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Preliminary Issues from SC&A's Review of NIOSH's Evaluation Report for Brookhaven National Laboratory Special Exposure Cohort Petition SEC-00113

Availability of Bioassay Records and Adequacy of Neutron Dosimetry

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Prepared by

S. Cohen & Associates
1608 Spring Hill Road, Suite 400
Vienna, Virginia 22182

Saliant, Inc.
5579 Catholic Church Road
Jefferson, Maryland 21755

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Preliminary Issues from SC&A's Review of NIOSH's Evaluation Report for Brookhaven National Laboratory Special Exposure Cohort Petition SEC-00113: ***Availability of Bioassay Records and Adequacy of Neutron Dosimetry***	Page 2 of 23
Task Manager: _____ Date: _____ Ron Buchanan, PhD, CHP	Supersedes: 0
Project Manager: _____ Date: _____ John Mauro, PhD, CHP	

TABLE OF CONTENTS

1.0 INTRODUCTION AND SUMMARY

At the Advisory Board on Radiation and Worker Health (Advisory Board) meeting held in Port Jefferson, New York, on October 20–22, 2009, the Advisory Board authorized SC&A to perform a focused review of the Brookhaven National Laboratory (BNL) Special Exposure Cohort (SEC) Petition and National Institute for Occupational Safety and Health (NIOSH) Evaluation Report (ER). The SEC petition (BNL SEC-00113) requested that the time period covered include 1947 through 2007. NIOSH's ER of September 29, 2009, recommends that a time period of 1947–1979 be granted SEC status, based on the lack of internal dose records. This leaves the period 1980 through 2007 in question—a time period of particular interest to the Advisory Board. This report presents SC&A's preliminary identification of potential BNL SEC issues with regard to this matter, based on a review of NIOSH's SEC-00113 ER and the BNL Site Profile. SC&A's focused investigations related to the BNL SEC petition and ER are continuing, as described in this, the first in a series of reports on this matter. SC&A has constructed a preliminary matrix that summarizes the two major SEC issues, bioassay records and neutron dosimetry, and included it in this report as Appendix A.

BNL bioassay records have been stored in hardcopy form in various departments at the laboratory until relatively recently (2002), when the Health Physics Record Storage (HPRS) system was used for storage of the bioassay records. Some electronic database systems were used to store bioassay records during the 1990s, but these were not centralized. Based on our review, it is not apparent that the electronic records are complete, nor do they appear to be readily accessible for dose reconstruction purposes. Some effort is currently ongoing to transfer the data from the older electronic databases to the HPRS system, but this has not been completed and may not be accomplished in the time frame necessary to process BNL claims. Therefore, dose reconstructors may need to rely on hardcopy bioassay records that are limited to those that are retrievable at BNL prior to 2002. There is no assurance that all the bioassay records are complete and retrievable for dose reconstruction purposes during either the earlier period (1947–1979) or for 1980 forward; this could present a potential Special Exposure Cohort (SEC) issue for 1980–2007.

In contrast to bioassay records, recordkeeping for external dose records at BNL appears to have been centralized, with hardcopies placed in the employee's file and on microfiche as the main form of record retention through 1995, and then the use of the HPRS system beginning in 1996 to store external dose records. Although dosimetry was prevalent and record keeping was more centralized for external exposures at BNL, neutron dosimetry is still a potential SEC issue.

2.0 AVAILABILITY OF BIOASSAY RECORDS

In NIOSH's September 29, 2009, ER of BNL SEC-00113, it is stated that there are sufficient bioassay records available after 1979 to perform dose reconstruction; therefore, the SEC is limited to 1947–1979. SC&A studied the ER and performed a preliminary review of the data used to support NIOSH's assumption that 1980 was a turning point in bioassay record retention at BNL. The following is a summary of SC&A's primary concerns.

2.1 1980 AS A TURNING POINT

NIOSH states the following on page 33 of the ER:

> *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)****.* [Emphasis added.]

NIOSH further states the following on page 51 of the ER:

> *As discussed in this report, 1980 corresponds with a period when monitoring program records-management changes were implemented at the site.*

However, there are no references to support the statement that there was a turning point in 1980, or any information concerning the 1979 site assessment. These statements may have been based on the references provided on page 54; however, those documents do not confirm that a bioassay records storage system was successfully implemented. This is further examined in the following discussion.

The following is stated on page 54 of the ER:

> *It is also likely evidence that shifting the whole-body counting responsibilities from the Medical Division to the S&EP* [Safety and Environmental Protection] *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).*

The main concerns of the first reference (Hull 1979) were as follows:

> *The* ***principal weaknesses*** *of our program that are suggested by this canvass of general practices are the lack of a* ***required initial count*** *for persons newly nominated to the list and/or of a* ***final count*** *for terminations from it. While it is not as apparent, I am also aware that our current program does not specifically provide for diagnostics or the* ***followup of "positives,"*** *as disclosed either by routine or "special" whole body counts.* [Emphasis added.]

