
Draft

Advisory Board on Radiation and Worker Health
National Institute for Occupational Safety and Health

**Review of ORAUT-RPRT-0092, Revision 00, “Evaluation of
Bioassay Data for Subcontracted Construction Trade
Workers at the Savannah River Site”**

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SC&A, Inc. Technical Support for the Advisory Board on Radiation and Worker Health's Review of NIOSH Dose Reconstruction Program

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Abbreviations and Acronyms

ABRWH, Advisory Board	Advisory Board on Radiation and Worker Health
ALARA	as low as reasonably achievable
Am	americium
ANSI	American National Standards Institute
BSRC	Bechtel Savannah River Company
Ce	cerium
Cs	cesium
CTW	construction trade worker
CW	coworker
DOE	U.S. Department of Energy
DPSOL	DuPont Savannah River Operating List
DPSOP	DuPont Standard Operating Procedure
E&I	Electrical and Instrumentation
EDWS	Electronic Document Workflow (Records) System
FP	fission product
HP	Health Physics (department)
HPO	health protection organization
HPT	Health Physics Technology
mrem	millirem
N/A	not applicable
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH Division of Compensation Analysis and Support Claims Tracking System
Np	neptunium
OCAS	Office of Compensation Analysis and Support
ORAU	Oak Ridge Associated Universities
Pu	plutonium
RCA	Radiologically Controlled Area
RCO	Radiological Control Operations
Ru	ruthenium
RWP	Radiological Work Permit

SAR	safety analysis report
SEC	Special Exposure Cohort
SID	sample identification
Sr	strontium
SRDB	Site Research Database
SRS	Savannah River Site
SRTC	Savannah River Technology Center
SRWP	standing radiological work permit
subCTW	subcontracted construction trade worker
SWP	Special Work Permit
TBM	technical basis manual
U	uranium
WSI	Wackenhut Services Incorporated
WSRC	Westinghouse Savannah River Company

1 Executive Summary

The report, ORAUT-RPRT-0092, revision 00, “Evaluation of Bioassay Data for Subcontracted Construction Trade Workers at the Savannah River Site” (NIOSH, 2019a, “RPRT-0092”), was issued by the National Institute for Occupational Safety and Health (NIOSH) on June 14, 2019. The Advisory Board on Radiation and Worker Health’s (Advisory Board’s) Savannah River Site (SRS) Work Group tasked SC&A, Inc. to review it on June 16, 2019.

This NIOSH evaluation is particularly important because construction subcontractors often performed nonroutine jobs involving unique radiological source terms or conditions, and permit-indicated, job-specific bioassays were necessary to verify whether intakes may have taken place. SC&A earlier raised concerns over identified gaps in such bioassay data for 1997 and questioned whether it was sufficiently complete and representative for earlier years to support the application of a coworker model for assigning internal doses.

SC&A reviewed NIOSH’s evaluation from three vantage points:

1. **Sampling premise:** From the standpoint of sampling experience and results, were the guiding assumptions upon which the evaluation was planned and conducted borne out for the time periods in question?
2. **Sampling execution:** From the standpoint of sampling execution, was its primary goal accomplished? In other words, did it “randomly select radiological workers from the various areas at the Savannah River Site (SRS), such that an evaluation of monitored and unmonitored workers can be conducted” (NIOSH, 2018a, p. 1)?
3. **Coworker datasets:** From the standpoint of NIOSH’s “Draft Criteria for the Evaluation and Use of Coworker Datasets” (NIOSH, 2015), did the evaluation satisfy its stated objective of demonstrating that “monitored subcontractor CTWs and unmonitored subcontractor CTWs worked side by side in the same radiological environment at the same time” (NIOSH, 2018a, p. 1)?

1.1 Sampling premise

For the first vantage point concerning the sampling premise, SC&A concludes that NIOSH’s guiding assumptions for sampling subcontractor bioassay data for 1972–1989 have neither been validated in practice nor adequately grounded in DuPont policies, procedures, and practices of that time period. In vitro and in vivo bioassays were linked to Special Work Permits (SWPs) and job plans without clear evidence that the former stemmed from the latter and were not merely incidental. None of the SWPs and job plans for that period reviewed by SC&A contain any bioassay requirements, despite the vast majority of them requiring respiratory protection. The basis for identifying “radionuclides of interest” for sampled permits does not account for inadequate radiological characterization cited by the U.S. Department of Energy (DOE). The scope of sampling is limited to only one SRS facility, 773-A, for incomplete operational periods, and is not representative of other critical SRS facilities. The inclusion of incident-driven bioassays is not appropriate, given the degree of procedural accountability provided special bioassays, as compared with that afforded the routine and job-specific bioassay program (for which DOE found a history of delinquent bioassays). Finally, the completeness of these and

other radiological records is questionable, given the acknowledged destruction of subcontractor records, DOE findings of missing occupational dose data, and firsthand worker accounts regarding dose records gaps.

For the post-1989 period, SC&A concludes there were similar concerns until such time as the new contractor, Westinghouse Savannah River Company (WSRC), was able to develop and implement improved internal dosimetry programs, and hold SRS line management more accountable, as part of its Radiological Improvement Plan. This plan included a spectrum of new and updated radiation protection and bioassay policies and procedures that evolved over time, including (1) the late 1990 “Internal Dosimetry Technical Basis Manual” (WSRC, 1990b), (2) the implementation of a 1990 standardized Radiological Work Permit (RWP) program (WSRC, 1990a) requiring job-specific bioassays (implementation began in 1991) that were required upon respirator use (WSRC, 1992b), and (3) manual 5Q1.1, “Radiation and Contamination Control Procedures” (WSRC, 1992b), which replaced DuPont Savannah River Operating List (DPSOL) procedures. However, it is not clear when effective implementation was actually achieved, given the persistence of former workplace practices, as illustrated by the significant job-specific bioassay gaps uncovered by WSRC and DOE in 1997–1998.

