show that the claimant was consistently monitored for external radiation for the duration of his employment at BNL. There are no gaps evident in the available monitoring record. Additionally, all external monitoring results were very low, usually below detection limits.

7.5 Summary of Feasibility Findings for Petition SEC-00113

This report evaluates the feasibility for completing dose reconstructions for employees at the Brookhaven National Laboratory from January 1947 through December 2007. NIOSH found that the available monitoring records, process descriptions and source term data available are sufficient to complete dose reconstructions for a portion of the evaluated class of employees.

Table 7-4 summarizes the results of the feasibility findings at Brookhaven National Laboratory for each exposure source during the time period January 1947 through December 2007.

Table 7-4: Summary of Feasibility Findings for SEC-00113
January 1, 1947 through December 31, 2007

Source of Exposure	Reconstruction Feasible	Reconstruction Not Feasible
Internal[1]		**X**[2]
H-3	X (1/1/1965-12/31/2007)	X (1/1/1947-12/31/1964)
Mixed Fission Products (MFP) and Mixed Activation Products (MAP)	X (1/1/1980-12/31/2007)	X (1/1/1947-12/31/1979)
Th-232	X (1/1/1980-12/31/2007)	X (1/1/1947-12/31/1979)
Uranium	X (1/1/1980-12/31/2007)	X (1/1/1947-12/31/1979)
Plutonium	X (1/1/1980-12/31/2007)	X (1/1/1947-12/31/1979)
Am-241	X (1/1/1980-12/31/2007)	X (1/1/1947-12/31/1979)
Po-210	X (1/1/1980-12/31/2007)	X (1/1/1947-12/31/1979)
Other	X (1/1/1980-12/31/2007)	X (1/1/1947-12/31/1979)
External	**X**	
- Gamma	X	
- Beta	X	
- Neutron	X	
- Occupational Medical X-ray	X	

[1] Internal includes an evaluation of urinalysis (*in vitro*), airborne dust, and whole-body count data (*in vivo*).

PARTIAL DOSE RECONSTRUCTION INFORMATION:

[2] INTERNAL: NIOSH will make use of any available internal monitoring data (that can be interpreted/evaluated using existing TBD methodologies) to support partial DRs from 1947 through 1979 for claims with non-presumptive cancers and those with less than 250-days of employment.

As of August 11, 2009, a total of 92 claims have been submitted to NIOSH for individuals who worked at BNL and are covered by the class definition evaluated in this report. DOE has not yet responded with BNL data to 28 of these claims. Dose reconstructions have been completed for 28 of the 64 individuals for which BNL response is available (44%).

8.0 Evaluation of Health Endangerment for Petition SEC-00113

The health endangerment determination for the class of employees covered by this evaluation report is governed by both EEOICPA and 42 C.F.R. § 83.13(c)(3). Under these requirements, if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, NIOSH must also determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. Section 83.13 requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for a number of work days aggregating at least 250 work days within the parameters established for the class or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

NIOSH has determined that there is uncertainty with regards to the retention and retrievability of BNL internal monitoring data prior to January 1, 1980. NIOSH's evaluation determined, therefore, that it is not feasible to estimate radiation dose with sufficient accuracy for members of the NIOSH-evaluated class employed before January 1, 1980 based on the sum of information available from available resources. Modification of the class definition regarding health endangerment and minimum required employment periods, therefore, is required.

9.0 Class Conclusion for Petition SEC-00113

Based on its full research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class to be added to the SEC includes all employees of the Department of Energy, its predecessor agencies, and its contractors and subcontractors who worked at Brookhaven National Laboratory in Upton, New York, from January 1, 1947 to December 31, 1979, for a number of work days aggregating at least 250 work days, occurring either solely under this employment, or in combination with work days within the parameters established for one or more other classes of employees in the Special Exposure Cohort. The class under evaluation was reduced because of data retention and retrievability uncertainties prior to 1980.

NIOSH has carefully reviewed all material sent in by the petitioner, including the specific assertions stated in the petition, and has responded herein (see Section 7.4). NIOSH has also reviewed available technical resources and many other references, including the Site Research Database (SRDB), for information relevant to SEC-00113. In addition, NIOSH reviewed its NOCTS dose reconstruction database to identify EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation.

These actions are based on existing, approved NIOSH processes used in dose reconstruction for claims under EEOICPA. NIOSH's guiding principle in conducting these dose reconstructions is to ensure that the assumptions used are fair, consistent, and well-grounded in the best available science. Simultaneously, uncertainties in the science and data must be handled to the advantage, rather than to the detriment, of the petitioners. When adequate personal dose monitoring information is not available, or is very limited, NIOSH may use the highest reasonably possible radiation dose, based on reliable science, documented experience, and relevant data to determine the feasibility of reconstructing the dose of an SEC petition class. NIOSH contends that it has complied with these standards of performance in determining the feasibility or infeasibility of reconstructing dose for the class under evaluation.

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Attachment 1: BNL Internal Data Analysis Matrix

(This table spans four pages)

Internal Data Analysis

Number of Employees Monitored per Year by Work Group and Specific Analysis

WBC and Urinalysis Results (SRDB, PM and Medical Files)

	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	Total
Reactor - BGRR & Pile[1]		**1950 to 1968; exhaust fan/filter until 1972**																																																			
Reactor - HFBR[1]																	**1965 to 1996**																																				
WBC												24	1	1										2	18	19	18	8	20	14	20	40	45	20		68	57	46	12	70	32	9		1	83	80	7	6	2	5	2	4	734
UA Gross & MFP		2	1	35	27	41	45	34	71	59	34	55	62	51	38	41	24	34	14	14	11	7																															700
Sr-90						2	27	7	3	1	2	10	31	24	16	13	6		2																																		144
H-3										1	1	2	3	2	2	17	19	31	35	28	24	22	15	17	16	15	13	12	8	9	9	9	9	9	7	8	5	7	8	7	11	9	8	8	6	5							417
U Less EU							1		1	1	9	11	2	8	10		1	2	5	4	6																																61
EU/U-235										1		1	1	1	3		1																																				8
Gross alpha												1	4	2																																							7
Po-210										2		3	1																																								6
Pu/Pu-239	4	14	17	1							1								2																																		39
I-131																	1																																				1
Gamma																					2	7																															9
Cs-137														1	1	1	1																																				4
Misc Bioassay[6]				2					2	3	5	7	3	5	8	8	6	9	6	3	5	4						1						1		1																	79
Other RA[4]											1					2											1																										4
	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	Total
Hot Lab, Medical & BLIP			**1951 to present (Hot Lab & Medical)**																					**1972 to present (BLIP)**																													
WBC																						1		4	8	14	14	1	3	4	4	11	16	5	6	23	1	25	23	16	18	3	1	2	9		2	2		1	3	2	222
UA Gross & MFP			1	1	5	5	26	20	17	16	33	21	29	35	38	27	33	30	25	19	9	7	8	2	8	1																											416
Sr-90							4	2	2		2	2	4	4	16	7	1	1	4																																		49
H-3[5]											2	2	1	2	1		4	7	9	7	4	4	8	6	14	1	5	3	4	4	3	3	3	1			1	1	1	2	3	3	2	1	1								113
U Less EU									7		9	4	2		12	4	8	2	5	2	3																																58
EU/U-235															1		1																																				2
Gross alpha											1	1	5	6	6		2																																				21
Po-210						3	13	9	4	2	3	2	1	1				1																																			39
Pu/Pu-239	2		6													1	3	2				1	1																														16
I-131														2	1	7	5		1																																		16
Gamma																			2	19	9	7	8	3	8		1																										57
Cs-137																6	30	25	18	1																																	80
Misc Bioassay[6]										1	3	1	4	4	4	4	3	4	2	3	1	1	3		2	1	5	3	2	1		1	1	1	1		2	1		1	2	2	1										65
Other RA											1					2											1																										4
	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	Total