> *Although the above could probably be accomplished within our current arrangement with the Medical Department, I feel that there are strong reasons why we should assume the program as a 100% S&EP operation now that we have the capability to do so.*

There was little emphasis on centralization and better bioassay record storage in this memorandum.

The complete content of the second reference (Cohn 1980) is very short and is as follows:

> *The medical whole body counter is always available for monitoring of BNL personnel in emergency situations, as you are aware.*
>
> *In response to your programatic needs in relation to the MIRSP* [Medical Isotope Research and Production], *we will make every effort to accommodate you for "interim service." Availability of the counter for routine monitoring of personnel is, of course, subject to the clinical research demands made on the counter. I assume that you will continue to be responsible for the analysis and interpretation of the whole body counting data obtained during this interim service period.*

It appears that this was a statement from the medical group [that at the time had whole-body counting (WBC) capabilities] to the monitoring group (that apparently was in the process of acquiring WBC capabilities, referred to as the interim period), indicating that the medical group's WBC facility could be used, if available, for routine bioassays if necessary. It does not support the assumption that bioassay records were centralized and that there were improved controls over personnel monitoring, sample collection, analyses, follow-up work, and record maintenance as a result of a reorganization, as was indicated on page 54 of the ER report.

Additionally, a related reference (Hull 1978) does not emphasize the need for improved record keeping; instead, the article is mainly concerned with the technical, personnel, and budget issues associated with S&EP obtaining a WBC facility. It is not apparent from these references that a definite plan was put into place and successfully carried out to centralize and improve storage/retrievability of bioassay data beginning in 1980.

In general, SC&A did not find that the documentation provided in the ER supports the assumption that a plan to centralize and store bioassay records (urinalysis and others, as well as WBCs) was successfully initiated in 1980, carried through to completion, and maintained.

2.2 BIOASSAY DATA

NIOSH performed substantial BNL data capture for use in evaluating the BNL SEC. Much of the bioassay data capture is presented in the ER in the form of tables and attachments. SC&A performed a preliminary review of this data, looking at the number of bioassays as function of the year the bioassay was taken. If there is a pivot point (such as in 1980, as suggested by NIOSH) at which BNL instituted a program to centralize and store the bioassay records, then there should be trends in the data that indicates a change in:

- The number of bioassay records retrievable (generally, an increase would be expected).
- The consistency of the number of bioassay records (less fluctuation would be expected).
- Both the number and consistency of the bioassay records.

Changes in facility operations and regulatory monitoring requirements could add perturbations to these trends that could complicate the analysis; however, some useful information should be able to be gathered from this data to verify NIOSH's assumptions, if they are correct. SC&A plans to perform further analyses and create plots of this data to detect if there was any turning point at which bioassay records were more consistent and retrievable. The following is SC&A's preliminary analysis of the bioassay data captured by NIOSH and presented in the ER.

NIOSH's ER Table 6-3

NIOSH describes the data used in Table 6-3 (pages 36–38) of the ER on page 34, Section 6.1.1. Table 6-3 summarizes the data captured by NIOSH concerning the total number of in-vitro results by year (1949–1989) and by individual radionuclide and/or analytical procedure.

From SC&A's initial review of this data, it is not obvious that there is a change in the number of in-vitro results around 1980. SC&A plans to further analyze and plot the data to obtain more detailed information from it.

NIOSH's ER Table 6-4

NIOSH describes the data used in Table 6-4 (pages 40–41) of the ER on page 39, Section 6.1.2. Table 6-4 summarizes the data captured by NIOSH concerning the total number of in-vivo WBCs results by year (1960–2000) and by individual radionuclide. According to the ER, page 39:

> *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.*

From SC&A's preliminary review of this data, it appears that the number of WBCs increased substantially around 1973, and continued to increase until 1990. However, such a trend would be expected of a new technology that could replace numerous, more time-consuming, analytical procedures. There was considerable fluctuation in the number of WBCs from the early 1970s to the late 1990s; therefore, it is not obvious that a more precise method to store and retrieve bioassay records was instituted and maintained at any point during this 30-year period. SC&A plans to further analyze and plot the data to obtain more information.

NIOSH's ER Table 7-2

NIOSH describes the data used in Table 7-2 (page 54) of the ER on page 54, Section 7.1.1. Table 7-2 summarizes the results of using the data captured by NIOSH to compare the number of bioassays requested to the number actually performed and recorded for 69 persons between 1948 and 1992 for certain time intervals.

SC&A finds that the data in Table 7-2 indicate that there was an increase in the consistency of performing and recording requested bioassays as time progressed. These appear to be **specifically requested** bioassays; therefore, this trend may or may not apply to **routine** bioassays.

NIOSH's ER Attachment 1

NIOSH describes the data used in Attachment 1 (pages 102–105) of the ER on page 34, Section 6.1. Attachment 1 summarizes the results of NIOSH's data capture concerning the number of employees, in eight different work groups, monitored per year (1949–2000) by WBC and urinalysis (with the urinalyses broken down into different radionuclides and/or methods of analysis).

