APPENDIX A: EXAMPLES OF STRATEGIES USED BY SC&A IN REVIEWING THE COMPLETENESS OF AVAILABLE SITE-SPECIFIC RECORDS IN AN SEC CONTEXT

As stated previously in this document, two of the most important aspects in making an SEC determination are the "adequacy" and the "completeness" of available data sources. In this context, "adequacy" refers to the ability to use available data to accurately reflect real and meaningful exposures incurred by the worker population with sufficient accuracy. For example, during its review of thorium in-vivo (chest count) data for use in reconstructing internal exposures to Th-232 and associated daughter products, the Advisory Board determined that measurements given in units of "milligrams of thorium" were not "adequate" for the purposes of dose reconstruction. The basis of this determination was the lack of raw data and defined analytical methods that were used in arriving at the values of mg of thorium.[2] In this way, the dataset was not "adequate" to establish real and meaningful exposures for the exposed worker population.

"Completeness" of available datasets does not address the technical accuracy of the data, but rather how well the available records are representative of the potentially exposed worker population. The issue of data completeness is the subject of this appendix. The three most important facets of data completeness can be summarized by the following:

- Temporal coverage: Do the records cover the necessary time periods evaluated by the SEC?
- Job type coverage: Are the highest exposed job types covered by the available records?
- Work area coverage: Are the work areas of highest exposure potential represented by the available monitoring data?

Obviously, these facets are not mutually exclusive and are usually interdependent. For example, a particular dataset may have "complete" data as regards the chronology of the site, but is missing data for the highest job types and/or plant areas during some of those years. It must be noted that decisions regarding the "completeness" of a particular dataset in an SEC context are ultimately a judgment call. As such, there is no quantitative way to definitely determine whether particular monitoring records are complete. However, analytical methods have been used by SC&A in the past, which build a "weight of evidence" argument to assist the Advisory Board in making such determinations.

This appendix provides examples of some of the analytical approaches that have been used for SEC deliberations previously for four different sites (Hanford, Fernald, Nevada Test Site (NTS), and Mound). The examples were chosen to reflect many of the different scenarios and potential problems encountered by the Advisory Board in making SEC recommendations. The four chosen examples include analysis of an extensive electronic database (Example 1), compilation

[2] Th-232 cannot be measured directly in the lung and so must be inferred from the relative measurements of associated daughter products. The original daughter product measurements were not available, nor was the exact procedure used in calculating the lung burden of thorium.

of site-wide data from hardcopy records (Example 2), sampling of claimant dosimetry records (Example 3), and use of workplace monitoring in the absence of adequate bioassay records (Example 4).

Example 1: Electronic Internal Dosimetry Database for the Hanford Site

Background Summary:

In 2011, SC&A was tasked with performing a review of the most recent Hanford Site Profile (ORAUT 2010a–2010f) with a focus on remaining SEC issues for the period of July 1, 1972,[3] through December 31, 1990. One aspect of this site profile review was to assess the data completeness of internal monitoring records during this period. Hanford is somewhat unique, in that it has a very extensive electronic database (known as the Radiological Exposure or "REX" Database) of worker records, which are available for analysis. As described below, SC&A used the REX database to assess the extent of worker monitoring for individual radionuclides as it relates to temporal considerations, job title, and work location. The basic methodology and information available are described below. For the full results of the completeness analysis, the reader is referred to SC&A 2011, Appendix A.

Analytical Approach Taken:

SC&A 2011 states the purpose of the completeness analysis as follows:

> *The purpose of this report is to examine the internal monitoring records contained in the Radiological Exposure Database (REX) for adequacy and suitability in constructing the coworker model presented in Appendix C of the Hanford Site internal dose TBD (ORAUT 2010e). Specifically, this report will seek to identify monitoring practices, exposure potential, and potential gaps as they pertain to worker job categories, as well as periods of production and exposure potential during the SEC period.* (SC&A 2011)

As specified previously, a rather extensive database (REX) contains worker monitoring records for the Hanford Site. The REX database itself is made up of nearly 70 individual files; some of these files contain monitoring data, while most others represent reference tables that can be used to interpret the dosimetry files. As an example, the reference files "REX_DOE_OCCUPATION" and "REX_HAN_FACILITY" provide individual codes for job title and some individual work areas to be used in other database files. These reference files are necessary in order to be able to decode and associate the appropriate job titles and work locations with specific workers and monitoring results.

Inspection of the available REX Database files identified five main database files to be used in the internal completeness analysis. These files are described in Table A-1. The first file listed, REX_WORK_HIST, does not actually contain any monitoring data; however, it enables the tracking of individual workers (via an individual ID number) and their respective employment

[3] On October 20, 2009, the Advisory Board accepted the NIOSH recommendation to extend the Hanford SEC to cover all workers who meet the eligibility criteria up to June 30, 1972.

periods across the three internal dosimetry files of interest: 'INV_RESULT,' 'INV_ISO_RESULT,' and 'EXC_RESULT.' The last file in Table A-1, 'DOS_SUM_RESULTS,' is related to external dosimetry; however, it also contains individual worker job title information, which can be used to supplement job title information contained in the internal dosimetry files.