Attachment 1: BNL Internal Data Analysis Matrix (cont.)

(This table spans four pages)

HP, S&EP & Waste	Assumed activities from 1949 to present																																																			
WBC												2												1	4	21	7		1	3		15	15	1	5	18	11	21	35	16	20			1	14	4							215
UA Gross & MFP		1	1	5	11	24	14	10	14	12	12	15	12	14	15	12	10	16	10	4	7	3		1				1																										224
Sr-90	1	1				2	10	5	7	5	2	3	4	4	9	5	1	3	1																																			63
H-3									1	1	1	1	1	1	1	2	9	9	16	15	13	14	8	9	4	5	3	5	4	4	4	4	4	3	2	2	3	2	3	2	2	1		1	1								161
U Less EU										1	2	1		1	6			1			5																																17
EU/U-235													1																																								1
Gross alpha																											2																										2
Po-210								6				2				1																																					9
Pu/Pu-239		1	6								1				4				2			3																															17
I-131											1					1	3	1			2																																8
Gamma																			1	3	6	4		1			2	1					3		1	1	1		2														26
Cs-137																			4																																		4
Misc Bioassay[6]				1						3	2	1	1	1		1	1	2			1		1	1				1										2			1	1											21
Other RA			1						1	1					1																					6																	10
	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	Total
Accelerators (AGS, TVDG)	1960 to present (AGS)																					1970 to present (TVDG)																															
WBC																					2			1	5	2	7	3		9	1	13	13		2	2	20		33		27			1		1							142
UA Gross & MFP				1	1	1	1	1	1		1		2	2	1	2	4	2	1		2																																23
Sr-90							1							1																																							2
H-3																	1	1	1	1					2																												6
U Less EU															2		1				1																																4
EU/U-235																	2																																				2
Gross alpha																																																					N/A
Po-210																																																					N/A
Pu/Pu-239			1														1																																				2
I-131																1					1																																2
Gamma																					2		1																														3
Cs-137																1	3	1																																			5
Misc Bioassay[6]																							1																		1	2					1						5
Other RA																																																					N/A
	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	Total

Attachment 1: BNL Internal Data Analysis Matrix (cont.)

(This table spans four pages)

DAS & Nuclear Engineering[2]		Assumed activities from 1949 to present																																																			
WBC																									5	3	3	2	1		2	11	19	1	8	24	1	22	24	17	25	4		1	1								174
UA	Gross & MFP				3	3	13	12	63	8	17	21	27	14	22	20	7	1	14	21	7	5	6	8	3	6	3	5																									309
	Sr-90							7	4	1	2	5	3	2	3	7	2			1																																	37
	H-3																1		7		7	2	1	11	5	8	3	10	5	6	3	4	2		2		2		2	1	1	2	2	1										88
	U Less EU							1		2		11	16	3	8	25	6	1	16	16	7	11																																123
	EU/U-235												1			8	1	2	1	1		1																																15
	Gross alpha											3	6	8		5					3							1																										26
	Po-210						12	2	13				12	3			1		1	1																																		45
	Pu/Pu-239		6	6								2										1	1																															16
	I-131													1																																								1
	Gamma										1						1			2	15	15	5	7	4	6	3	4																										63
	Cs-137															1		1	2	1	1																																	6
	Misc Bioassay[6]							1		1		2	2	2	2	3	3	2	4	2	1		1	4		1		2	2					1	2	1			3	3	2	2	1	1										51
	Other RA								1	1					1																		1				13																	17
		49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	Total
Chem., Biology & Physics		Assumed activities from 1949 to present																																																			
WBC																									1	1	2	2			4		4			1	3	9	2	5													34
UA	Gross & MFP		1	1	1			2		3	5	1	10	6	4	5	2	5	1	3		4																																54
	Sr-90		1								1		1	4	1	3																																						11
	H-3															1	1	2		13	11	10	5	3			1	1																										48
	U Less EU												2			3		3																																				8
	EU/U-235										1							1	1																																			3
	Gross alpha												3			2																																						5
	Po-210						1			3			1				1	1																																				7
	Pu/Pu-239		6																																																			6
	I-131																																																					N/A
	Gamma																					1																																1
	Cs-137																																																					N/A
	Misc Bioassay[6]															1	1		1					1			1															1												6
	Other RA									3													1		1																	1												6
		49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	Total

Attachment 1: BNL Internal Data Analysis Matrix (cont.)

(This table spans four pages)

Plant Eng./Maint. & Shops	Assumed activities from 1949 to present																																																			
WBC																										1			1				5			5	2	7	6	1	60	5				1	1				1		96
UA Gross & MFP					1	5	11	8	31	12	7	12	29	33	40	32	20	13	11	17	12	9																															303
Sr-90							3	5	4	1		2	9	8	11	3																																					46
H-3																1	5	4	12	10	12	19	1	2	3	1	1	1	1	2	3	2	2	2			1	1	2	2	3	3	1	1	1	1							100
U Less EU											2	1			3	1			3	2	1																																13
EU/U-235													1				2																																				3
Gross alpha																																																					N/A
Po-210										1		2			1	1																																					5
Pu/Pu-239																																																					N/A
I-131																																																					N/A
Gamma																				14	10	8																															32
Cs-137																			1																																		1
Misc Bioassay[6]														1	2	2	2	2	2	2	1	1																1		1	1	1											19
Other RA																																				3																	3
	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	Total
Other Work Groups[3]	**Assumed activities from 1949 to present**																																																			
WBC													1		3										5	16	2	3	8	1	1	4	1		10	6		1		2	44						1						109
UA Gross & MFP				13	4	11	14	2	2	1	1	1		1	1	1	1										1																										54
Sr-90	1	1					3									1																																					6
H-3													1							2		1	2	1	2		1				1						1		2														14
U Less EU							1		6		5	9	2	2	10	1		5	3	3	5																		3														55
EU/U-235								1					2	3			2																																				8
Gross alpha																																																					N/A
Po-210						2	3	1																																													6
Pu/Pu-239	3	15	34	1											1																																						54
I-131																																																					N/A
Gamma																											1				1		4						2														8
Cs-137																1																1																					2
Misc Bioassay[6]																																																					N/A
Other RA									1																					1						16																	18

Notes: Represents operational time frame per BNL TBD Table 2-2.