SC&A found that Attachment 1 contains a large amount of data that needs to be further analyzed and plotted. A preliminary review of the data indicates that there were considerably more, and varied, analytical procedures performed before 1980, as compared to 1980 and afterwards; however, a number of these analyses may have been replaced by the advent of WBC, which showed a substantial increase in the 1970s for most of the work groups. A preliminary review of this data does not indicate a pivot point around 1980; further analysis of this data may confirm, or change, this initial indication.

NIOSH's ER Attachment 3

NIOSH describes the data used in Attachment 3 (pages 112–113) of the ER on page 53, Section 7.1.1. Attachment 3 contains the results of NIOSH's data capture for 200 BNL workers and summarizes the number of persons, in eight different work groups, monitored per year (1949–2008) by tritium urinalysis, WBC, and miscellaneous bioassays (urinalysis).

Similar to Attachment 1, SC&A found that Attachment 2 contains a large amount of data that needs to be further analyzed and plotted. A preliminary review of the data on both sides of 1980 indicates that there is a considerable amount of data during each time period, but with numerous fluctuations. A preliminary review of this data does not indicate a pivot point around 1980; further analysis of this data may confirm, or change, this initial indication.

NIOSH's ER Attachments 4, 5, and 6

NIOSH describes the data used in Attachments 4, 5, and 6 (pages 114–116) of the ER on page 53, Section 7.1.1.

NIOSH's ER Attachment 4

Attachment 4, page 114, summarizes the results of NIOSH's data capture concerning the number of persons with **H-3** bioassays results in the Index files and the Medical files, plus the Personnel Monitoring (PM) files by year (1949–2008). It also provides the number of tritium bioassays found in NIOSH's data capture not found in any of these three sets of files (Index files, Medical, and PM files) by vertical red bars. NIOSH describes the term "Index" file on page 53 of the ER as follows:

> *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.* [Emphasis added.]

For these 200 BNL workers, this information indicates that most of the bioassay data for tritium is contained in the Medical and PM files after 1976, and that there was none in the NIOSH data capture that was not also found in the Medical, PM, and/or Index files after 1973. Therefore, starting in the mid-1970s, the tritium bioassay data for these 200 workers appear to be consistent in the major databases, which are discussed further in Section 2.3.

NIOSH's ER Attachment 5

Attachment 5, page 115, shows the same type of information for **Misc.** bioassay data.

For these 200 BNL workers, this information indicates that most of the data for miscellaneous (urinalysis) bioassays is contained in the Index files before 1974 and in the Medical and PM files after 1974. The number of bioassays began to decrease noticeably in the 1970s, most likely because of the introduction of WBC technology. The red bars indicate that there were several instances where the contents of the data capture by NIOSH do not match that found in the three major databases prior to 1985.

NIOSH's ER Attachment 6

Attachment 6, page 116, shows the same type of information for **WBC** bioassay data.

For these 200 BNL workers, this information indicates that the bioassay data for WBC increased rapidly in the 1970, as expected, and continued to the early 1990s. The WBC data in the PM and Medical files encompass that contained in the Index files. The red bars indicate that there were several instances where the contents of the data capture by NIOSH do not match that found in the three major databases during the 1980–1994 timeframe.

SC&A's preliminary analyses of the number and consistency of the bioassay data in the ER does not indicate that there was an effective change in the bioassay recording and retention system beginning in 1980 and continuing through 2007 at BNL.

2.3 BIOASSAY RECORD STORAGE SYSTEMS

The above analyses were mainly concerned with the details of the number of bioassay records as a function of time; however, it is also necessary to consider how/where these bioassay records are presently stored and if they can be sufficiently coordinated, so that they can be made available for use by the dose reconstructor in a reasonable amount of time. NIOSH provides a description of the bioassay record storage systems in Table 6-1 (page 32) and Table 6-2 (page 33) of the ER, which helps to summarize the location of bioassay (urinalysis, WBC, and others) records at BNL. SC&A used the information in Tables 6-1 and 6-2 to create a spreadsheet that illustrates where the bioassay data that were recorded were/are stored as a function of time. This spreadsheet helps to illustrate the progression of the recordkeeping process up to and beyond NIOSH's recommended pivot year of 1980, and is included in this report as Attachment B. This information indicates that the bioassay records were not consolidated into one electronic database (HPRS) until 2002. Before 2002, the majority of the bioassay records that are available are stored in the PM, Medical, and Index files, with some files in stand-alone electronic databases beginning in the 1990s. Additionally, NIOSH has recently captured and retained some of this bioassay data that could be used for dose reconstruction purposes. Unfortunately, as Attachment B indicates, the bioassay data at BNL are not conveniently located in any one database system, nor is it known if all of the bioassay records are contained in the presently available databases. On page 58 of the ER, third paragraph, it is indicated that all **three** sources (PM, Medical, and Index files) are checked by BNL for information when an EEOICPA request is received; however, this brings up several questions:

- Are all the other various data sources [microfiche, WBC office, hard copies, electronic databases (i.e., NIOSH ER, page 32, Table 6-1, Column 3, Row 1), ASL, etc.] complete and are they also queried during each response?
- What time periods are currently addressed in the HPRS with respect to bioassays records that are available for dose reconstruction purposes? Does it indeed contain <u>all</u> bioassay records during this time period?
- Is all relevant data contained in the HPRS also supplied to the dose reconstructor?
- Does NIOSH have a procedure that automatically retrieves any relevant data from their data-captured spreadsheets and then provides it to the dose reconstructor?