1.2 Sampling execution

For the second vantage point concerning sampling execution, SC&A concludes that for 1972–1989, NIOSH’s interpretation of “effective monitoring”¹ to include unmonitored workers who are matched to workers monitored via an internal dosimetry method (in vivo or in vitro) that is not used in the development of the ORAUT-OTIB-0081 coworker models (NIOSH, 2019c; “OTIB-0081”) is not appropriate. Likewise, NIOSH considered chest count data that were more than 2 years past the end of the job plan as a valid monitoring result. However, NIOSH’s own policies regarding chest counts for long-lived nuclides consider periods longer than 2 years to be “unmonitored” (refer to ORAUT-OTIB-0060 (NIOSH, 2018b, pp. 24–25) and RPRT-0092 (NIOSH, 2019a, p. 34). When SC&A revised the “matching” percentage in RPRT-0092 based on removing these two questionable adjustments, it was found that the effective monitoring for americium for 1981–1987 dropped to 33 percent versus 76 percent reported in RPRT-0092; for plutonium for 1972–1974, the effective monitored population decreased to 64.7 percent versus 69 percent.; and for fission products for 1972–1974, it dropped to 69.9 percent from 94 percent, and for 1980–1989, it dropped to 73.9 percent from 99 percent (see section 5 of this report).

For all evaluated periods (1972–1998), SC&A concludes that the NIOSH review did not appear to adhere to its sampling plan because bioassays for all of the radionuclides listed on the RWP were not addressed in the corresponding data analyses for the specific time intervals. When SC&A recreated and compared data from RPRT-0092, table 6-4, “Rates of Monitoring of subCTW for at Least One Radionuclide, 1981 to 1998,” when considering *all radionuclides* on a work permit, it was found that results adjust downward to significantly lower percentages, particularly in the earlier periods. For 1972–1974, the percentage of directly monitored workers reported drops from 76 percent to 47.1 percent, and that of effectively monitored workers drops from 85 percent to 55.1 percent. For 1980–1989, the percentage of directly monitored workers

¹ “Effective monitoring” as used in RPRT-0092 indicates the percentage of workers who were monitored directly (in vitro or in vivo) plus those who were on the same job plan/work permit with an individual who was monitored directly.

reported drops from 90 percent to 51.3 percent, and the effectively monitored percentage drops from 99 percent to 65.5 percent. For 1990–1998, the percentage of directly monitored workers reported drops from 96 percent to 77 percent, and that of effectively monitored workers drops from 98 percent to 89 percent.

1.3 Coworker datasets

For the third vantage point concerning establishing that unmonitored subcontractors worked side by side with monitored subcontractors, SC&A concludes that the current sampling effort in RPRT-0092 was not successful in identifying suitable coworkers for americium for 1981–1987, as just 13 percent of the overall population (16 percent of the unmonitored population) was matched based on coworker urinalysis. For fission products 1980–1989, just 1.4 percent of the overall population (37 percent of the unmonitored population) were effectively matched by in vivo. No suitable coworker matches were identified for fission products in the 1972–1974 period, and only a single unmonitored worker was identified for americium exposure during this same period. No coworker evaluations for any radionuclides were possible for 1975–1979. For plutonium, the sampling effort identified coworker matches for about 15 percent of the worker population (29 percent of the unmonitored population), which raised the effective monitored population from 50 percent to 65 percent for 1972–1974.

For 1990–1998, a focused review of plutonium coworker matches during the WSRC period notes that while nearly 96 percent of the identified coworker matches involve the same job plan, inclusion of additional criteria (e.g., the same date, time, and craft) decreases this percentage significantly. When considering all four criteria for a coworker match (job plan, date, time, and craft), appropriate coworker matches for plutonium were identified in RPRT-0092 just 45 percent of the time.

1.4 Overall conclusions

Overall, SC&A concludes that the RPRT-0092 assessment of subcontractor data completeness for 1972–1998 (1) does not reflect the policies, procedures, and practices during the DuPont operating era of 1972–1990 and (2) makes unfounded assumptions, inferences, and claims for monitoring “success” rates for bioassay performance that sometimes lead to errant results and conclusions, as a function of the radionuclide and timeframe involved. These sitewide SRS operational conditions only change with the advent of new and updated RWP and bioassay procedures implemented by WSRC in the early 1990s, at which point the basis and assumptions for the RPRT-0092 assessment can be better substantiated, and results considered valid. SC&A finds that applying the same assumptions and evaluation criteria concerning permit-driven, job-specific bioassays for the entire 26-year span of SRS operations under evaluation is not plausible and does not consider critical changes in work controls and bioassay procedures during that timeframe. Further, questions of overall data completeness persist based on reported destruction of subcontractor records and gaps in worker exposure records, compounded by issues of records retention and retrievability.

In summary, without a validation of subcontractor data completeness for all relevant SRS radionuclides and representative facilities that the RPRT-0092 evaluation was to provide, there has not been adequate substantiation for 1972–1990 that there are sufficient job-specific bioassay measurements available to ensure that the coworker data in OTIB-0081 are either bounding or

representative of the exposure potential of subcontractors performing permit-driven work across the SRS site. Further, based on SC&A's review, this question of completeness is not confined to subcontractor CTWs but extends to all CTWs who would have been subject to permit-required bioassays in 1972–1990.

The next section (section 2) provides a summary of SC&A's review findings and observations for RPRT-0092.

2 Summary of Findings and Observations

This section presents SC&A's 11 findings and five observations from its review of RPRT-0092.