1) Reactor includes all reactor work groups (BGRR, Pile, and HFBR); overlapping years of operation (1965-1969) may be BGRR/Pile or HFBR.
2) DAS-CA-NE includes the work groups Dept. of Applied Science, Critical Assembly, Nuclear Engineering, Cosmotron, Instrumentation, Metallurgy, Fuel Fission, LMFR, Research, Support & Materials, and Bldgs 192, 197 & 480.
3) Other Work Groups includes AEC, Administrative, Management, PEP, Security, Technical Photo, Underwater Rig, Marshall Island, Visitor, Bldg 100, and Unknown groups.
4) Includes three fecal samples for one employee in 1975.
5) Includes one seminal fluid sample for a Medical worker in 1963.
6) Misc bioassay includes data found in PM and Medical files; only one result/person per year was counted (may have more than one analyses per sample).

Attachment 2: Number of Persons Monitored Each Year at BNL

(This table spans six pages)

Year	Monitoring Status	Total Not Monitored	Total Number Monitored	Number with Meas. Dose	Total Collective Dose (TEDE in person-mrem)	Average Meas. Dose (TEDE in mrem)	No Meas. Exposure	<1000	1000 - 1999	2000 - 2999	3000 - 3999	4000 - 4999	5000 - 5999	6000 - 6999	7000 - 7999	8000 - 8999
2007	Employee		2058	184	6004	33	1874	184	0	0	0	0	0	0	0	0
2007	Public		137	6	266	44	131	6	0	0	0	0	0	0	0	0
2007	Govt Agency		25	1	7	7	24	1	0	0	0	0	0	0	0	0
2006	Employee		2031	144	5968	41	1887	144	0	0	0	0	0	0	0	0
2006	Public		127	3	139	46	124	3	0	0	0	0	0	0	0	0
2006	Govt Agency		11	0	0	0	11	0	0	0	0	0	0	0	0	0
2005	Employee		2346	214	10190	48	2132	214	0	0	0	0	0	0	0	0
2005	Public		162	2	26	13	160	2	0	0	0	0	0	0	0	0
2005	Govt Agency		10	0	0	0	10	0	0	0	0	0	0	0	0	0
2004	Employee		2461	297	23650	80	2164	297	0	0	0	0	0	0	0	0
2004	Public		164	4	28	7	160	4	0	0	0	0	0	0	0	0
2004	Govt Agency		14	0	0		14	0	0	0	0	0	0	0	0	0
2003	Employee		1731	247	11270	46	1484	247	0	0	0	0	0	0	0	0
2003	Terminated		2203	53	819	15	2150	53	0	0	0	0	0	0	0	0
2003	Govt Agency		51	3	69	23	48	3	0	0	0	0	0	0	0	0
2003	Public		150	3	25	8	147	3	0	0	0	0	0	0	0	0
2002	Employee		1896	335	23364	70	1561	335	0	0	0	0	0	0	0	0
2002	Terminated		2495	88	2599	30	2407	88	0	0	0	0	0	0	0	0
2002	Public		211	13	248	19	198	13	0	0	0	0	0	0	0	0
2002	Govt Agency		70	3	33	11	67	3	0	0	0	0	0	0	0	0
2001	Employee		1952	270	11507	43	1682	270	0	0	0	0	0	0	0	0
2001	Terminated		2718	108	2863	27	2610	108	0	0	0	0	0	0	0	0
2001	Public		299	6	151	25	293	6	0	0	0	0	0	0	0	0

Attachment 2: Number of Persons Monitored Each Year at BNL (cont.)

(This table spans six pages)

Year	Monitoring Status	Total Not Monitored	Total Number Monitored	Number with Meas. Dose	Total Collective Dose (TEDE in person-mrem)	Average Meas. Dose (TEDE in mrem)	No Meas. Exposure	<1000	1000 - 1999	2000 - 2999	3000 - 3999	4000 - 4999	5000 - 5999	6000 - 6999	7000 - 7999	8000 - 8999
2001	Govt Agency		79	3	106	35	76	3	0	0	0	0	0	0	0	0
2000	Active		1776	311	18081	58	1465	311	0	0	0	0	0	0	0	0
2000	Govt Agency		2583	58	2175	38	2525	58	0	0	0	0	0	0	0	0
2000	Terminated		1007	56	1927	34	951	56	0	0	0	0	0	0	0	0
2000	Visitors		90	3	153	51	87	3	0	0	0	0	0	0	0	0
2000	Govt Agency		28	2	48	24	26	2	0	0	0	0	0	0	0	0
1999	Active		1821	320	16664	52	1501	320	0	0	0	0	0	0	0	0
1999	Terminated		631	79	3767	48	552	79	0	0	0	0	0	0	0	0
1999	Non-Emp Rad		2672	110	2800	25	2562	110	0	0	0	0	0	0	0	0
1999	Visitors		472	10	113	11	462	10	0	0	0	0	0	0	0	0
1999	Govt Agency		57	2	27	14	55	2	0	0	0	0	0	0	0	0
1998	Active		2236	533	52777	99	1703	533	0	0	0	0	0	0	0	0
1998	Non-Emp Rad		2758	466	8866	19	2292	466	0	0	0	0	0	0	0	0
1998	Terminated		155	25	941	38	130	25	0	0	0	0	0	0	0	0
1998	Visitors		381	25	232	9	356	25	0	0	0	0	0	0	0	0
1998	Govt Agency		66	6	149	25	60	6	0	0	0	0	0	0	0	0
1997	Active		2483	629	54142	86	1854	629	0	0	0	0	0	0	0	0
1997	Non-Emp Rad		2735	772	13588	18	1963	772	0	0	0	0	0	0	0	0
1997	Terminated		91	27	798	30	64	27	0	0	0	0	0	0	0	0
1997	Visitors		675	35	420	12	640	35	0	0	0	0	0	0	0	0
1996	Active		2449	719	92652	129	1730	714	5	0	0	0	0	0	0	0
1996	Non-Emp Rad		3384	717	23569	33	2667	716	1	0	0	0	0	0	0	0
1996	Terminated		94	12	550	46	82	12	0	0	0	0	0	0	0	0
1995	Active		1851	505	88215	175	1346	498	7	0	0	0	0	0	0	0
1995	Non-Emp Rad		537	191	35347	185	346	191	1	0	0	0	0	0	0	0

Attachment 2: Number of Persons Monitored Each Year at BNL (cont.)