Table A-1: Description of REX Database Files Used in Completeness Study

DATABASE NAME	DESCRIPTION
REX_WORK_HIST	Identifies workers by a 'REX ID,' which allows for the tracking of individual workers across the different database files. Also contains employment start and end dates.
INV_RESULT	Lists in-vivo counting samples by REX ID and date, and assigns a tracking number to each in-vivo sample, which can be used to obtain the results of the count in 'INV_ISO_RESULT' described in the next row.
INV_ISO_RESULT	Uses the tracking number from 'INV_RESULT' and provides the radionuclides and result of the in-vivo sample.
EXC_RESULT	Contains the urinalysis data for workers listed by REX ID.
DOS_SUM_RESULTS	Contains external monitoring results, which are not part of this analysis; however, the database also contains job title information, which can be linked to the internal database files by REX ID

In many instances in the database, work location and/or job title are not specified for each individual internal monitoring result. For example, a worker might have dozens of urinalysis data points available, but only one of those results specifies the job title and work area. SC&A 2011 states the following on this issue:

> *Because taking this information at face value (i.e., only considering worker employment periods with a job title specified or only internal monitoring results that specify a work area) would severely limit the amount of data available for analysis, an approximate approach was developed, so that as much data as possible could be included. To this end, it has been assumed that, if a worker is identified with a specific job title, they held that job title throughout their SEC employment. Similarly, if a worker is identified with a specific area of work, it is assumed they spent their entire employment at that location.* (SC&A 2011)

Clearly this type of approach would result in some "double counting" for cases in which a worker may have held more than one job title or worked in more than one area of the site. SC&A 2011 explored the potential issue of double counting in its completeness study. For example, it was found that over 93% of the surveyed workers were associated with only one job title in the REX_Database. Less than 1% had more than two job titles, and no worker had more than 4 job titles. The effect on work location analyses was less easily quantified; however, it was deemed that the assumption of grouping workers into specific areas for the length of their employment was more beneficial than any potential loss in accuracy.

Using this assumption and available information on job title and work location scattered throughout the database, SC&A was able to modify the information in REX so that the majority of internal monitoring results could be used in the completeness study. The subsequent analysis was able to draw some of the following conclusion/findings:[4]

(1) For the main radionuclides analyzed (Am, Cs, MFP, Pu, and U), workers associated with the 200 Tank Farms were most likely to be monitored during their employment.

(2) 'Radiation monitors,' 'electricians,' 'operators,' 'pipefitters,' and 'science technicians' were consistently among the five job titles most likely to be monitored during their SEC employment.

(3) In general, the most commonly monitored job titles by area and year were 'managers and administrators' (for the 100, 100-N, 200, and 300 Areas), 'operators' (for the 200, 200 Tank Farms, and 300 Area), and 'scientists' (for the 300 Area).

(4) In-vivo records analysis for americium, cesium, mixed fission products, and uranium monitoring showed a significant decrease in worker sampling in 1975 (generally less than 1% of the worker population was monitored). Other significant decreases in worker monitoring include 1974 (iodine), 1976–1977 (mixed fission products), and 1985 (cesium). Thorium-232 was sparsely monitored throughout the period, and there are very few data points overall. No significant decreases in worker monitoring were identified for plutonium.

(5) Exotic radionuclides with sparsely available records include thorium, iodine, polonium, neptunium, radium, curium, californium/berkelium, and 'total actinides.' Polonium, curium, and 'total actinides' were mostly periodic sampling, while radium and neptunium appear to be incident related.

Finding 1 demonstrates that one of the known areas of highest exposure potential, the 200 Tank Farms, had a higher percentage of workers monitored compared to the other areas. Finding 2 shows that high exposure potential jobs, such as 'operators' and 'technicians,' were often monitored more frequently than many of the other job types. However, Finding 3 also notes that 'managers and administrators' were the most commonly monitored job title for the 100 Area, and it is not likely that they would be among the highest potentially exposed job types.

Finding 4 notes where there are significant temporal gaps by radionuclide. It is important in the context of completeness to establish whether a greater risk for potential exposure might have occurred in those years. As part of its completeness review, SC&A also established what years and areas particular radionuclides are known to have been handled, so parallels can be drawn between any data gaps and any "off-normal" operations. Finally, Finding 5 notes that the available records for some of the more exotic radionuclides are sparse and likely not suitable for the development of a coworker model from a completeness standpoint.

Example 1 Discussion:

One of the major advantages to this type of approach of a completeness evaluation is the sheer amount of information and data contained in the REX database. Though certain assumptions had

[4] It must be noted that findings are meant to be summary conclusions and that much more quantitative information is contained in SC&A 2011 than is appropriate to include here.

to be made when applying the information (such as presumed job title and work location), this allowed for the inclusion of the vast majority of data available and provided a very good overview of the monitoring practices of the site as applied to nearly all workers (nearly 50,000 workers and their associated bioassay records were included in the completeness study). However, the advantages of this type of "site-wide" approach can also be viewed as a drawback, since issues such as the inconsistency of reporting the work location and job type require that workers be "grouped" based on the available information. This results in some "double counting," which can potentially cause the accuracy of conclusions regarding monitoring practices to suffer (for example, if one particular job title was 'reported' more often in the REX database).

One potential solution to this difficulty would be to perform both types of analyses:

- One analysis that only considers job and area information directly related to an individual monitoring result and ignores all other results for that worker
- A second analysis that associates job and area information with a particular worker for their entire employment (as was done in SC&A 2011)

The combined findings and observations from both analyses would likely provide a sufficiently solid analytical base from which to draw conclusions about the completeness of the available records. It should be noted that on May 31, 2012, NIOSH recommended that the SEC class be expanded to also cover the period from July 1, 1972, to December 31, 1983, on the basis of insufficient information to reconstruct doses to enriched uranium, U-233, neptunium or thorium. The Advisory Board agreed with this recommendation during its July 2012 meeting.