- Finding 1: No SWPs or job plans sampled by NIOSH for 1972–1990 contain any requirements or indications for job-specific bioassays, despite respiratory protection being required, bringing into question the approach taken to satisfy RPRT-0092's first evaluation objective. See section 4.1.
- Finding 2. “Radionuclides of interest” assumed for sampled permits in RPRT-0092 are of questionable accuracy given cited lack of adequate radiological source term characterization prior to 1990. See section 4.2.
- Finding 3. The scope of permit sampling for 1972–1990 at SRS is essentially limited to one facility, 773-A, falling short of achieving NIOSH's sampling objective and the representativeness called for in NIOSH's coworker guidelines. See section 4.3.
- Finding 4: SRS incident-based/special bioassays were provided by workers on a more stringent procedural basis and should not be used to supplement the evaluation of permit-related, job-specific bioassays for 1972–1989 as a measure of historic data completeness. See section 4.4.
- Finding 5: The incompleteness of SRS dose records for 1972–1990 is substantiated by the acknowledged destruction of subcontractor records and firsthand worker accounts, coupled with DOE findings of missing occupational radiation dose data from many SRS personnel files, as well as systemic bioassay delinquencies, and wide gaps in NIOSH's capture of permit documentation. See section 4.5.
- Finding 6: For the period 1980–1989, only 20 percent of the identified subcontractor-job plan combinations identified by NIOSH as requiring americium sampling had internal monitoring performed within an acceptable timeframe (i.e., within 2 years for chest counting). See section 5.2.1.
- Finding 7: The total “effectively monitored” population for americium (those monitored directly or have a coworker on the same job plan with a urinalysis result) during the 1980–1989 period is approximately 33 percent. If a urinalysis sample taken during 1991 as [REDACTED] in a different SRS location (and is not currently used in the SRS coworker model) is removed, the effective monitored population drops to 26.5 percent. See section 5.2.1.
- Finding 8: Many of the workers (around 70–73 percent) who should have been monitored for fission products underwent appropriate internal sampling during the two periods evaluated prior to 1990 (1972–1974 and 1980–1989). However, very few of these monitored workers underwent in vivo counting for fission products. Thus, they are not included in the coworker model developed for SRS and are not considered representative of the unmonitored worker. See section 5.3.
- Finding 9: SC&A does not find that the data collected as part of the RPRT-0092 review support the premise that subcontractors on job plans that should have required internal monitoring for americium were either directly monitored (around 20 percent) or,

alternately, appropriately represented in the derived coworker models for SRS (around 13 percent). See section 5.3.

- Finding 10: Data for 1990 are lacking. Therefore, 1990 should be included with the period of limited data, 1972–1989, and not bundled in with the year 1991. See section 6.1.
- Finding 11: For both the 1972–1989 and the 1990–1998 periods, when considering all radionuclides requiring internal monitoring per work permit, as opposed to “at least one radionuclide” requiring monitoring, the percentage of monitored workers drops significantly (particularly in the earlier periods). Directly monitored workers ranged from 47 percent to 77 percent (in comparison to 76–96 percent in RPRT-0092), and effectively monitored workers ranged from 55 percent to 89 percent (in comparison to 85–99 percent in RPRT-0092). See section 7.2.
- Observation 1: The back application of assumptions regarding work permits, job-specific bioassays, and target radionuclides to conduct a completeness review for 1972–1998 is not plausible given the significant changes in radiological policies, procedures, and practices that occurred in the early 1990s. See section 4.6.
- Observation 2: During the 1972–1974 period, RPRT-0092 only evaluates one job plan/worker combination (Job Plan 46) for potential americium exposure. However, attachment D, table D-1 indicates at least one other job plan (Job Plan 47) requiring americium monitoring during this period. Neither of the workers were directly monitored nor had an appropriate coworker monitored for americium. See section 5.1.1.
- Observation 3: Only 13 percent of the subcontractor-job plan combinations (17 total) had americium urinalysis performed that could be considered relevant to coworker modeling. Eleven of the 17 urinalysis data points represented a single worker who had a single sample taken in 1991 as [REDACTED] that occurred in a different area ([REDACTED]) during that year (i.e., representative of a different area and different period). See section 5.2.1.
- Observation 4: SC&A’s analysis indicates that identified coworker matches may not be sufficiently representative of the subCTW intakes in all cases unless strict criteria are applied, such as the same craft designation as well as the same date and time of the work performed. See section 6.3.
- Observation 5: Bioassay data in the 1990s are not entirely free of the earlier data issues. The implementation of methods used to correct for the bioassay deficiencies seen in the 1970s and 1980s did not take place immediately with the change in the contracting company in 1990. It was not a step function that took place in 1990; instead, it took a number of years to identify, address, and effectively implement the changes. For example, there was only one RWP with one subCTW listed for 1990 in RPRT-0092, and specific radionuclides were not required on the RWPs until the mid-1990s. See section 6.4.

3 Introduction and Background

SC&A was originally tasked by the Advisory Board in 2017 to conduct a broad review of bioassay data completeness for subcontracted construction trade workers (subCTWs) at SRS, resulting in its report, “Evaluation of Savannah River Site Subcontractor Bioassay Data Completeness” (SC&A, 2017a). This completeness review was undertaken in parallel with a NIOSH effort to review the completeness of bioassay data for building 773-A for the years 1981–1986 (ORAUT-RPRT-0083, revision 00 (NIOSH, 2017a)). At the time, the Advisory Board was concerned that NIOSH’s review would be too narrow (in terms of facility scope and timeframe) to resolve the issue of subcontractor CTW bioassay data completeness on a sitewide basis (ABRWH 2016a, p. 49; 2016b, pp. 150–172).

Establishing data adequacy and completeness is a prerequisite for developing and applying any coworker model, as is currently proposed by NIOSH in OTIB-0081 for construction trade workers (CTWs), including subcontractors (NIOSH, 2019c). As has been emphasized in various meetings and forums, SC&A finds that the rapidly changing operational circumstances at SRS beginning in the late 1980s and extending into the 1990s, with emphasis given to reactor restart, decontamination and decommissioning, waste management, and environmental cleanup, contributed to a rapid influx of subcontractor CTWs to augment onsite resources. This led to questions by SC&A and the Advisory Board about their bioassay monitoring. In particular, transient subcontractors may not have been bioassayed adequately in light of their often-intermittent work on site and the lack of a comprehensive termination bioassay program. This concern was underscored by an earlier finding that DOE had, in fact, cited and fined WSRC in 1998 for not adequately monitoring workers performing radiation work under job-specific RWPs (DOE, 1998a).

NIOSH has since discovered 852 boxes of RWPs, job plans, and SWPs for SRS that encompassed the years of interest, 1972–1998. Given the paucity of RWPs identified to that point in time, these records offered a means to conduct sampling for bioassay completeness and to characterize the subcontractor CTW cohort for the years in question. The ABRWH Savannah River Site Work Group requested that NIOSH conduct such an evaluation based on its experience evaluating bioassay completeness for building 773-A for 1981–1986 in ORAUT-RPRT-0083, “Evaluation of Monitoring of Construction Workers Identified in High-Level Cave Job Plans at the Savannah River Site” (NIOSH, 2017a).