(This table spans six pages)

Year	Monitoring Status	Total Not Monitored	Total Number Monitored	Number with Meas. Dose	Total Collective Dose (TEDE in person-mrem)	Average Meas. Dose (TEDE in mrem)	No Meas. Exposure	<1000	1000 - 1999	2000 - 2999	3000 - 3999	4000 - 4999	5000 - 5999	6000 - 6999	7000 - 7999	8000 - 8999
1995	Visitors		275	246	17438	71	29	246	0	0	0	0	0	0	0	0
1995	Terminated		188	31	4840	156	157	31	0	0	0	0	0	0	0	0
1994	Active		1945	443	66230	150	1502	438	5	0	0	0	0	0	0	0
1994	Visitors		217	215	13660	64	2	215	1	0	0	0	0	0	0	0
1994	Non-Emp Rad		631	189	11340	60	442	189	0	0	0	0	0	0	0	0
1994	Terminated		203	18	1050	58	185	18	0	0	0	0	0	0	0	0
1993	Active		1971	462	50070	108	1509	459	2	0	0	1	0	0	0	0
1993	Non-Emp Rad		587	116	6030	52	471	116	0	0	0	0	0	0	0	0
1993	Visitors		124	120	3150	26	4	120	0	0	0	0	0	0	0	0
1993	Terminated		123	15	650	43	108	15	0	0	0	0	0	0	0	0
1992	Active		2129	440	43090	98	1689	440	0	0	0	0	0	0	0	0
1992	Non-Emp Rad		1185	512	14740	29	673	512	0	0	0	0	0	0	0	0
1992	Terminated		121	19	810	43	102	19	0	0	0	0	0	0	0	0
1992	Visitors		2	2	50	25	0	2	0	0	0	0	0	0	0	0
1991	Active		1977	602	69430	115	1375	597	5	0	0	0	0	0	0	0
1991	Non-Emp Rad		787	276	15790	57	511	275	1	0	0	0	0	0	0	0
1991	Visitors		133	122	3310	27	11	122	0	0	0	0	0	0	0	0
1991	Terminated		97	19	960	51	78	19	0	0	0	0	0	0	0	0
1990	Active		1888	613	60450	99	1275	611	2	0	0	0	0	0	0	0
1990	Non-Emp Rad		723	319	22960	72	404	319	0	0	0	0	0	0	0	0
1990	Visitors		355	349	8580	25	6	349	0	0	0	0	0	0	0	0
1990	Terminated		114	36	1910	53	78	36	0	0	0	0	0	0	0	0
1989	Active		1809	860	98578	115	949	848	10	2	0	0	0	0	0	0
1989	Non-Emp Rad		684	368	20700	56	316	368	0	0	0	0	0	0	0	0
1989	Terminated		163	76	4700	62	87	76	0	0	0	0	0	0	0	0

Attachment 2: Number of Persons Monitored Each Year at BNL (cont.)

(This table spans six pages)

Year	Monitoring Status	Total Not Monitored	Total Number Monitored	Number with Meas. Dose	Total Collective Dose (TEDE in person-mrem)	Average Meas. Dose (TEDE in mrem)	No Meas. Exposure	<1000	1000 - 1999	2000 - 2999	3000 - 3999	4000 - 4999	5000 - 5999	6000 - 6999	7000 - 7999	8000 - 8999
1989	Visitors		538	527	14510	28	11	526	1	0	0	0	0	0	0	0
1988	Active		1900	801	116000	145	1099	786	13	2	0	0	0	0	0	0
1988	Visitors		927	642	33000	51	285	641	1	0	0	0	0	0	0	0
1987	Active		1849	964	133000	138	885	938	25	1	0	0	0	0	0	0
1987	Visitors		941	657	37000	56	284	652	5	0	0	0	0	0	0	0
1986	Employee		1817	771	173000	224	1046	738	25	8	0	0	0	0	0	0
1986	Visitors		705	444	38000	86	263	442	1	0	1	0	0	0	0	0
1985	Employee		1808	1019	219000	215	789	968	42	9	0	0	0	0	0	0
1985	Visitors		835	421	45000	107	183	414	7	0	0	0	0	0	0	0
1984	Employee		1772	983	249000	253	845	927	48	7	1	0	0	0	0	0
1984	Visitors		481	303	41000	135	178	300	3	0	0	0	0	0	0	0
1983	Employee		1733	854	239000	280	879	793	47	10	4	0	0	0	0	0
1983	Visitors		404	245	30000	122	159	244	0	1	0	0	0	0	0	0
1982	Employee		1775	758	174000	230	1017	730	25	2	1	0	0	0	0	0
1982			391	206	28000	136	185	204	1	1	0	0	0	0	0	0
1981	Employee		1885	1414	262000	185	471	1366	38	9	1	0	0	0	0	0
1981	Visitors		441	295	38000	129	146	293	1	1	0	0	0	0	0	0
1980	Employee		1974	1791	192000	107	183	1741	39	9	2	0	0	0	0	0
1980	Visitors		473	385	9000	23	88	381	2	2	0	0	0	0	0	0
1979	Employee		2011	1820	421000	231	191	1717	75	19	8	1	0	0	0	0
1979	Visitors		420	328	49000	149	92	319	7	2	0	0	0	0	0	0

Attachment 2: Number of Persons Monitored Each Year at BNL (cont.)

(This table spans six pages)

Year	Monitoring Status	Total Not Monitored	Total Number Monitored	Number with Meas. Dose	Total Collective Dose (TEDE in person-mrem)	Average Meas. Dose (TEDE in mrem)	No Meas. Exposure	<1000	1000 - 1999	2000 - 2999	3000 - 3999	4000 - 4999	5000 - 5999	6000 - 6999	7000 - 7999	8000 - 8999
1978	Employees		1971	1656	448000	271	315	1537	80	23	13	3	0	0	0	0
1978	Visitors		416	311	46000	148	105	307	3	1	0	0	0	0	0	0
1977	Employees		1871	1666	644000	387	205	1461	122	52	25	6	0	0	0	0
1977	Visitors		405	327	80000	245	78	311	9	7	0	0	0	0	0	0
1976	Employee		1843	1709	621000	363	134	1519	125	37	23	4	1	0	0	0
1976	Visitors		469	382	71000	186	87	#REF!	5	4	0	0	0	0	0	0
1975	All		2183	2052	839000	409	131	1823	127	56	30	16	0	0	0	0
1974	All		2108	2040	874000	428	68	1785	142	66	29	18	0	0	0	0
1973	Employee	1276		1774				1514	152	67	23	18	0	0	0	0
1973	Visitors	8000		2016				2010	5	1	0	0	0	0	0	0
1972	Employee	1239		1796				1609	100	44	16	27	0	0	0	0
1972	Visitors	9200		2444				2441	3	0	0	0	0	0	0	0
1970	Employees	1484		2132	430000	201		2021	65	20	21	5	0	0	0	0
1970	Visitors	10000		3334				3333	1	0	0	0	0	0	0	0
1969	Employees	1761		2244	431000	192		2149	60	27	8	0	0	0	0	0
1969	Visitors	14300		3732				3725	6	0	1	0	0	0	0	0
1968	Employees	1683		2358	658000	279		2174	106	30	30	18				
1968	Visitors	9800		4906				4900	6	0	0	0				

Attachment 2: Number of Persons Monitored Each Year at BNL (cont.)