It is unclear at this point if all the BNL bioassay records still exist, and for the ones that do exist, if they are retrievable (from old electronic databases, etc.), and if there is a protocol in place at BNL/NIOSH that ensures all this bioassay data is gathered and supplied to the dose reconstructor for each case. Even if bioassay data do exist in some form (old electronic databases, etc.), if it cannot be extracted because it is no longer supported, then it is potentially an SEC issue.

Bioassay records were not routinely entered in the HPRS until after 2001 (NIOSH ER, page 32, Table 6-1), with some earlier bioassay data currently being added. This brings up several areas of concern that could be potential SEC issues:

- Why does the number of bioassay records decline and become erratic in the 1990s?
- Were there procedural and/or operational changes instituted in the early 1990s that caused this decrease in bioassays? According to Table 2-2 and Table 2-3 in ORAUT-TKBS-0048, many of the facilities continued to operate to the present, or at least to 1999. One of the main facilities that necessitated bioassays was the HFBR, which operated from 1965–1989 and 1991–1996. Therefore, it is not obvious why the number of bioassays changed noticeably in the 1990s.

NIOSH's ER concentrated on addressing the availability of bioassay data in the 1980–1990 era; however, the retrievability and completeness of bioassay records during the period of 1990–2007 is unclear at this point.

2.4 SUMMARY OF AVAILABILITY OF BIOASSAY RECORDS

There does not appear to be a clear indication of any certain time period when a methodology was implemented to improve the recording and retention/retrievability of bioassay results at BNL until perhaps 2002, when bioassay records were added to the HPRS. The **documents** reviewed to date do not reveal that a definite plan was implemented during a certain period (such as in 1980) and maintained to improve the recording and retrieval of bioassay records, which would ensure that all bioassay results are available for dose reconstruction purposes. Neither does a preliminary analysis of the currently available **data**, as described above, produce reasonably conclusive results that would indicate that the number and/or consistency of the bioassay data improved during the period 1980–2007, as suggested in NIOSH's ER. Additionally, this review brings up questions concerning the completeness and location of bioassay records for 1990s–2007, as well as for the 1980–1990 time period.

3.0 ADEQUACY OF NEUTRON DOSIMETRY

In contrast to bioassay records, the records for external exposures at BNL appear to be more centralized, complete, and retrievable. External monitoring was instituted when operations began at BNL, and the records were kept on hard copies in the Personnel Monitoring (PM) organization files through 1985, then on microfiche for the period 1986–1995, and then on the BNL HPRS database starting in 1996 and continuing to the present. NIOSH's ER summarizes the external monitoring records in Attachment 2, pages 106–111. The information in Attachment 2 covers the period 1958–2007 (except for 1971) and provides a list of the total number of persons monitored, number with measureable dose, average measured dose, number of persons with no measurable dose, and a breakdown of the number of recorded doses in nine dose intervals ranging from <1,000 mrem to 8,999 mrem. Additionally, there is some breakdown into general categories of the persons' affiliation (i.e., BNL employee, visitor, etc.). The external monitoring data appear to be reasonably adequate (concerning the amount available) and accurate (concerning the dependability of the records).

However, the neutron dosimetry/processing/recording methodologies used to generate the dose of record could create potential SEC issues. The period in question could extend from 1980–2007. SC&A reviewed a number of documents (mainly BNL memorandums) that indicate that there were significant neutron dosimetry problems in the 1985–1995 timeframe; no documentation of the resolutions to these problems has been located to date. SC&A has not located documented evidence of neutron dosimetry problems in adjacent time periods (i.e., 1980–1984 and 1996–2007); but, barring any new developments, it would have to be assumed that these problems were not isolated to only the 1985–1995 time period and could have existed prior to, and sometime after, this time period, considering that high-energy accelerators were operational at BNL during most of its recent history.