NIOSH prepared an “SRS Work Permit Sampling Plan” that had as its primary goal to “randomly select radiological workers from various areas at the Savannah River Site (SRS), such that an evaluation of monitored and unmonitored workers can be conducted” (NIOSH, 2018a, p. 1). NIOSH noted in its transmittal of the Plan that “the attached SRS Work Permit Sampling plan describes what we have learned and proposes details of how information can be sampled to obtain an unbiased data set to evaluate subcontractor monitoring for both co-worker applicability (original question – did monitored and unmonitored subcontractor CTWs work together) and to evaluate specific radionuclides of interest (new question – appropriate source term)” (Taulbee, 2018).

SC&A’s approach to reviewing RPRT-0092 is distinguished by the two time periods and two corresponding SRS operating contractors—DuPont and Westinghouse—who programmatically

defined and implemented distinctly different work permit and job-specific bioassay programs for 1972–1989 and 1990–1998, respectively. This distinction manifested itself in a number of ways but was most apparent in the lack of procedural requirements, permit records, job-specific bioassays, and other program documentation before 1990, with major initiatives thereafter by WSRC to update requirements, define formal technical bases and procedures for internal dosimetry, and hold line management and workers more accountable for adhering to them.

The lack of available records led NIOSH to diverge from its sampling plan for the 1972–1989 period and collect all applicable records, which happened to be for only one area, 773-A/776-A, SRS’s analytic laboratory operation. SC&A divided its review in a similar manner, focusing first on the premise and assumptions underpinning NIOSH’s evaluation for each of the two time periods, with a second assessment of how the sampling was actually performed for plutonium, americium, and fission products consistent with the sampling plan goals and evaluation objectives. Although there were more bioassay records that covered plutonium, americium, uranium, neptunium, and fission products for more of the major work areas at SRS for the 1990–1998 period compared to the 1972–1989 period, SC&A found that some issues carried over into the 1990s, and that it took time to implement new procedures in the field.

SC&A’s goal was to test both the central thesis for RPRT-0092—that bioassays can be linked to corresponding work permits so that monitored subcontractor CTWs can be compared with unmonitored subcontractor CTWs—and whether the actual sampling process was conducted in a sound manner. As such, it is a “weight of evidence” assessment that reviews all aspects of NIOSH’s evaluation, from sampling premise and design, to sampling execution, and finally, to results achieved.

4 Review of Assumptions and Basis for Subcontractor Data Sampling, 1972–1989

In an earlier presentation to the SRS work group (NIOSH, 2017b), NIOSH found that 91 percent of 371 subcontractor claimants in NIOSH’s Division of Compensation Analysis and Support Claims Tracking System (NOCTS) (340 of 371) have internal monitoring data. Based on NIOSH’s qualitative review, any lack of monitoring appeared to be “randomly distributed.” However, as emphasized before the Advisory Board in 2017, SC&A believes that the key question is the representativeness of that data. As concluded by SC&A (2017b),

- “Representativeness” is a key issue: How relatable are exposures of subcontractors on RWP job-specific bioassays compared to those working under “typical” or general work conditions with prescheduled routine bioassays? NIOSH needs to adequately demonstrate that routinely monitored workers were doing the same jobs or tasks as those solely on job-specific bioassay.
- RWPs before 1999 at SRS were neither complete nor consistently applied with respect to job-specific bioassays. Unmonitored intakes may have occurred due to workplace radiological source terms not being properly characterized and included in RWPs. Most RWPs appear to be missing for WSRC 1989–1995^[2]; few remain for the DuPont era (past interviews indicate subcontractor records destruction in 1989 during contract transfer).

While the lack of available work permits (RWPs) for the earlier SRS time periods precluded an examination of these issues at the time, NIOSH’s discovery of 852 boxes of such records spanning the 1972–1998 timeframe led to the job-specific bioassay sampling evaluation whose results are presented in RPRT-0092. However, as with any sampling of historic monitoring records, the goals, assumptions, protocol (including evaluation criteria), and operational basis are critical. In the April 2018 version of its “SRS Work Permit Sampling Plan” (NIOSH, 2018a), NIOSH defined its approach, as follows.

The primary goal of this sampling plan is to randomly select radiation workers from the various areas at the Savannah River Site (SRS), such that an evaluation of monitored and unmonitored workers can be conducted. A concern has been raised by the Advisory Board on Radiation and Worker Health (ABRWH) that a co-worker model, even if the models are stratified by operations workers and construction trades workers, might not be representative for subcontractor CTWs. The ABRWH’s Savannah River Site Workgroup’s contractor indicated that they would be more comfortable with the co-worker models if it could be demonstrated that monitored subcontractor CTWs and unmonitored subcontractor CTWs worked side by side in the same radiological environment at the same time. The NIOSH/ORAU team determined the best way to demonstrate this monitoring is to randomly pull Special Work Permits (SWPs), Job Plans, and Radiological

² The correct time span for WSRC permits is now established as 1990–1998.

Work Permits and directly compare the monitoring of subcontractor workers listed as having worked on the individual Work Permit. [(NIOSH, 2018a, p. 1)]

SC&A provided comments on this sampling plan (SC&A, 2018b). These included agreement that Standing Radiation Work Permits (SRWPs) should not be included (typified more routine work), that permits involving tritium exposures should not be included (less dose significance, more data availability), and that while in vivo monitoring should be considered, caution needed to be exercised to account for all of the target radionuclides in the periodic counting performed.

Most importantly, SC&A expressed a concern over how NIOSH would address pre-1989 permit sampling. While the use of subcontractors was more limited during the DuPont era (i.e., before 1990, although increasing numbers of subcontractors were being brought on site beginning in the mid-1980s), SC&A emphasized the need for “obtaining a representative sample from which a bioassay completeness assessment can be performed for that earlier period,” and the “need to reflect the availability of RWPs/SWPs for 1972–1988, and encompass a sufficient scope of facilities and timeframe” (SC&A, 2018b, p. 5). While it was observed, at the time, that NIOSH’s sampling approach may differ for this earlier period due to relatively fewer subcontractors and permits, and that clearly 773-A was the only facility represented, SC&A stressed the need for “continued scrutiny for any additional boxes of permit records that may apply for pre-1989 facilities beyond just A Area” (SC&A, 2018b, p. 6).