(This table spans six pages)

Year	Monitoring Status	Total Not Monitored	Total Number Monitored	Number with Meas. Dose	Total Collective Dose (TEDE in person-mrem)	Average Meas. Dose (TEDE in mrem)	No Meas. Exposure	<1000	1000 - 1999	2000 - 2999	3000 - 3999	4000 - 4999	5000 - 5999	6000 - 6999	7000 - 7999	8000 - 8999
1967	Employees	1679		2479	687000	277		2274	144	41	20					
1967	Visitors	9100		5527				5524	3	0	0					
1966	All			3184	901000	283		2920	139	61	35	29				
1965	All			3088				2960	103	18	6	1				
1965	Visitors		6900													
1964	All	1493		3005				2885	93	20	4	3	0	0	0	0
1964	Visitors	7500		0												
1963	All	1,043		3225				3122	79	17	4	3	0			
1963	Visitors	12,600	7,200	0												
1962	All	757		3215				3134	41	26	10	3	1			
1962	Visitors	11100		0												
1961	All	948		2399				2296	47	36	17	1	1	1	0	0
1960	All	679		2417				2315	48	13	25	9	3	3	0	1
1959	All			2048				1925	45	29	39	4	2	2	2	
1958	All			1592				1495	45	30	14	0	2	2	4	

Attachment 3: Two-Hundred-Person Data Capture

(This table spans two pages)

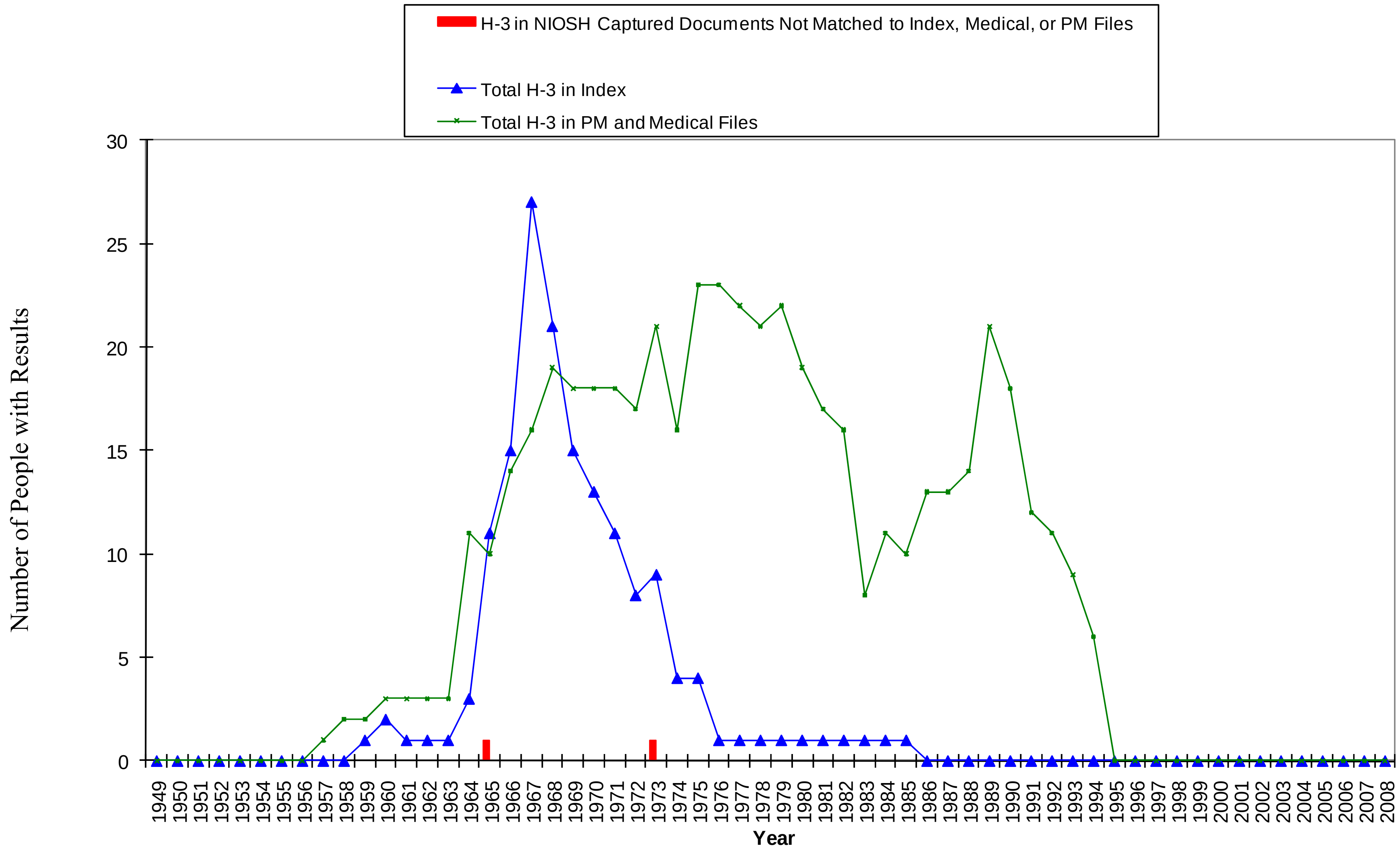
Org or Workgroup	Analysis	Record Type	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
Reactors (51 people total)	Tritium Bioassay	PM File										1	1	2	2	2	2	9	7	10	12	11	14	12	11	11	11	11	10	11	8	9	9	9	9	9	7	8	5	7	8	7	11	9	8	8	6	5														
		Medical File																		1																																										
	Misc. Bioassay	PM File				7	4	7	7	3	6	7	7	10	10	11	10	9	7	9	8	3	6	5						1						1		1																								
		Medical File			2	1																																																								
	Whole Body Count	PM File																								1	9	9	12	6	9	5	8	10	9	8		9	9	8		10	6	8		1	4	3	5	4	1	3	1	3	1	2	3	2	3	2	2	3
		Medical File																									6	5	3	4	7	5	7	1				9																								
HP, S&EP & Waste (32 people total)	Tritium Bioassay	PM File									1	1	1	1	1	1	1	1	2	2	3	4	3	4	4	4	3	3	3	3	3	3	3	3	3	2	1	1	2	2	1	2	2	1		1	1															
		Medical File																																																												
	Misc. Bioassay	PM File				1	1	3	3	1	3	5	4	3	4	4	3	3	3	5	1	1	2	1	1	1				1					2			2		2			1	1																		
		Medical File				1		1				1								1																		1		1																						
	Whole Body Count	PM File												1												1	2	4	4	1	1	2		5	4	1	3	4	2	3	1	2	2				1															
		Medical File						1															1					1										1	2																							
DAS & Nuclear Engineering (35 people total)	Tritium Bioassay	PM File																				1			3		2		5	5	6	3	4	2		2		2		2	1	1	2	2	1																	
		Medical File																																																												
	Misc. Bioassay	PM File						1	1	2	2	1	2	3	2	2	3	3	2	5	4	1		1	4		1		2	2					1	2	1	1		3	3	2	2	1	1																	
		Medical File		1										1																																															
	Whole Body Count	PM File																									1	2	3	2				5	7	1	6	4		6	7	5	5	4		1	1									1						
		Medical File																1																																												
Hot Lab, Medical & BLIP (32 people total)	Tritium Bioassay	PM File																				1					3	1	4	3	4	4	3	3	3	1			1	1	1	2	3	3	2	1	1															
		Medical File																																																												
	Misc. Bioassay	PM File						2	2	3	5	1	6	4	4	4	5	4	3	4	3	4	1	1	3		4	2	5	3	3	1		1	1	1	1	2	2	1		1	2	2	1															1	1	1
		Medical File																																																												
	Whole Body Count	PM File																						1		1	3	3	4		1	3	2	4	5	3	4	5	2	5	5	4	5	4	1	2	3		1	2		1	2	2		2	1	1				
		Medical File																									2				1					2				1																						
Accelerators (AGS, TVDG) (13 people total)	Tritium Bioassay	PM File																																																												
		Medical File																																																												
	Misc. Bioassay	PM File											1						1				1		1																3		2	2					1													
		Medical File					1																																																							
	Whole Body Count	PM File																							1		1	1	1	2		1			2		2			1	1	1	1			1		1														1
		Medical File																					2									1																														