Example 2: Fernald In-Vivo Lung Count for Thorium

Background Summary:

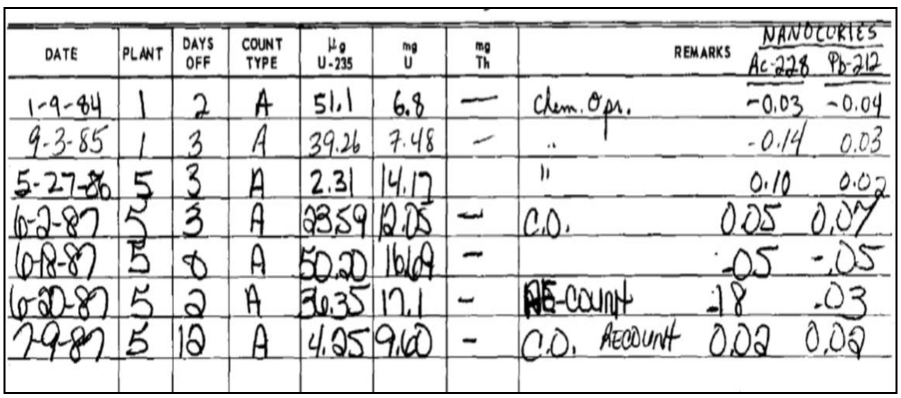
While the majority of processing at Fernald concerned uranium compounds, thorium compounds were also processed at the site, at least up until 1979 and perhaps afterwards in a minimal capacity. Fernald also became the Department of Energy's (DOE's) national repository for thorium compounds beginning in 1972. Therefore, even after the end of most processing in 1979, exposure potential would have existed through stewardship and repackaging operations up through the end of the SEC period in 1989.

From 1953 up through 1967, Fernald utilized Daily Weighted Exposure (DWE) studies to characterize the alpha contamination present in the worker's breathing zone as a way of controlling radiation intakes. Starting in 1968, Fernald began receiving periodic visits from the Mobile In-Vivo Radiation Monitoring Laboratory (MIVRML), which was a mobile lung counter developed at Y-12. Once the MIVRML arrived on site, the practice of performing DWE studies ceased and monitoring for thorium deposition, along with uranium, was assigned to the mobile counter. The MIVRML went through two different periods of reporting conventions for thorium; from 1968–1978, thorium measurements were reported in "milligrams of thorium," while post-1978 thorium measurements were reported as the daughter products of Ac-228 and Pb-212.

In March 2008, NIOSH released its coworker model for thorium exposure entitled, *Thorium In Vivo Coworker Study for FEMP – A Proposed Attachment for ORAUT-TKBS-0017-5, Revision 1* (ORAUT 2008). On April 26, 2012, the Advisory Board determined that Th-232 internal doses cannot be reconstructed with sufficient accuracy for the 1968 to 1978 period (when thorium lung burdens were reported in mg of Th). Therefore, the following completeness study example will focus on the later period of thorium in-vivo monitoring (1979–1988).

Analytical Approach Taken:

No electronic database previously existed to characterize in-vivo monitoring at Fernald. Therefore, ORAUT 2008 developed its coworker model using site-specific hardcopy logbooks, which would document the in-vivo results for individual workers. These logbooks contained the worker's name, a badge number, date of the measurement, number of days off, measurement result, and in most cases the work location (by plant) and job title. An example of a typical logbook is shown in Figure A-1. One vital piece of evidence that the logbooks do not contain is which workers might have handled thorium, and how the in-vivo measurements might reflect these potential exposures. The available hardcopy logbooks contained both claimants and non-claimants, and were compiled into an electronic database by NIOSH/ORAUT.



DATE	PLANT	DAYS OFF	COUNT TYPE	µg U-235	mg U	mg Th	REMARKS	NANOCURIES Ac-228	NANOCURIES Pb-212
1-9-84	1	2	A	51.1	6.8	—	Chem. Opr.	-0.03	-0.04
9-3-85	1	3	A	39.26	7.48	—	..	-0.14	0.03
5-27-86	5	3	A	2.31	14.17		"	0.10	0.02
6-2-87	5	3	A	23.59	12.05	—	C.O.	0.05	0.07
6-18-87	5	0	A	50.20	16.69	—		.05	-.05
6-20-87	5	2	A	36.35	17.1	—	RE-COUNT	.18	.03
7-9-87	5	12	A	4.25	9.60	—	C.O. RECOUNT	0.02	0.02

Figure A-1. Example of Thorium Logbooks used in ORAUT 2008

Because the practice of reporting the job title and work area was so prevalent, the approach and assumptions utilized in Example 1[5] were not deemed necessary. The first step in the completeness evaluation involved looking at an overview of records by year to determine the number and relative magnitude of the results. The purpose of this is to determine if there are years with significantly less monitoring, but which might have shown greater exposure potential via the magnitude of available sampling. An example of this analysis is shown in Table A-2, which displays the relative magnitude of results by counting the number of results above the minimum detectable activity (MDA). As seen in the table, the number of total samples generally increased from 1979 onward, with a significant jump in 1984. Meanwhile, the number of "positive" samples decreased from 1979 onward, although they still only constituted a small

[5] The approach taken in Example 1 assumed that if a worker was associated with a specific job title/work area that they held that title and location for their entire employment.

percentage of the overall monitored population. There do not appear to be significant gaps in the number of samples on an annual basis. Based on historical records for Fernald, the large increase in frequency of sampling in the mid-1980s is likely due to the increased focus on radiological protection, which generally coincided with the change in management from National Lead of Ohio to Westinghouse.

Table A-2: Overview of Available In-Vivo Data 1979–1988

Year	# Samples	# Samples with both Ac and Pb Results above the MDA	# Samples with Only the Ac Result above the MDA	# Samples with Only the Pb Result above the MDA	# Samples with no Results above the MDA
1979	177	26 (14.7%)	4 (2.3%)	2 (1.1%)	145 (81.9%)
1980	188	13 (6.9%)	14 (7.4%)	1 (0.5%)	160 (85.1%)
1981	141	8 (5.7%)	3 (2.1%)	1 (0.7%)	129 (91.5%)
1982	180	8 (4.4%)	1 (0.6%)	5 (2.8%)	166 (92.2%)
1983	169	4 (2.4%)	1 (0.6%)	1 (0.6%)	163 (96.4%)
1984	371	9 (2.4%)	3 (0.8%)	0 (0.0%)	359 (96.8%)
1985	382	2 (0.5%)	3 (0.8%)	4 (1.0%)	373 (97.6%)
1986	463	4 (0.9%)	2 (0.4%)	5 (1.1%)	452 (97.6%)
1987	562	4 (0.7%)	1 (0.2%)	5 (0.9%)	552 (98.2%)
1988	108	1 (0.9%)	1 (0.9%)	0 (0.0%)	106 (98.1%)
All In-Vivo Data (1979–1988)	2741	79 (2.9%)	34 (1.2%)	24 (0.9%)	2604 (95.0%)