Contrary to NIOSH’s statement that its bioassay comparisons in RPRT-0092 would serve to make the Board’s contractor “more comfortable with the co-worker model” (Taulbee, 2018), more importantly, it is the Advisory Board that needs assurance that the approach taken in the RPRT-0092 evaluation achieved its intended goals, that the assumptions made proved sound, and that sampling itself was conducted in a manner consistent with the sampling plan, SRS operational practice, and established NIOSH technical positions.³ SC&A addresses the first two questions in this section (section 4) and the question of sampling execution in sections 5 and 6 for the 1972–1989 and 1990–1998 periods, respectively.

4.1 Special Work Permits, job plans, and required bioassays (1972–1989)

As NIOSH notes in RPRT-0092, very few boxes were identified with job plans and Special Work Permits (SWPs) for the period before 1991, and those were only for work in A Area (facility 773-A). SWPs most closely resembled the later RWPs in intent and format, with not only procedural checkoffs for radiological practice, monitoring, and equipment but also an explicit requirement for a job-specific bioassay to be left “before leaving building” (DuPont, 1972; see figure 1 under item 1 below). NIOSH indicates that SWPs were phased out sometime between 1972 and 1976,⁴ with DuPont Standard Operating Procedures (DPSOPs) (or DuPont Savannah River Operating Lists (DPSOLs))⁵ becoming the sole source of bioassay sampling guidance (NIOSH, 2019a). However, as NIOSH confirmed, these procedures were too general in terms of monitoring guidance and did not specify bioassay requirements.

³ Including the OTIB-0081 coworker model (NIOSH, 2019c), plutonium CTW stratification refinement (NIOSH, 2019d), and internal dose reconstruction (NIOSH, 2018b).

⁴ However, some were still in use in 1985, based on SC&A’s review of NIOSH’s “List of Construction Trade Workers Identified in Job Plans” (NIOSH, 2019b).

⁵ DuPont issued its procedures as DPSOPs, with some contained in DPSOLs.

Because of the relatively small number of SWPs and job plans available for 1972–1989,⁶ NIOSH forwent its planned sampling regime and collected all subcontractor work data from job plans that required bioassay or respiratory protection. Job plans and SWPs were collected covering portions of 1972, 1973 through 1976, and 1979 through 1988 for work done in facility 773-A, with a total of 204 work permits (“permits”⁷ meaning SWPs and job plans) included in the sampling review by virtue of NIOSH’s sampling protocol. Following a detailed review of all permit “folders of interest” that were identified based on these criteria, NIOSH excluded a number of permits as not actually requiring bioassay for their task, resulting in 146 permits of interest encompassing 662 subcontractors for 1972–1989 (NIOSH, 2019a).

SC&A reviewed CTW permits obtained for 1971–1988⁸ and determined that none of those reviewed actually specified a job-specific bioassay requirement. It is clear that the vast majority of permits identified as “of interest” in terms of an assumed job-specific bioassay requirement are actually so designated because of a specified requirement for respiratory protection. SC&A considers the assumed linkage between a work permit and a related bioassay to be faulty for the following reasons:

1. None of the SWPs reviewed for the 1972–1989 period have a required job-specific bioassay checked off.

SWPs are the only work permits for the 1972–1989 period that actually provide for a job-specific bioassay requirement, but none that SC&A reviewed, at least in NIOSH’s survey, have that requirement checked off, and no indication for a job-related bioassay is provided in the comment portion of the SWP for any bioassay monitoring. This is despite most of the selected SWPs requiring respiratory protection, with the work location being 773-A, a facility that involved laboratory services that included high-level cells used in the analysis and testing of highly radioactive material from onsite and offsite facilities (La Bone, 1996). These operations involved plutonium-239 (Pu-239), curium-244, americium-243 (Am-243), californium-252, and fission products, all of which posed an exposure potential given the scope and magnitude of work activities and the presence of contamination. An illustrative example of a 1972 SWP selected by NIOSH, without the bioassay requirement being checked but requiring an “assault mask” (respirator), is provided in figure 1.

⁶ While NIOSH bifurcated its review into two periods, 1972–1989 and 1990–1998, SC&A found little permit documentation was identified for 1990, for unknown reasons. However, it should be noted that WSRC had just assumed management of the SRS operating contract and was in the process of implementing a new, formal RWP system. Any conclusions for 1972–1989 would, therefore, also apply for 1990. Additionally, no permits were identified after March 1988.

⁷ SC&A is using “permits” to signify SWPs and job plans in the context of DuPont operations at SRS in 1972–1989. RWPs did not exist at SRS during this timeframe, until implemented by WSRC in the 1990–1991 timeframe.

⁸ This was accomplished by reviewing every SWP and job plan listed in NIOSH’s internally compiled “List of Construction Trade Workers Identified in Job Plans” (NIOSH, 2019b) for 1972–1981, and a sampling of one every month for 1981–1988 (given the larger numbers involved), for a total of 430 individual permits reviewed. The disparity between NIOSH’s number of permits and that of SC&A’s review stems from SC&A’s review of available CTW permits identified (including subCTW permits) before they were culled in the selection process.

Figure 1. Example of Special Work Permit (DuPont, 1972)

DSR 14-B (Rev. 9-61)

SPECIAL WORK PERMIT

TIME: 8:00 AM to 4:30 PM BLDG.: 776-A DATE: 3/3/72 SWP NO.:

LOCATION: 776-A LOADING DOCK DEPARTMENT(S): CONSTRUCTION

JOB DESCRIPTION: Remove remaining lead shielding. Remove drip pans, and piping. Scaffolding is required.

SPECIAL INSTRUCTIONS - MONITORING: AT START OF JOB INTERMITTENT CONTINUOUS

INSTRUCTIONS:

WHEN MORE THAN ONE RATE IS LISTED ON SWP, STATE WHICH RATE WAS USED.

ENTER TIME IN RDZ ON TIME SHEET.

HEALTH PHYSICS SHALL BE PRESENT FOR LINE BREAKS.

PERSONAL SURVEY IS REQUIRED WHEN LEAVING RADIATION DANGER ZONE.

NO PERSONAL OUTER CLOTHING

SPECIAL PROTECTION REQUIRED FOR CUTS OR ABRASIONS.

TAPE GLOVES-CANVAS BOOTS TO COVER ALLS.