3.1 NIOSH EVALUATION REPORT ANALYSIS OF NEUTRON DOSIMETRY

NIOSH's ER addresses neutron dosimetry briefly on pages 71–72. NTA film was used from the start-up of BNL through 1995, when it was replaced by TLDs. Additionally, in locations where there was a potential for exposure from high-energy neutrons, such as around some accelerators, CR-39 was used during the period 1985 through the present, and Lexan was used during the period 1985 through June 1997. The use of neutron dosimetry is summarized in the following table:

Table 1. Neutron Dosimeters at BNL

Dosimeter	Period of use
NTA	1950s–1995
TLD	1996–Present
CR-29	1985–Present
Lexan	1985–June 1997

From the beginning, BNL used a relative biological effectiveness (RBE) or quality factor (QF) of 10 to encompass the possible range of potential, but not fully known, QFs. An RBE or QF is a numerical value by which the absorbed dose (rads) is multiplied to derive the dose equivalent

(rem). In NIOSH's ER and the BNL Site Profile document (ORAUT 2006a), it is assumed that the dosimetry at BNL was appropriate, because of the use of RBE or QF = 10; and hence, this created a built-in safety factor. This is stated on page 71 of the ER:

> *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 et al. 1964). *Throughout BNL history, the evaluation of the film always assumed a QF or RBE of 10.*

A review of the reference Cowan et al. (1964) shows that the main items of concern in that article were as follows:

> *After a discussion of methods of high energy dosimetry, data on linear energy transfer and quality factors of* ***pions, protons, deuterons,*** *and* ***alpha*** *particles in water are summarized.* [Emphasis added.]

Neutrons were only briefly mentioned in this article, and no QF analysis was performed for them. Regardless of the conservatism of the QF used, the recorded dose will not be representative of the dose received if there are portions of the neutron energy spectra that the neutron dosimeter is not responsive to, or under-responds in a manner that substantially diminishes the usefulness of the data. Additionally, correct and consistent calibration and processing of the dosimeters is required. These are the main issues concerning the neutron dose of record at BNL, as discussed below.

3.2 NEUTRON DOSIMETRY RESPONSE FUNCTIONS AS ADDRESSED IN NIOSH'S EVALUATION REPORT AND BROOKHAVEN NATIONAL LABORATORY TECHNICAL BASIS DOCUMENT

NIOSH's ER addressed the response functions of BNL neutron dosimetry on page 71 as follows:

> *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* [ORAUT 2006a], *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.*

Table 6-7 from ORAUT-TKBS-0048 (ORAUT 2006a) is reproduced below:

Table 6-7. Bias and Uncertainty

Site-specific dosimetry system	Bias magnitude and range		Uncertainty factors	
	Overall bias[b]	Range in bias	Systematic[c]	Random[d]
Multi element Start-up thru 1995[a]	1.02	0.86–10	1.1	1.4
Site TLD	1.01	0.95–1.05	1.05	1.2
NTA film				
0.1 to 2 MeV	1.35	0.5–1.5	1.5	
2.0 to 14 MeV	1.35	0.65–1.35	1.35	
CR-39	Unknown	Unknown	Unknown	

a. These values agree with Landauer since NVLAP certification (Yoder 2005).
b. Based on most likely distribution of energy levels and geometries. Divide recorded dose by table's bias value to determine deep dose.
c. Systematic uncertainty due to lack of knowledge of actual distributions of energies and geometries.
d. Random uncertainty due to variations among workers in energy levels and geometry.

SC&A assumes that NIOSH is stating that if the dose reconstructor uses the information in ORAUT-TKBS-0048 (ORAUT 2006a, Table 6-7), then the under-response of NTA film to low-energy neutrons and any problems with NTA film, CR-39, and/or Lexan neutron dosimetry/processing at any neutron energy will be adequately corrected. The following sections explore these issues further.

3.3 NTA FILM UNDER-RESPONSE TO LOW-ENERGY NEUTRONS

The threshold energy of NTA film (0.5–1.0 MeV) and the amount of dose not registered because of this threshold is important in neutron dosimetry and should be accounted for.

If the information in ORAUT-TKBS-0048 (ORAUT 2006a), Section 6.11, pages 95–97, is analyzed, it can be seen that:

- There were no bias or uncertainty factors found for the BNL site.
- The values in Table 6-7 for photon film and TLDs were taken from the Hanford TBD (ORAUT 2004), because they should be similar to BNL.
- The NTA film values were taken from the Atomics International (formerly ETEC) TBD (ORAUT 2006b), because the adjusted neutron energy values are similar and were based on Y-12 data (ORAUT 2005a).
- Footnote (b) of Table 6-7 of ORAUT-TKBS-0048 (ORAUT 2006a) instructs the dose reconstructor to **divide** the recorded dose by the bias value to obtain the deep dose (DD), Therefore, contrary to the statement on page 71 of the ER that the correction factors in ORAUT-TKBS-0048 (ORAUT 2006a) Table 7-6 would appropriately account for the NTA film under-response, the bias value would decrease the assigned dose even further.

Additionally, SC&A could not locate any statement in the Hanford TBD (ORAUT 2004) that specifically lists the bias value of 1.35 for NTA film.

From this information, it is unclear exactly where the values were obtained, and there is no supporting evidence to link the BNL neutron energy spectra to these other sites from which the parameters were obtained. The lack of details on this issue may lead to a lack of understanding

on the part of the dose reconstructor of how to address low-energy neutrons in dose reconstruction. **For example, SC&A found that 80% of the final dose reconstruction reports for BNL claimants that required neutron dose determination, completed after the site profile was issued, did not include the neutron adjustment factors of 1.35 for bias or 1.5 for uncertainty for low-energy neutrons**; only the ICRP factors of 1.91 or 2.00 as listed in ORAUT-TBKS-0048 were used.