The next step in the completeness study was to break down the in-vivo records by job title to see which jobs were sampled the most frequently and how their results compare to other less-monitored job types. The results are shown in Table A-3, which demonstrate that the most commonly monitored job title (Chemical Operator) also had the highest results among any other job title. This demonstrates that monitoring was generally focused on the job types with higher exposure potential. However, as mentioned previously, the inability to actually identify which workers handled thorium and to what extent they are reflected in the monitoring records is still somewhat of a concern.

A similar analysis was performed based on plant area; however, the results were less conclusive. It is worth noting that a large portion of the results were associated with "other areas" of the site (not Plants 1–9). Repackaging and redrumming operations at Fernald were not generally carried out inside any of the main plants, so these "other areas" likely cover some of the places where these stewardship activities occurred.

Table A-3: Comparison of In-Vivo Results by Job Title (1979–1988)

Job Title	# of Samples (%of Total)	Magnitude of Results	
		95th Percentile* (Ac-228)	95th Percentile* (Pb-212)
Chemical Operator	1207 (55.0%)	0.387	0.330
Unknown	549 (25.0%)	0.150	0.160
Construction Trades	248 (11.3%)	0.096	0.056
Other Operator	156 (7.1%)	0.278	0.194
Millworker	141 (6.4%)	0.100	0.020
Engineer/Technician	81 (3.7%)	0.100	0.030
Supervisor	73 (3.3%)	0.186	0.200
ITO	68 (3.1%)	0.120	0.113
Laborer	59 (2.7%)	0.104	0.071
Inspection/QA	53 (2.4%)	0.084	0.050
Oiler/Degreaser	28 (1.3%)	0.097	0.070
Health and Safety	21 (1.0%)	0.090	0.260
Administrative	20 (0.9%)	0.061	0.057
Mechanic	16 (0.7%)	0.073	0.040
Security	12 (0.5%)	0.183	0.282
Laundry	10 (0.5%)	0.081	0.000

*95th percentile evaluated using Microsoft Excel's Percentile Function

The last analysis performed for this completeness evaluation involved gaining insight into how workers were selected for counting regardless of job type or work area. Specifically, the analysis sought to determine if workers who displayed "positive" lung counts were scheduled to be monitored more frequently than workers whose results were less than the detection limit. It was found that geometric mean number of days that passed between counts for workers with results below the detection limit was nearly a year (364 days), while the number of days for workers with positive results was only 36, nearly 1/10th the time elapsed when compared to results less than the MDA.

In summary, the completeness analysis was able to determine that (1) there were no significant gaps in the monitoring data on an annual basis, (2) higher potential job types (such as chemical operator) were sampled more frequently, and (3) the time elapsed between samples for workers with positive results was approximately 1/10th the elapsed time of those with no positive result. While the work area analysis was generally inconclusive, it also did not demonstrate a bias towards sampling areas with lower exposure potential. SC&A concluded that the dataset was suitably complete for the purposes of dose reconstruction, though cautioned that the implementation of any coworker model should account for the inability to identify the specific workers who handled thorium.

Example 2 Discussion:

This approach used a large cross section of workers (not just claimants, as shown in the next example) and had reasonably extensive work location and job type information included in the hardcopy records. Given these characteristics of the dataset, it is reasonable to conclude that any quantitative analysis including the job and work area was accurate for the group of monitored workers. However, it is not clear to what extent these records reflect the entire affected worker population. As stated previously, the lack of information identifying which workers actually handled thorium and to what extent they were monitored is not currently available. However, reasonable claimant-favorable assumptions regarding the implementation and assignment of thorium intakes using this dataset likely obviates this uncertainty from an SEC perspective.

Example 3: Internal Dose to Workers at Nevada Test Site during the Underground Testing Period (1963–1990)

Background Summary:

The NTS operated from 1951 until 1992 and was one of the primary sites for testing nuclear explosive devices during that time. From the beginning of site operations until 1963, the United States conducted more than 100 aboveground nuclear tests, at which point all further nuclear testing was conducted underground until radiological operations ceased in 1992. In April of 2006, NIOSH evaluated the period of atmospheric testing (1951–1962) and determined that it could not reconstruct doses with sufficient accuracy. The Advisory Board accepted NIOSH's findings and the SEC was granted in May of 2006.

Subsequent to this Advisory Board recommendation, NIOSH produced a new evaluation report covering the period of 1963 through 1992 (NIOSH 2007). In this evaluation report, NIOSH proposed an internal dose coworker model based on the bioassay data from a group of 100 claimants with evidence of radiological exposure at NTS. Specifically, NIOSH 2007 states:

> *NIOSH examined the records supplied by DOE for 100 NS claimants with significant total external whole-body photon exposures (cumulative above 1.0 rem). The nature of the potential exposure scenarios at NTS makes it most likely that significant internal exposure would be associated with significant external exposure.* (NIOSH 2007)

At the time, DOE had supplied records for 1,287 total claims for NTS, and over 400 of those claims contained some internal dosimetry data.

Analytical Approach Taken:

In this example, the proposed coworker model is based on a sample of 100 claimants, which differs from the first two examples that contained an expansive electronic radiological database (Example 1) or site-wide hardcopy records that represent both claimants and non-claimants (Example 2). It must be noted that at the time of the initial evaluation report (NIOSH 2007), no electronic database was known to be available that would encompass a larger portion of the workers at NTS. It is the absence of a radiological database that necessitated the approach of using claimant records to attempt to characterize the potential dose at NTS.