PROVIDE TIMEKEEPER.

PRE-PLAN MEETING REQUIRED. *

CONTACT HEALTH PHYSICS FOR A SURVEY BEFORE STARTING WORK IN A NEW LOCATION.

PROVIDE ASSISTANCE FOR THE REMOVAL OF PROTECTIVE CLOTHING.

GIVE BIO-ASSAY SAMPLE BEFORE LEAVING BUILDING.

NOTE: [REDACTED] WILL CONTACT SIGN FOR CONSTRUCTION EACH MORNING BEFORE INITIATING WORK. * FOR LINE BREAK OF ABANDONED PROCESS PIPING.

1) Double bag lead pieces.
2) Provide bag under piping when lines are broken and when lead caps are removed from flanges.

PROTECTIVE CLOTHING		RATE	EXPOSURE	DISTANCE	TIME FOR 50 mrem OR 250 µC/H ²	BODY OR HANDS	SURVEYED BY	TIME
HEAD	CAP	A	150 mrem/hr	with scaffolding	20 min	BODY	[REDACTED]	9:00 AM
	HOOD					HANDS		AM
	SHOE COVERS	B	25 mrem/hr	East wall	150	BODY		PM
	RUBBERS					HANDS		AM
FEET	CANVAS BOOTS	C	15 mrem/hr	East wall	3 hr 20 min	BODY		PM
	CANVAS GLOVES	D	300 mrem/hr	East wall	10 min	BODY		AM
HANDS	RUBBERIZED CANVAS							
	SURGEONS - SHORT RUBBER							
	RUBBER GAUNTLET							
APPROVALS	DIVISION: 8700 TO 1:30 SHIFT TO SHIFT TO SHIFT HEALTH PHYSICS: [REDACTED] OPERATIONS: [REDACTED] MAINTENANCE: [REDACTED] CONSTRUCTION: [REDACTED] CAUSE: FOREMAN [REDACTED]							
COVERALLS - 2 PAIR	[REDACTED]							
LAB COAT	[REDACTED]							
SUIT - RUBBER PLASTIC	[REDACTED]							
AIR PAK AIR LINE MASK	[REDACTED]							
ASSAULT MASK	[REDACTED]							
FILM BADGE	[REDACTED]							
PENCILS	[REDACTED]							

NAME	DEPT.	PAYROLL NUMBER	RATES USED	TIME RECORD				TOTAL TIME	ESTIMATED EXPOSURE OR ASSIMILATION			PENCIL READER
				IN	OUT	IN	OUT		mrem	mrem	µC/H ²	
[REDACTED]				9:00	10:40	1:00	2:20	3:00				1:20
[REDACTED]				9:00	10:40	1:00	2:20	3:00				80
[REDACTED]				1:00	2:20			1:20				10
[REDACTED]				9:00	10:40			3:00				60
[REDACTED]						1:00	2:20	1:20				10

2. None of the job plans reviewed for the 1972–1989 period have a required job-specific bioassay indicated, despite DPSOPs providing such an option to line supervisors and health physics.

Job plans can include provisions for tritium and other nuclides being required for bioassay, as outlined in DPSOP-40 (for tritium) or “as specified by area Health Protection in Construction Job Plan” (DuPont, 1972–1992). These procedures indicate that area health physics can specify radionuclides and sampling frequencies beyond routine ones (DuPont, 1989). Line organizations also had the discretion to develop procedures for “routine bioassay samples at frequencies equal to or less than one month” (DuPont, 1987).

Such nonroutine,⁹ job-related bioassay sampling would complement what routine sampling would have been already required at a particular SRS facility, in terms of radionuclide type and frequency. Ensuring that workers who moved from job to job and facility to facility were monitored for all applicable radionuclides is something that would be later termed “composite” bioassay monitoring by WSRC and be required for “Roving Employees,” such as CTWs and subCTWs, as follows:

Roving Employees

Personnel whose job assignment requires them to enter RCAs in different facilities across the Site during the course of their regular work should be placed on a bioassay schedule which ensures they are counted (*in-vivo* program) and/or sampled (*in-vitro* program) for the appropriate radionuclides. Examples of these groups may include Site Support Services such as E&I and Maintenance, HPO inspectors and supervisors, WSI personnel, and Bechtel Construction personnel and their subcontractors. For these individuals a composite routine bioassay program is required. [(WSRC, 1992b, PDF p. 37)]

Such explicit requirements for “composite” routine bioassays for construction workers, specifically for those that moved (“roving”) from facility to facility, and from job to job, did not exist in DuPont procedures.

The importance of this dictum was emphasized in the same procedure, WSRC’s first version of 5Q1.1, procedure 506, revision 0, as follows:

⁹ Job-specific bioassays were defined as “non-routine” bioassays until the mid-1990s, when they were redefined in the WSRC 5Q1.1 procedure and incorporated in the routine program as part of internal exposure verification; they were defined as part of the routine bioassay program in the internal dosimetry Technical Basis Manual beginning in 1991.

5.2 Routine Bioassay Program Assignment

Caution: It is **EXTREMELY IMPORTANT** to note that the effectiveness of the bioassay program in general depends on combining both the routine program and the non-routine, job-specific program. Any time unusual events occur, or jobs are performed that may expose personnel to unusual hazards, a job-specific program should be considered per Section 5.1.2.1. [(WSRC, 1992b, PDF p. 36)]

DPSOL procedures for bioassay¹⁰ provided different guidelines for construction workers versus operational workers. Operational workers had type and frequency of bioassay sampling designated by specific area and facility, while construction workers had general requirements, with discretion provided facility managers or local health physics to specify bioassay for job-specific radionuclides. The only sitewide requirement was for plutonium, tritium, and fission products, with all other radionuclides to be addressed in construction job plans (DuPont, 1971). However, there is no evidence in the sampled permits referenced in RPRT-0092 for 1972–1989 of any such sampling for “other radionuclides” being required in job plans for CTWs or subCTWs. Without job-specific bioassays to complement the required plutonium, tritium and fission product routine bioassays, “roving” construction workers would not have been adequately enrolled for the radionuclides to which they may have been potentially exposed, and the bioassay database for both CTWs and subCTWs would accordingly be incomplete.