However, even if these bias and uncertainty factors were used, they are not specific to BNL and have not been shown to be applicable to BNL radiation exposures, dosimetry, dosimeter processing, and methods of data interpretation.

Additionally, the subject of lost recorded neutron dose because of track fading is not addressed in the ER or the site profile. The magnitude of the proton recoil tracks in NTA film resulting from neutron interactions depends on the energy of the interacting neutron. Lower-energy neutrons create less dense proton recoil tracks; these tracks fade more rapidly with time than heavier tracks caused by more energetic recoil protons resulting from energetic neutrons (i.e., 0.5–1.0 MeV neutrons in the workplace versus 1.3 MeV neutrons from a calibration source). The ER should address this issue and make clear and technically sound recommendations to compensate for the incomplete neutron doses as would be read from NTA film because of track fading.

It is apparent from this information that the decreased response of NTA film to lower-energy neutrons and associated track fading has not been sufficiently investigated and compensated for in the dose reconstruction process for BNL workers. These findings indicate insufficient accuracy concerning neutron doses and could lead to potential SEC issues.

3.4 HIGH-ENERGY NEUTRON DETECTOR (NTA/TLD/LEXAN/CR-39) PROBLEMS

The problems associated with the NTA film's 0.5–1.0 MeV threshold, track fading, and the fact that NTA film has a practical upper neutron energy limit for personnel monitoring initiated a search for other neutron dosimeters; among those tested and selected for use at BNL were the TLD, CR-39, and Lexan neutron dosimeters. However, these neutron dosimeters were not without their own problems. From the BNL documents that SC&A has analyzed, the two major issues that were prevalent are (1) no single neutron detector sufficiently covered all the neutron energies encountered in the many different radiation environments; and (2) there were problems with the vendors of these detectors providing consistent and accurate neutron and photon dose results.

Data, such as that found in some BNL documents (e.g., Xie and Rohrig 1985 and Schaefer 1995), indicate that there were locations at BNL accelerator facilities where the NTA film may not have sufficient sensitivity and/or be correctly calibrated to adequately measure neutron dose because of its decreased sensitivity at higher neutron energies. This information points out the need to have dosimetry results that compliment each other, are consistent and reliable, and to work with a vendor that is aware of the mixed and varied radiation fields and who is responsive to the facility's needs. However, this does not appear to have always been the case at BNL, and this has led to two important issues, one concerned with the fact that no single neutron detector

sufficiently covered all the neutron energies, and the other one related to problems with the results from the vendors who processed the dosimeters. These issues are inter-related, because the properties of the neutron detectors were such that several types of detectors had to be used to cover the neutron energy range found at BNL; and if the readings from the vendors were not consistent, the obvious question is which dosimeter(s) results should have been used for the dose of record? From the BNL documents reviewed by SC&A and from interviews conducted with contemporary health physicists, it appears that there was a problem in this area, as found in a number of documents dating from 1986–1995, examples of which are discussed below. A summary spreadsheet depicting the timeline of events of these problems is provided in Attachment C of this document. This condensed version of the neutron dosimetry problems at BNL will be expanded upon in the near future (similar to SC&A's analysis of this issue for the BNL site profile review) using material found in references, such as Casey 1987, Miltenberger 1995, Musolino 1988, Schopfer 1986, Schopfer 1988, Schaefer 1995, and SM 1987.

3.5 SUMMARY OF ADEQUACY OF NEUTRON DOSIMETRY

In general, there appears to be sufficient recorded and retrievable external dose data at BNL for dose reconstruction purposes, and that a conservative RBE/QF factor has been used at BNL to provide a safety factor to compensate for the uncertainties involved in the different radiation fields found around BNL facilities. However, it is apparent that neither an RBE/QF of 10, or a bias factor of 1.35, nor an uncertainty factor of 1.5 is going to adequately, and consistently, compensate for the problems with the neutron dosimetry at some of the BNL facilities, as outlined above. Neither the NIOSH's ER nor the BNL site profile mentioned these dosimetry problems, if they were solved, or made any recommendations concerning the use of the neutron dose records in light of these significant issues.

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ATTACHMENT A: PRELIMINARY MATRIX ISSUES FOR THE BROOKHAVEN NATIONAL LABORATORY SEC PETITION AND NIOSH EVALUATION REPORT REVIEW

This matrix contains a list of the preliminary issues for the Brookhaven National Laboratory (BNL) SEC Petition with a proposed class from January 1, 1947, through December 31, 2007. It is based on a preliminary assessment of the following:

- The NIOSH Evaluation Report dated September 29, 2009
- The BNL Petition SEC-00113
- SC&A's Site Profile Review
- A partial review of BNL documents

NIOSH has proposed that the classes of workers be reduced to cover only the period of January 1, 1947, to December 31, 1979, because sufficient monitoring data are available to estimate exposures with sufficient accuracy for all workers employed beginning January 1, 1980.