Since the group of claimants chosen for the basis of the coworker model (henceforth referred to as the "NIOSH 100") only comprise 25% of the NTS claimants with internal dosimetry information, the first step taken in evaluating this approach was to construct an alternate group of claimants for comparison. In order to get a sense for the exposure potential for different job categories, SC&A randomly selected 20 claimants each from 6 job classifications (radiological safety, laborers, welders, wiremen, miners, and security guards). This semi-randomly selected group is comprised of 120 claimants and can be referred to as the "SC&A 120." It should be noted that since the claimants were randomly selected, some of the claimants were included in both the NIOSH 100 and SC&A 120 sampling groups.

SC&A then compiled radiological information provided in the claimant records for both the NIOSH 100 and SC&A 120. From this compilation and analysis, it became clear that the internal monitoring program at NTS was biased, from a frequency standpoint, towards the job titles of radiological safety and security guard. However, there was no evidence from this analysis that those job types exhibited a higher exposure potential than other job types at NTS. Also apparent was the fact that many claimants in the remaining trades analyzed (laborer, welder, wireman, and miner) did not have any available bioassay data.

Subsequent to this comparison, a large electronic database was discovered that contained a significant amount of bioassay data (over 122,000 samples in the evaluated SEC period) which were not previously available to ORAUT. This database did not specify job title; however, SC&A was able to identify the claimants in the database by their social security number and assign them their job titles based on information in the individual claim files. By doing this, SC&A was able to expand on the number of sampled workers in the six job categories of interest. SC&A then analyzed the database by the four major types of internal monitoring at NTS: beta/gross fission products, gamma, plutonium, and tritium. Similar trends to the previous analysis were apparent, in that radiological safety and security guards were sampled much more frequently than the other job types.

An example of the analysis results is shown for tritium in Table A-4, which presents an overview of the frequency that the particular job titles were monitored, as well as providing some indication of the magnitude of the actual results. As shown, though radiological safety workers only compromised 13 of the 134 claimants identified with 1 of the 6 job titles, they accounted for over 50% of the samples taken. Figure A-2 shows a rank order plot of the magnitude of tritium results (MI/cc) for the job categories surveyed. As can be seen, the job categories that had the highest results for tritium were actually the miners, wiremen, and laborers, even though they had significantly less samples present in the dataset. In fact, the magnitude of tritium bioassay for radiological safety was slightly lower than the "all claimant average" at most percentiles and lower than the "all worker average" at the upper percentiles. Similar findings were observed for the other major bioassay categories (beta/gross fission products, gamma, and plutonium); the reader is referred to SC&A 2010 for the full analysis.

Based on this review of job-specific bioassay results, it can reasonably be concluded that the monitoring program was not focused on the most highly exposed workers, and often times did not include those job designations in the sampling program. On January 25, 2010, NIOSH recommended to the Advisory Board that the class of employees at NTS from 1963 through 1992 be included in the SEC. In May of 2010, the Advisory Board accepted NIOSH's recommendation.

Table A-4: Analysis of Electronic Database for Tritium Data Including Data Overview and Characteristics

Tritium Data	Claims							All Workers
	RadSafe	Laborers	Welders	Wireman	Miners	Security	All Claimant Pu	
Data Overview								
Total Samples	1985	221	39	37	817	826	4977	42748
# Individuals	13	17	9	13	48	34	244	4724
Urine Samples	1900 (95.72%)	207 (93.67%)	35 (89.74%)	31 (83.78%)	757 (92.66%)	764 (92.49%)	4673 (93.89%)	40253 (94.16%)
Whole Body Counts	85 (4.28%)	14 (6.33%)	4 (10.26%)	6 (16.22%)	60 (7.34%)	62 (7.51%)	304 (6.11%)	2495 (5.84%)
Data Characteristics								
Number of Positive Results	1718 (86.55%)	202 (91.40%)	29 (74.36%)	28 (75.68%)	717 (87.76%)	755 (91.40%)	4320 (86.80%)	36805 (86.10%)
Number of Results Listed as 'Less than'	148 (7.46%)	3 (1.36%)	2 (5.13%)	2 (5.41%)	23 (2.82%)	3 (0.36%)	276 (5.55%)	2447 (5.72%)
Number of Negative Results	21 (1.06%)	1 (0.45%)	4 (10.26%)	-	1 (0.12%)	6 (0.73%)	41 (0.82%)	-
Number of Zero Results	13 (0.65%)	-	-	-	2 (0.24%)	-	19 (0.38%)	135 (0.32%)
Number of Results listed as 'No Detectable'	-	-	-	-	-	-	-	-
Number of Blank Results	85 (4.28%)	15 (6.79%)	4 (10.26%)	7 (18.92%)	74 (9.06%)	62 (7.51%)	321 (6.45%)	3361 (7.86%)