Attachment 3: Two-Hundred-Person Data Capture (cont.)

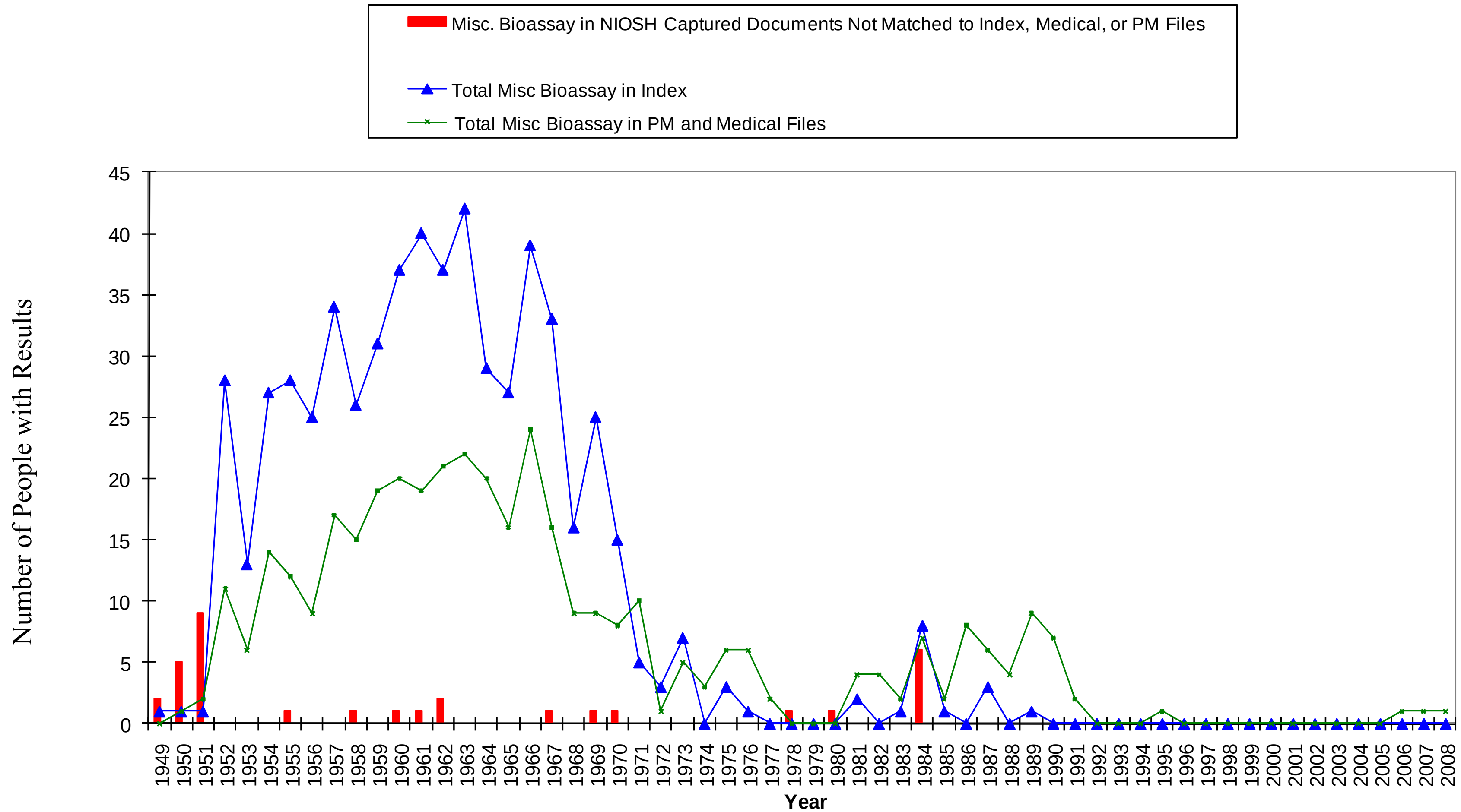
(This table spans two pages)

Chem., Biology & Physics (21 people total)	Tritium Bioassay	PM File																																																											
		Medical File																																																											
	Misc. Bioassay	PM File									2							1	1		1					1			1																1																			
		Medical File																																																											
	Whole Body Count	PM File																										3	3	2		1			1				1	1																							
		Medical File																																																											
Plant Eng./Maint. & Shops (11 people total)	Tritium Bioassay	PM File															1	1	1	1	2	1	2		2	2	1	1	1	1	2	3	2	2	2			1	1	2	2	3	3	1	1	1	1														
		Medical File																																																											
	Misc. Bioassay	PM File														1	2	2	2	2	2	2	1	1														1		1		1	1	1																		
		Medical File																																																											
	Whole Body Count	PM File																															1	2	1		2	2	2	1	2	3	5			1	2	1				1								1	
		Medical File																																			1																								
Other Work Groups (5 people total)	Tritium Bioassay	PM File																																				1																							
		Medical File																																																											
	Misc. Bioassay	PM File																																																											
		Medical File				1																																																							
	Whole Body Count	PM File																										1															1	1																			
		Medical File																																																											