A typical job plan selected by NIOSH is shown in figure 2.

¹⁰ Examples of bioassay procedures include DPSOL 47-137 (DuPont, 1973a) and DPSOL 193-302, revision 7 (DuPont, 1976).

Figure 2. Example job plan (DuPont, 1983)

JOB PLAN

Date: 3-10-83

Time of Oper: _____

Contact: _____

Done by: _____

Phone: 3615

Operation

Describe operation, safety precautions, and radiation and contamination control precautions

Title of Job: Remove ceiling tiles in F004 and install electrical conduit for cell 11 Reverse Osmosis

PROTECTIVE CLOTHING		Rq'd
1. Coveralls	<u>One</u> Two	✓
2. Respirator	<u>Com So II *</u>	✓
3. Breathing Air		✓
4. Shoe Covers	<u>Hood *</u>	✓
5. Shoe Covers		✓
6. Gloves		✓
7. TLD Badge (By)		
8. Self-reading Dosimeter		
9. Safety Belt		
10. Rubber Boots		
11. Lab Coat		
12. RT-1 Pers. Rad. Monitor		
13. Neutron Badge		

* Respirator & Hood required to remove ceiling. BLV

JOB EVALUATION		Rq'd
Does job alter ventilation patterns?		<u>NO</u>
Rigging approved?		<u>YES</u>
Building Services?		<u>NO</u>
Will operation effect other jobs or personnel?		<u>YES</u>
Does job require a special procedure?		<u>NO</u>
Has area been properly cleared for job?		<u>YES</u>
Procedure review for HLC personnel?		<u>NO</u>
Procedure review with Crafts (Maint., E&I, T&T)?	<u>Cont</u>	<u>YES</u>
Fire Hazard?		<u>NO</u>
Lockout required?		<u>NO</u>
Does job equipment meet safety specs?		<u>YES</u>
Voice Announcement		<u>NO</u>
Preplan required		<u>YES</u>

ESTIMATED EXPOSURE			
	Body Pencil mR	Left Hand mrem	Right Hand mrem
[Redacted]	<u>6</u>		

MONITORING		Rq'd
Self-monitoring permitted		
Monitoring at start of job by Radiation Control		✓
Intermittent monitoring by Radiation Control		✓
Continuous monitoring by Radiation Control		

SURVEY RESULTS

Surveyed by: _____

6 mR/hr average @ job site

AUTHORIZATIONS

HLC Supv: _____

Rad. Cont. Supv: _____

Maint. Supv: _____

T&T Supv: _____

E&I Supv: _____

While NIOSH concludes that DPSOPs are too “general” to be a basis for identifying specific permit-related, job-specific bioassay requirements, it is still apparently assumed

NOTICE: This report has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.

that DuPont line managers and health physicists would have done so, either through SWPs and job plans or by some other means. However, while respiratory protection requirements are often checked and workplace contamination cited in the permits sampled, there is no evidence that related job-specific bioassays were indicated or required. Such a procedural requirement would not have been in standard practice until 1991, when a formal RWP system with job-specific bioassay requirements was implemented by WSRC.

3. No identified procedural requirement or practice supports the linkage between respiratory protection requirements in job plans “of interest” and related job-specific bioassays.

One of NIOSH’s guiding assumptions for ascertaining whether a job-specific bioassay would have been required in conjunction with an SWP or job plan during 1972–1989 is reflected in the following provision:

Because of the low number of boxes identified for 1972 through 1990 in the sampling plan, the team was charged with collecting all subCTW work data from Job Plans that required bioassay or respiratory protection.
[(NIOSH, 2019a, p. 47)]

The assumption that a respirator requirement on the job plan made it one “of interest” (i.e., one having a corresponding job-specific bioassay) has no clear basis in DuPont practice. It was not made a sitewide guideline for routine respirator use until 1992 in WSRC manual 5Q1.1, revision 0 (WSRC, 1992b), as follows:

Personnel who wear respiratory protection or who work in posted Contamination or Airborne Radioactivity Areas must be sampled for the nuclide to which they are potentially exposed, via either the routine sampling program or non-routine, job-specific sampling program.
[(WSRC, 1992b, PDF p. 60)]

While it can be considered good practice and may have been implemented by DuPont facility managers or area health physicists on a job-by-job basis, until 1992, there was no sitewide procedure for workers using respiratory protection, and for those working in contamination, to be bioassayed for the radionuclides to which they were potentially exposed. There may have been routine bioassays performed as called for by DPSOL procedures governing bioassay types and frequencies by facility, but there is no evidence provided in either RPRT-0092, DPSOL procedures, or other records from the DuPont era reviewed by SC&A that job-specific bioassays were procedurally linked to a respirator requirement in the job plan.

The survey of subcontractor bioassay completeness conducted in RPRT-0092 for 1972–1989 is founded on the key assumption that SWPs and job plans “of interest” can be identified by their required job-specific bioassays or respirator requirements. However, none of the permits sampled by NIOSH and reviewed by SC&A show any bioassay requirements, and there is no basis provided, in either DuPont procedures or practice, for

a procedural link between respirator requirements and follow-on job-specific bioassays. On the contrary, a formal RWP program with clearly defined job-specific bioassay requirements was not initiated until the early 1990s under WSRC. Likewise, a formal procedure for job-specific bioassays linked to a respiratory protection requirement in a work permit was not promulgated until 1992.

Finding 1: No SWPs or job plans sampled by NIOSH for 1972–1990 contain any requirements or indications for job-specific bioassays, despite respiratory protection being required, bringing into question the approach taken to satisfy RPRT-0092’s first evaluation objective.

4.2 Basis for identifying “radionuclides of interest” for sampled permits

As noted in RPRT-0092, NIOSH conducted three evaluations of permit-related subCTW data:

(1) the fraction of subCTWs identified on RWPs of interest who were monitored for internal intakes of radionuclides, (2) identification of appropriate coworker(s) who were internally monitored to use as surrogates for unmonitored subCTWs, and (3) radionuclides of interest for each RWP along with the bioassay monitoring for those radionuclides. [(NIOSH, 2019a, p. 28)]

To support the third evaluation criterion, regarding “radionuclides of interest” for the work area or facility, NIOSH first investigated the work area identified in the permit (NIOSH 2019a). However, for 1972–1989, the SWPs and job plans did not typically include “radionuclides of interest” based on a SC&A review of those sampled by NIOSH. At most, survey readings and sometimes contamination levels are indicated.