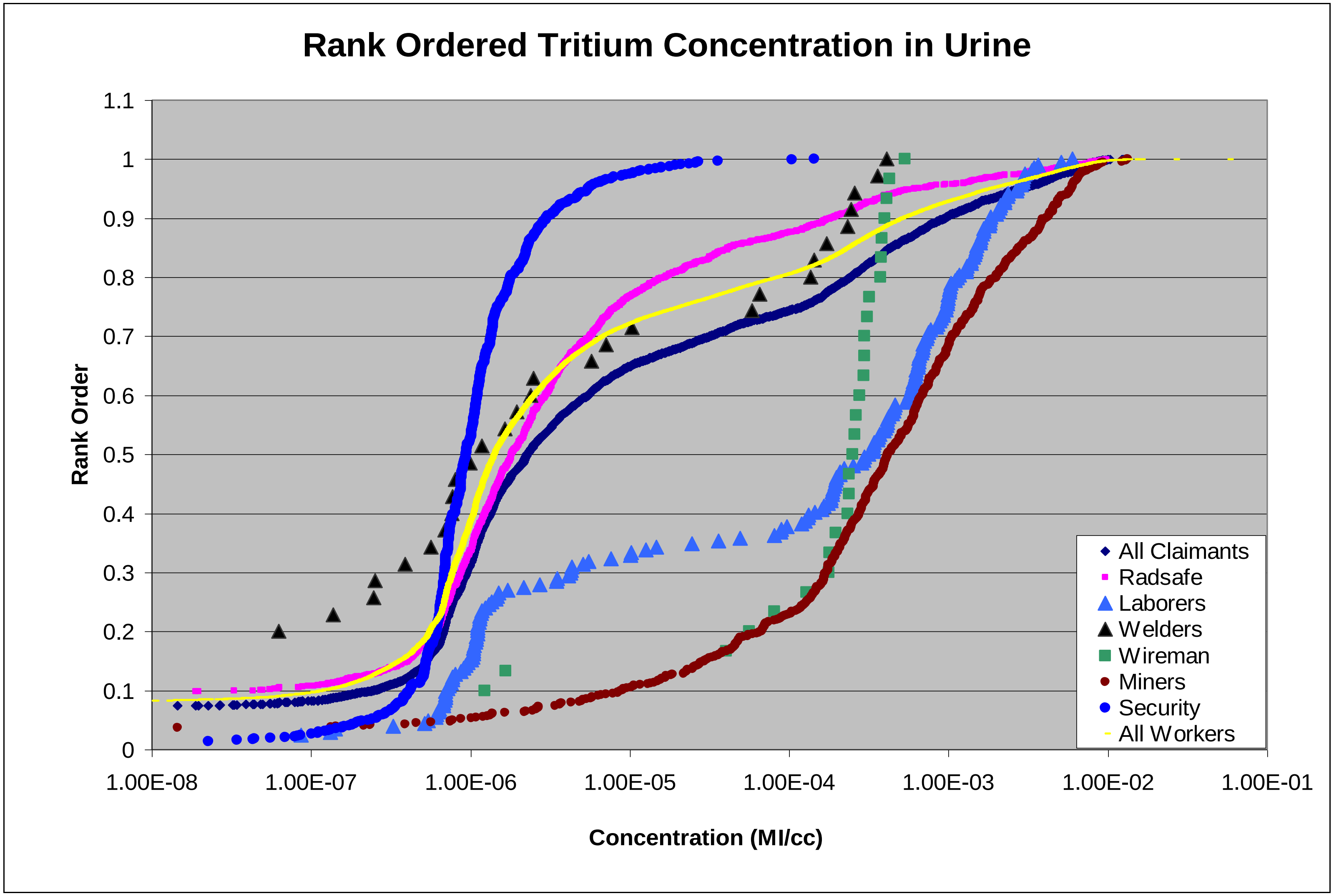


Figure A-2. Rank Ordered Tritium Concentration in Urine (MI/cc) for Surveyed Job Titles

Example 3 Discussion:

The approach described above was clearly an iterative process due to the unavailability of an electronic database in the beginning stages of the completeness evaluation process. Nevertheless, the methodology of using claimant samples can be an effective instrument in gathering information and insight into the monitoring practices of a particular site. This is illustrated by the corroborating analysis of the electronic database later uncovered, though care must be taken to put such claimant sample-based analyses in their proper frame of reference. Though it is always preferable to analyze data that are representative of the workforce as a whole, absent the availability of such information, claimant sampling is a useful tool to gain insight into the completeness of available data in an SEC context.

Example 4: Bounding Internal Exposures to Stable Metal Tritides at the Mound Plant

Background Summary:

Stable metal tritides (SMTs) are a form of insoluble tritium that do not metabolize from the lung like normal tritiated compounds, and, as a result, it is not possible for traditional bioassay methods, such as urinalysis, to accurately reflect the actual exposure to SMTs. It has been established that SMTs were handled in specific known areas of the Mound Plant, and it is also known who the primary workers are who handled the material. Air monitoring data are available; however, it is equally problematic, because this material would have been caught in the air filters prior to being counted by the detector.

Since it is known who the primary handlers of the material were, maximizing assumptions can be made to adjust those individual urinalysis results to effectively bound the potential exposure to these workers. However, this type of bounding model would be inappropriate to use on ancillary or support workers whose exposure to the material would likely have been infrequent and the potential for intake minimal. Therefore, an alternate method was constructed, which used area swipe samples to model the resuspension and intake of the tritiated material. This method was finalized in the NIOSH report: *Potential Stable Metal Tritide Exposures at the Mound Laboratory* (NIOSH 2012a).

Analytical Approach Taken:

As stated in the previous section, the proposed model is not based on actual bioassay or in-vivo monitoring of workers, but rather workplace sampling in the form of swipe data. Though the specific areas/rooms where the work was performed are known, there is still the potential that particular areas of the room may not have been sufficiently monitored via swipe samples. Fortunately, the original swipe sample reports are available and inspection of these reports shows that swipes were taken all over the rooms of interest (an example of one such report is shown in Figure A-3). Therefore, it is not likely that an area within the room had significantly higher contamination and was routinely missed by the swipe sampling program.