Preliminary Issues Matrix for the Brookhaven National Laboratory SEC Petition and NIOSH Evaluation Report
February 23, 2010

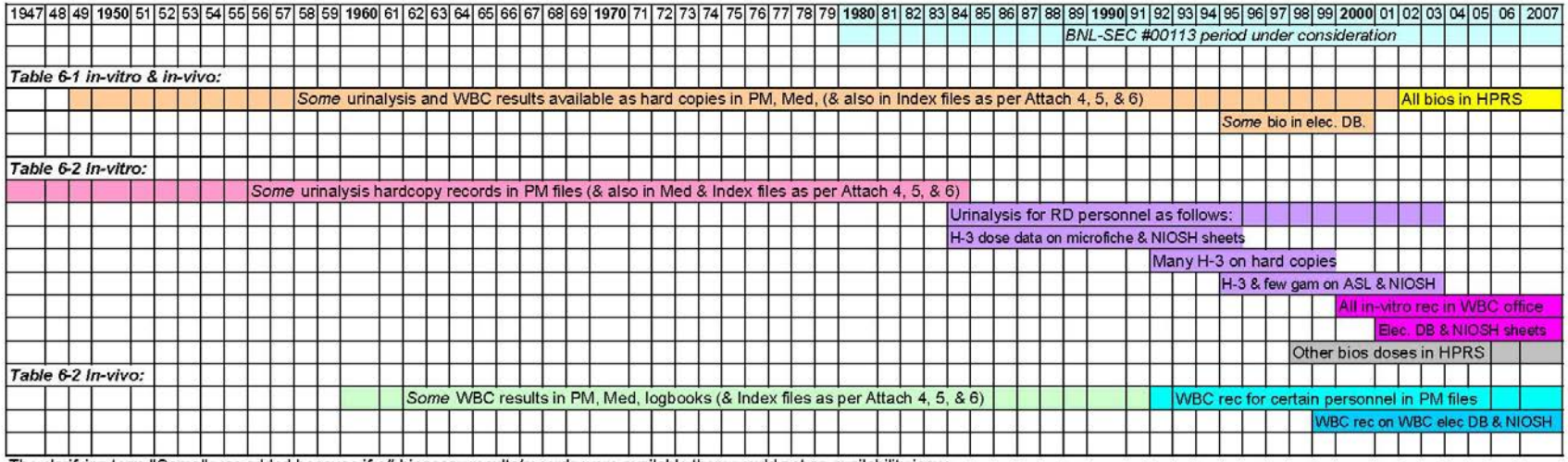
No.	Issue	NIOSH ER position (SC&A reading)	SC&A Initial Review
1	Availability of Bioassay Records: 1980–2007	• NIOSH has stated in their ER for BNL SEC-00113 that according to the information in the BNL documents NIOSH has captured, 1980 was the turning point at which bioassay data become sufficiently available to perform adequate dose reconstruction. • NIOSH has stated that according to the data presented in the ER, there are sufficient bioassay records available, beginning around 1980, to perform adequate dose reconstruction; therefore, the SEC should be limited to 1947–1979. • NIOSH assumes that all the bioassay records contained in the numerous historical database systems have been coordinated and are available to the dose reconstructor. • NIOSH assumes that there are no SEC issues concerning bioassay data for the period 1980–2007.	(1) SC&A's analyses of the documents referenced in the ER do not support the assumption that there was a turning point, such as 1980, in which the bioassay data and records became sufficiently available to allow for adequate dose reconstruction after 1979. (2) SC&A's preliminary technical analyses of the large amount of bioassay data presented in the ER do not indicate that bioassay data and records became sufficiently available around 1980 to allow for adequate dose reconstruction. (3) The ER does not establish that bioassay records that have been stored on numerous historical bioassay data storage systems at BNL have been sufficiently coordinated and are accessible for the dose reconstruction. (4) The reason(s) for and impact of the decline in the number, and erratic behavior in the consistency, of bioassay data beginning in the 1990s, during which time many of the facilities were still operating, has not been addressed in the ER. (5) In summary, SC&A did not find that the documentation and data provided in the ER supported the assumption that a plan to centralize and retain bioassay records (urinalysis and others, as well as whole-body counts) was successfully initiated in 1980, carried through to completion, and maintained through 2007, to allow for adequate dose reconstruction.

Preliminary Issues Matrix for the Brookhaven National Laboratory SEC Petition and NIOSH Evaluation Report
February 23, 2010