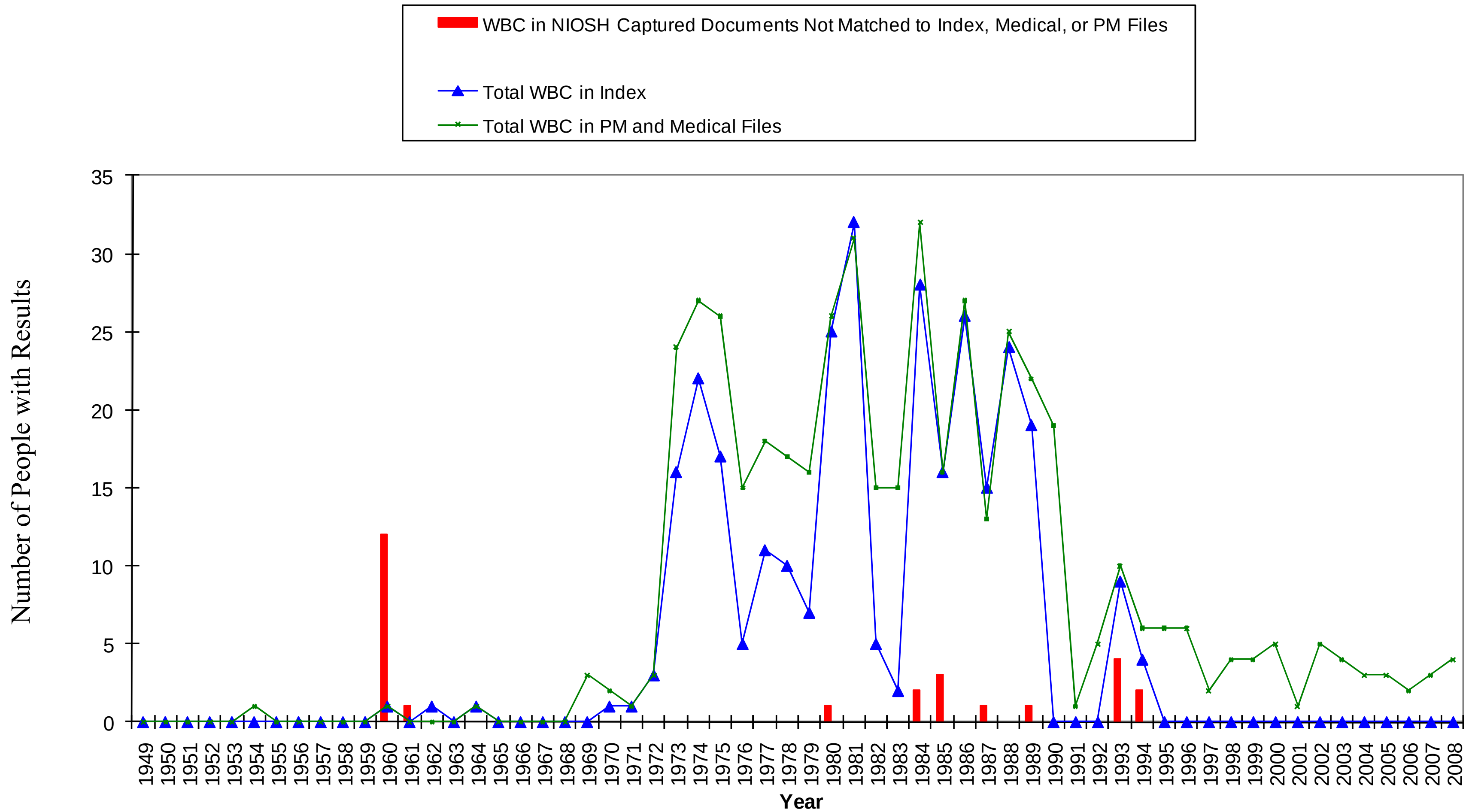
Attachment 4: H-3 Results Not Matched, Total Results in the Index, and Total Results in PM and Medical Files



Attachment 5: Misc Bioassay Results Not Matched, Total Results in the Index, and Total Results in PM and Medical Files



Attachment 6: WBC Results Not Matched, Total Results in the Index, and Total Results in PM and Medical Files



Attachment 7: Data Capture Synopsis

Table A7-1: Data Capture Synopsis for Brookhaven National Laboratory			
Data Capture Information	**Data Captured Description**	**Date Completed**	**Uploaded**
Primary Site/Company Name: Brookhaven National Laboratory (DOE 1947-present) Other Company Names: Associated Universities, Incorporated Brookhaven Science Associates	Brookhaven histories and highlights, bioassay and whole body count reports, bioassay TBD for the Brookhaven Graphite Research Reactor (BGRR) decommissioning, High Flux Beam Reactor (HFBR) dose assessment reports, neutron dose distributions, Alternating Gradient Synchrotron (AGS) neutron dosimetry and surveys, internal dosimetry TBD's, medical x-ray QC report, incident reports, HFBR stack samples, the Radiation Control Manual, Health Physics summaries, HFBR whole body counts and bioassay results, dosimetry procedures, thyroid counting results, Tristan reports and dosimetry reports, individual employees' dosimetry results from their personnel monitoring and medical files, radiological and environmental surveys, facility progress and status reports, Marshall Islands reports, S. Cohn whole body counter logbooks, HFBR visitor registers, annual reports through 1970, accelerator radiation monitoring systems, and decommissioning surveys and plans.	08/03/2009	2,443
State Contacted: NA	Note: Contacting the state was not considered necessary since Brookhaven is an active DOE site and cooperated with relevant data collection.	09/11/2009	0
Curtiss-Wright	Report from a radiological waste meeting hosted by Brookhaven.	03/10/2009	1
Department of Labor/Paragon	Material transfer reports and reports on uranium oxide reduction.	12/30/2008	21
DOE Argonne National Laboratory - East	A listing of Chicago Operations Office facilities, and AEC and ERDA neutron dosimetry conferences.	09/01/2005	3
DOE General Atomics	Material transfer reports and a report which cites Brookhaven's work on neutron beam teletherapy.	01/09/2006	2
DOE Germantown	Reports on beryllium hazards and proposed standards.	Unknown	1
DOE Hanford Declassified Document Retrieval System (DDRS)	Monthly reports on Hanford/Brookhaven metallurgical projects and discussions of neutron monitoring and dosimetry.	11/20/2008	12
DOE Legacy Management - Grand Junction Office	Material transfer requests and reports, characterization of the Brookhaven Graphite Research Reactor (BGRR) canal, and environmental reports.	06/11/2009	41
DOE Legacy Management - MoundView (Fernald Holdings, includes Fernald Legal Database)	Waste management reports, air emissions reports, AEC reports to Congress, and a report on the uptake and effects of thorium dioxide.	11/26/2008	15
DOE Los Alamos National Laboratory (LANL)	Reports on mixed waste streams, AEC facilities, and photodosimetry.	12/06/2007	3