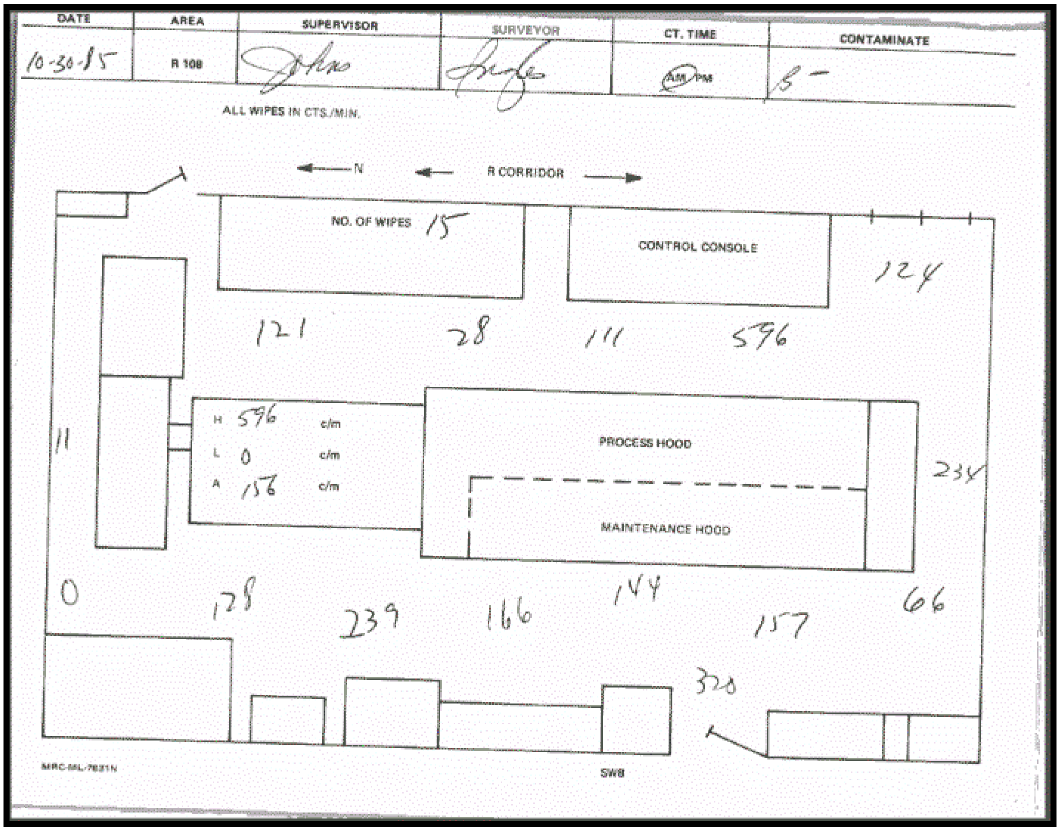
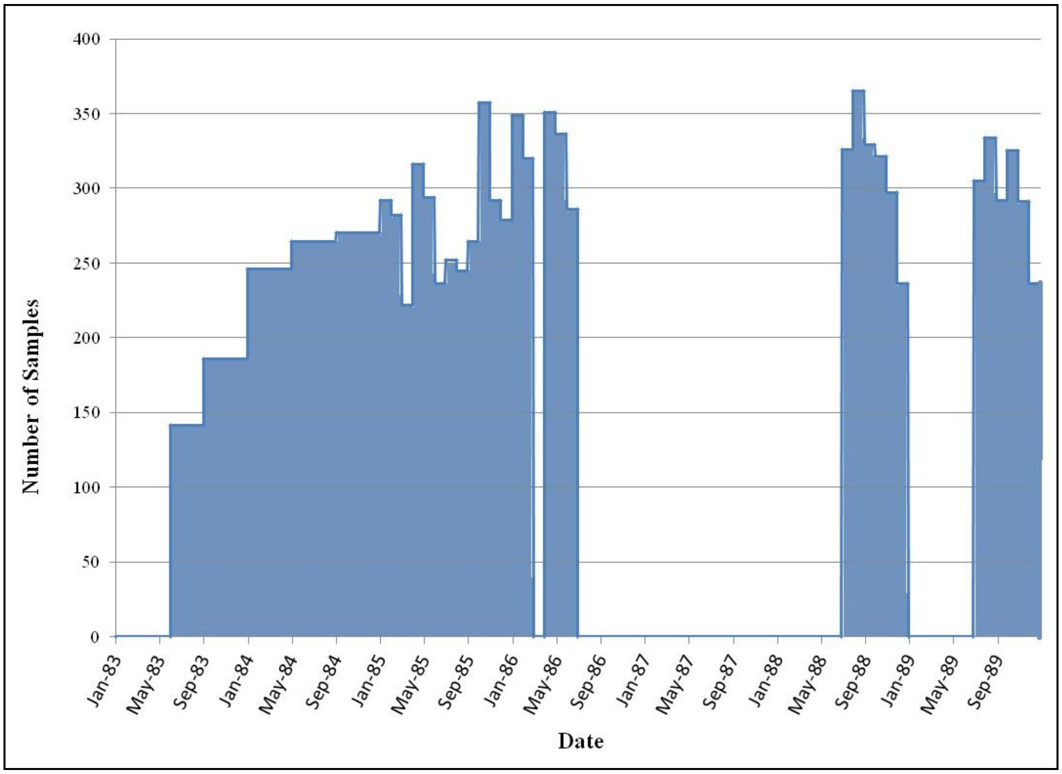


Figure A-3. Example of a Swipe Sample Report Showing the Layout of the Room and Areas that were Sampled

The primary handlers of the SMT material have been identified and a bounding approach has already been developed; therefore, the proposed resuspension model only applies to ancillary or support workers. Since it is not possible to identify which of these workers might have been exposed, the model applies to all workers who entered radiological areas. At Mound, if a worker entered a radiological area, then a tritium urinalysis sample was mandatory. As a result, anyone with tritium bioassay is considered to have been potentially exposed to SMTs. Therefore, any evaluation of the completeness of the proposed approach need only consider the temporal coverage of the available swipe results and not the job types and areas of interest (which are both known).