No.	Issue	NIOSH ER position (SC&A reading)	SC&A Initial Review
2	Adequacy of Neutron Dosimetry	• NIOSH apparently did not consider neutron dosimetry to be an issue at BNL; therefore, it only required a brief mention on pages 71–72 of the ER. • NIOSH apparently did not consider neutron energy fields in the work place, and associated dosimetry responses, to be an issue at BNL; therefore, it was not addressed in detail in either the BNL TBD or the ER. • NIOSH recommends relying on the BNL tradition of using a quality factor (QF) of 10, and the bias and uncertainty values in Table 6-7 of the TBD, to compensate for: o Any under-response or undetected neutron doses at low or high energies o Differences in neutron dosimetry methods o Problems with vendor dosimetry processing, calibration, and reporting procedures.	(1) SC&A did not find that the neutron dosimetry systems at BNL were without problems. Neither the under-response nor fading of NTA film was sufficiently addressed. The problems with NTA, TLD, Lexan, and CR-39 neutron response, vendor dosimetry processing, and dose determination were not addressed. (2) The reliance on the traditional use of a QF of 10 and the bias and uncertainty factors in Table 6-7 of the TBD does not adequately address the neutron dosimetry issues at all the varied facilities at BNL. (3) Most of the bias and uncertainty values in Table 6-7 of the TBD were from other DOE sites; they were not derived from BNL data. (4) Using a QF of 10 cannot compensate for dosimetry under-response or undetected neutrons.

ATTACHMENT B: BIOASSAY DATA ISSUES FOR BNL-SEC MATRIX

Timeline of BNL Bioassay Records in Various Storage Databases (from Tables 6-1 and 6-2 of NIOSH's ER)



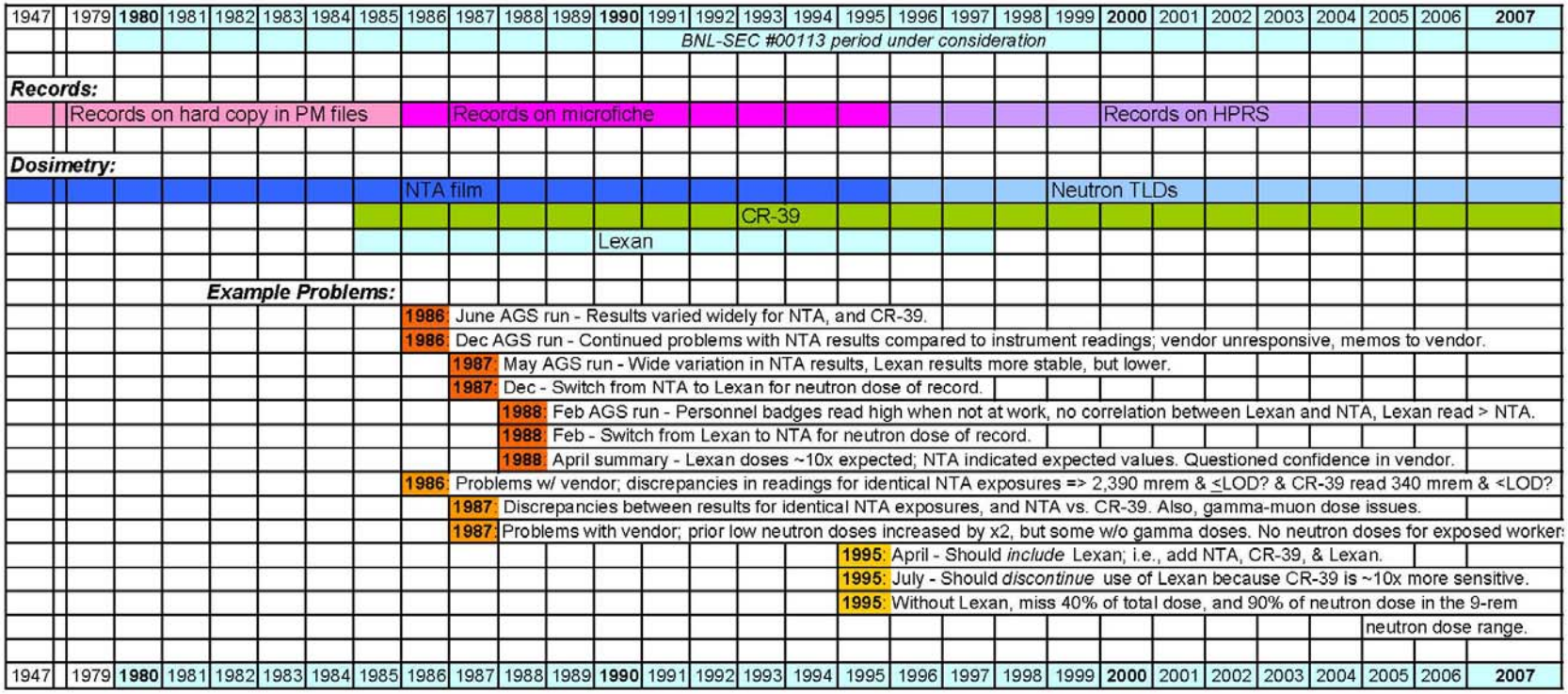
The clarifying term "*Some*" was added because if *all* bioassay results/records were available there would not an availability issue.

bio = bioassay(s)
DB = database
elec = electronic storage
gam = gamma counts
med = medical files
PM = personnel monitoring files
rec = records

9 Feb 2010

ATTACHMENT C: NEUTRON DOSIMETRY ISSUES FOR BNL-SEC MATRIX

Timeline of BNL Neutron Dosimetry and Associated Problems



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