Table A7-1: Data Capture Synopsis for Brookhaven National Laboratory			
Data Capture Information	**Data Captured Description**	**Date Completed**	**Uploaded**
DOE Oak Ridge Operations Vault	1947 film badge results, a 1955 site inspection, and transcripts of 1964 interviews.	10/26/2005	3
DOE Oak Ridge National Laboratory (ORNL)	Report on the machining of uranium for the Brookhaven Graphite Research Reactor.	04/12/2007	1
DOE OpenNet	New York Operations Office (NYOO) status reports and AEC reports to Congress.	12/31/2007	11
DOE OSTI Energy Citations	Brookhaven Highlights 1978-1994 and appendices to the Tiger Team Assessment.	02/13/2009	11
DOE OSTI Information Bridge	Stannard's Radioactivity and Health, report on human radiation experiments, and U-232 content of sapphire material.	01/05/2008	3
DOE Savannah River Site	Savannah River Site dosimetry visitor cards from the 1950's.	08/26/2008	7
Google	Histories of the Brookhaven Graphite Research Reactor and Medical Reactor, environmental reports, and reports to Congress.	03/22/2008	16
Health Physics Journal	Articles on using a whole body counter to measure body burdens of a fallout-exposed population, an improved TLD system, radiation detection and alarm system for an accelerator complex, and the design and dosimetry of a strontium-yttrium beta irradiator.	08/06/2009	4
Interlibrary Loan	Brookhaven papers describing radiopharmaceuticals and defining low radiation doses.	08/18/2009	2
Kansas City (Lee's Summit) Federal Records Center (FRC)	Film badge reports and individual employees' dosimetry information from their medical files.	07/01/2009	86
NARA - Atlanta	DOE indoor radon study results, contamination of a Brookhaven zetraton neutron generator, polonium requests and requirements, and U-233 reports.	05/22/2008	7
Office of Compensation Analysis and Support (OCAS)	Highly enriched uranium working group reports.	02/16/2006	5
Office of Scientific and Technical Information (OSTI)	The 2002 site environmental report, reactor progress report, Tiger Team action plan, pile operating manual, survey of irradiation facilities, and observations on chronic lymphocytic leukemia.	08/06/2009	10
ORAU Team	Summary site profile and process knowledge expert interviews.	01/29/2009	10
Pacific Northwest National Laboratories (PNNL)	Results of the 1965 film badge reliability study.	12/29/2004	1
San Bruno Federal Records Center (FRC)	1963 Associated Universities organizations and objectives and summaries of fuels and materials development programs.	02/01/2006	2
Sandy Cohen & Associates (SC&A)	Process knowledge expert interviews.	08/14/2009	14
Science Applications International Corp (SAIC)	Radiation exposure summaries.	09/02/2004	7
Southern Illinois University, Edwardsville, IL	Disposal of Brookhaven wastes in the St. Louis area, AEC construction cost differentials, and the AEC cryptographic telephone network.	10/16/2008	3

Table A7-1: Data Capture Synopsis for Brookhaven National Laboratory			
Data Capture Information	**Data Captured Description**	**Date Completed**	**Uploaded**
University of Colorado Norlin Library	Sixth ERDA workshop on personnel neutron dosimetry.	09/10/2005	1
University of Rochester Miner Library	Using threshold detectors for neutron measurement at the Cosmotron.	08/21/2009	1
Unknown	Site and NYOO status reports, environmental reports, and beryllium reports.	04/25/2005	92
Viacom Records	Newsletter noting that Westinghouse equipment powered the Brookhaven Cosmotron.	12/06/2004	1
TOTAL			**2,840**

Table A7-2: Database Searches for Brookhaven National Laboratory			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded**
Note: The normally-prescribed publicly-accessible Internet database searches were not performed for Brookhaven. These searches were not performed due to Brookhaven being an active DOE site and the cooperation of the site in making available to the Data Capture Teams the collections of relevant data of which the site was aware. Limited Internet searches were conducted to attempt to locate data not available via the site's resources.			

Table A7-3: OSTI Documents Ordered for Brookhaven National Laboratory			
Document Number	**Document Title**	**Requested**	**Received**
NA OSTI ID: 4410609 SRDB: 71851	Design and Dosimetry of a Strontium-90--yttrium-90 Beta Irradiation Facility from Health Phys., v. 26, no. 1, pp. 99-101	07/21/2009	08/25/2009
CONF-8705273- OSTI ID: 5168103 SRDB: 71828	What is a Low Dose of Radiation from Int J Radiat Biol Relat Stud Phys, Chem, Med Vol. 53(1):1-12, 01/02/1988	07/21/2009	08/18/2009
NA OSTI ID: 4096108 SRDB: 71827	Radiopharmaceuticals from Phys. Rep., v. 21, no. 6, pp. 315-367	07/21/2009	08/18/2009
BNL-22664 OSTI ID: 6621747 SRDB: 71825	Chronic Lymphocytic Leukemia: Concepts and Observations from Blood Cells Vol 3:637-649	07/21/2009	08/06/2009

Table A7-3: OSTI Documents Ordered for Brookhaven National Laboratory			
Document Number	**Document Title**	**Requested**	**Received**
BNL-10490 OSTI ID: 4421770 SRDB: 71849	Improved Thermoluminescence Dosimetry System from Health Phys., 13: 567-73(June 1967).	07/21/2009	08/06/2009
BNL-17025 OSTI ID: 4569426 SRDB: 71850	Radiation and Alarm System (Amos II) for Habitable Areas of an Accelerator Complex from Health Phys. 24: No. 4, 442-443(Apr 1973)	07/21/2009	08/06/2009
NA OSTI ID: NA SRDB: 56600	A Whole Body Counter with an Invariant Response to Radionuclide Distribution and Body Size by S. H. Cohn, et al., Phys. Med. Biol. 14:4, pp. 645-658 (1969)	12/22/2008	12/29/2008 - Dr. Falco Provided
HKF-116(Rev) OSTI ID: NA SRDB: 54015	Quarterly Report for October 1 to December 31, 1951	10/19/2007	11/04/2008
HKF-1492D-41(Del) OSTI ID: NA SRDB: 54017	Plutonium Production Reactor Progress Memorandum dated 9/25/1951	10/19/2007	11/04/2008
M-4414 OSTI ID: NA SRDB: 54018	Brookhaven National Laboratory Pile Operating Manual Book No. 2 dated 4/1/1949	10/19/2007	11/04/2008
HKF-1492D-39 OSTI ID: NA SRDB: 53179	Criticality Hazards in Processing 1% Enriched Uranium dated 9/24/1951	10/19/2007	11/03/2008
BNL-52256 OSTI ID: 6628605 SRDB: 48682	Action Plan for the Tiger Team Assessment Report dated 8/30/1990	08/07/2008	09/18/2008
DOE/EH-0140 Vol. 2 OSTI ID: 6774838 SRDB: 48283	Tiger Team Assessment of the Brookhaven National Laboratory Volume 2 dated 06/01/1990	08/07/2008	08/28/2008