SC&A presented its completeness study in SC&A 2012 and found that there were significant temporal gaps in the available swipe data. One example is shown in Figure A-4, which plots the number of available swipe samples for Room R-108 during the period of interest. As seen in the figure, there is a gap in the swipe data that extends over 2 years, as well as a few other smaller data gaps. It is important to determine whether a surrogate data approach is appropriate to use during these gaps in data coverage, and that no off-normal operations involving SMTs occurred. Any off-normal operations or conditions might have posed a higher exposure potential, which would make using surrogate data from surrounding periods problematic.



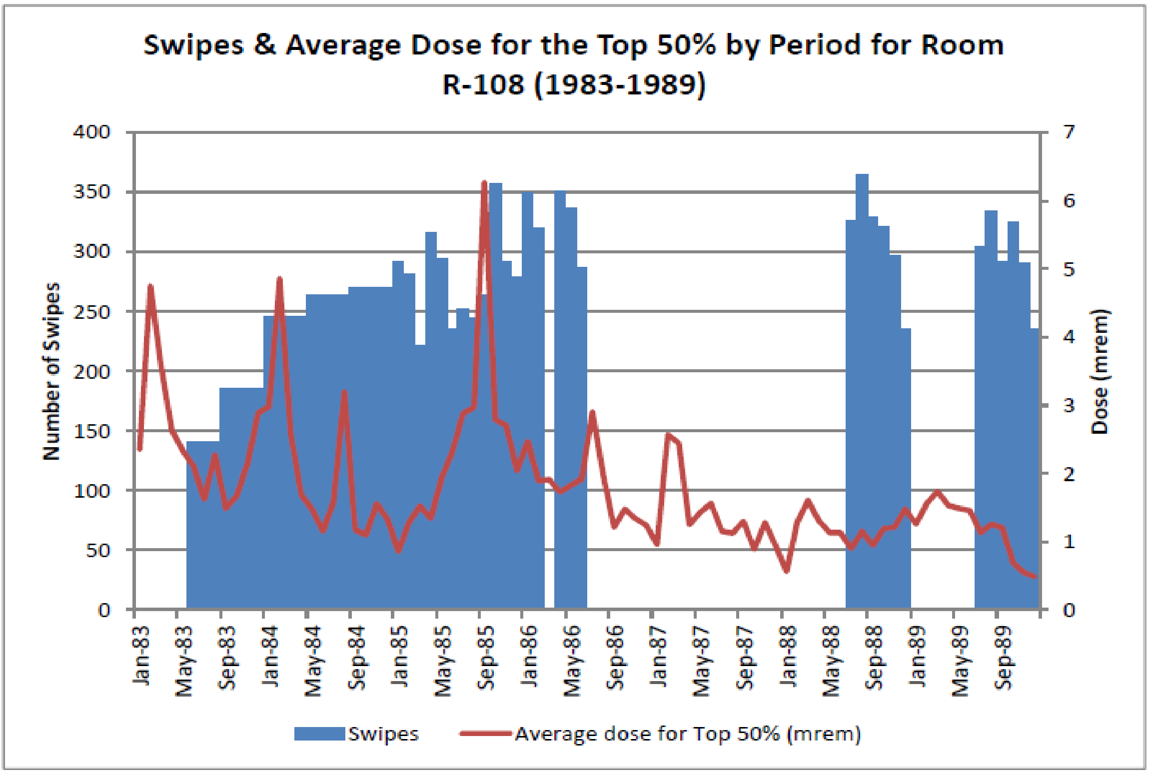
Source: SC&A 2012

Figure A-4. Number of Samples by Year for Room R-108 during the Period of Interest

NIOSH 2012b addressed these gaps in the data using two different approaches. First, NIOSH conducted further interviews with former workers who had direct knowledge of the SMT operations. These workers were shown the gaps in the available data and were asked if there was any reason to believe that operations would differ from the periods when swipe data were available. NIOSH 2012b states:

> *Interviews with the research chemists and radiological health personnel that have firsthand knowledge of the operations were specifically asked if any working situations occurred or they were made aware of that would have caused the missing swipe data to be different than the data on either side of the gap. The overall agreement was the data from both sides of the gaps should be adequate to extrapolate the data within the gaps.*

In the second approach, NIOSH analyzed the tritium urinalysis data during the entire period of interest, which included the periods with swipe data gaps. Though tritium urinalysis data are not indicative of exposure to SMTs, they do indicate whether site-wide tritium operations might have increased during the periods with no swipe data. This type of indirect test helps build a weight of evidence argument, since it is not unreasonable to assume that operations involving SMTs would generally parallel the other tritium operations at the site from a production and exposure standpoint. An example of this is shown in Figure A-5 for Room R-108, which essentially takes the plot shown in Figure A-4 and overlays the average tritium doses during the period. As seen in the figure, overall tritium doses at the site during periods with swipe data gaps were not significantly different than the periods with swipe data. In fact, the period with the highest tritium doses (late 1985) is covered by the swipe data. Therefore, reasonable application of surrogate data is likely appropriate to bound SMT exposures during the periods with no data. Similar results were found for the other room of interest (SW-8) that had identified data gaps.



Source: NIOSH 2012b

Figure A-5. Number of Swipe Samples Plotted against the Average Dose Based on Tritium Urinalysis

Example 4 Discussion:

While it is always preferable to use worker bioassay data to reconstruct doses and develop coworker models, in some situations, the bioassay information is unavailable or is not adequate for the task. In the case of Mound, urinalysis data are available, but are inappropriate for the purpose of reconstructing doses to the support workers. Therefore, the alternate approach of using workplace monitoring was adopted to bound doses to this group of workers.

This type of approach still requires the ability to identify the specific areas and workers that were involved in the operation of interest. Fortunately in this case, the pertinent information was available. Therefore, the main concern from a completeness perspective is the temporal considerations. Although there were significant data gaps identified, worker interviews and characterization of the overall site production during the gap mitigate any potential issues arising from the unavailability of swipe data.