A second-tier consideration for identifying appropriate radionuclide source terms in RPRT-0092 were “those that should have been required by SRS procedures in place at the time of work” (NIOSH 2019a, p. 30). While WSRC bioassay type and frequencies for the 1990s were based on comprehensive workplace exposure characterization as described in WSRC’s technical basis manuals for internal dosimetry (WSRC, 1990a, 1990b, 1992a, 1992b, 1993, 1996, 1997), DuPont DPSOL procedures for bioassay were “general” in nature (as noted by NIOSH), with health protection operations managers responsible for maintaining and updating DPSOL tables that listed facility radiological exposure sources and required bioassay frequencies. Line managers were also responsible for development of facility procedures governing bioassay sampling for radionuclides for which sampling frequency was equal to or less than 1 month (DuPont, 1987). For construction workers, including subcontractors, “Construction Job Plans” were relied upon to complement routine facility-based bioassays (for plutonium, tritium, and fission products) by ensuring that additional job-specific bioassays were conducted for “other nuclides” (DuPont, 1985).

Whether facility “radionuclides of interest” for bioassay purposes were accurate and updated for changes in operation or experience is questionable during the DuPont era. General DPSOL job plan and bioassay requirements, coupled with delegated implementation of those requirements through facility managers, would have made consistent radiological characterization and accurate radionuclide identification difficult. While SC&A did not find an internal (i.e., DuPont) self-assessment of this issue, the DOE Tiger Team review of 1990 made the following finding:

The internal dosimetry program does not comply with the requirements of DOE 5480.11. Radiological areas have not been sufficiently characterized to provide a technical basis for the assignment of bioassay sample types and frequencies. [(DOE, 1990, p. 4-193)]

This finding was based on a sitewide assessment of the internal dosimetry program that found the following, in part:

- The technical basis for determining bioassay type and frequency has not been established for the nuclides encountered at SRS. The Naval Fuel Facility was characterized (report dated February 16, 1989) to provide a basis for assigning the proper bioassay type and frequency to workers in that facility. However, no other nuclear facilities have been characterized in a similar manner. Consequently, bioassay assignments are made without the benefit of a sound technical basis. Health Protection (HP) Operations Managers decide the type and frequency of routine bioassays, based on DPSOP 193-211, Table A.
- Particle size and solubility are not well known or used to help decide bioassay type and frequency. [(DOE, 1990, p. 4-198)]

In its June 20, 1990, action plan response, WSRC agreed that “a formal technical basis for the SRS bioassay program has not yet been established” but emphasized that its program was “based on years of experience [and an] awareness of what has constituted good practice in the past, common sense, and conservative assumptions for determining employee doses” (WSRC, 1990a, PDF p. 432). It further noted that SRS was in the process of developing a technical basis document for the internal dosimetry program that would be “consistent with the requirements of the Order [5480.11] and appropriate guidance.” The action plan further detailed that, “during the development of the technical basis manual this year, the radionuclide materials at each area on the site are being characterized” (WSRC, 1990a, PDF p. 432).

The development of the internal dosimetry technical basis manual (WSRC, 1990b) and new “Radiation and Contamination Control Procedures” in WSRC manual 5Q1.1 (WSRC, 1992b), and their respective, successive revisions, were intended to update and replace DuPont’s procedures, as part of an overall SRS Radiological Improvement Plan. This plan addressed “the necessity for the line management to accept responsibility for radiological protection of their employees and facility visitors” (WSRC 1990a, PDF p. 433).

The specific issue of workplace characterization was raised again in a 1999 WSRC self-assessment following the 1998 DOE enforcement action surrounding implementation of the WSRC job-specific bioassay program (Morgan, 1999). At that time, it was determined that for two SRS facilities, Am-241 was present as an operational source term but not included in the routine bioassay program.¹¹

¹¹ This issue was raised separately in SC&A’s memorandum report of January 11, 2018 (SC&A, 2018a). A response was provided by NIOSH in ORAUT-RPRT-0091, revision 00, “Evaluation of Savannah River Site Americium-241 Source Terms between 1971 and 1999 Using Bioassay Frequency Tables” (NIOSH, 2019d). SC&A is currently responding to this report, separately.

The apparent reliance of DuPont era facility managers and health protection organizations on their longstanding radionuclide sampling tables and their knowledge of facility operations is similar to the identified root cause of the 1999 concern, which was described as a reliance on programmatic facility knowledge rather than continuing and rigorous radiological source-term characterization, as noted below:

Historically, bioassay requirements were identified by the Radiological Control Operations (RCO) organization through facility process knowledge (i.e., safety analysis documentation), procedural guidance and professional judgement. The [new] methodology discussed in this memorandum [Farrell & Findley, 1999] was used by Health Physics Technology (HPT) to update and/or reverify facility specific radionuclides of concern for bioassay program compliance. [(Farrell & Findley, 1999, p. 1)]

The updated methodology provided by this memorandum was a detailed, facility-by-facility baselining of relevant radiological source terms based on review of “existing waste certification or process stream analysis data,” coupled with alternative means such as isotopic workplace air and contamination sampling. The basis for including target radionuclides were those isotopes with “dose fractions greater than 10%” based on respective Annual Limit on Intake Values, which is indicative of “which isotopes contribute the majority of internal dose to an individual for a specific source term” (Farrell & Findley, 1999, p. 2).

The facility characterization process was defined and implemented by WSRC, as reflected in its technical basis manual (TBM), beginning in 1990, with refinements through the 1990s (WSRC, 1990b, 1992a, 1993, 1997). The 1997 Manual predated the Farrell and Findley (1999) guidance, but provided similar guidelines:

Radionuclides of concern are determined in the following manner: All radionuclides in a facility to which workers could be exposed are identified from contamination survey records, safety analysis reports (SARs), technical reports, the open literature, personal interviews, etc. The radionuclides whose radiotoxicity and exposure potential combine to deliver the majority of the dose, say 90%, are deemed to be the radionuclides of concern. All other radionuclides may be ignored unless they are suitable for use as a tracer. This process for selecting radionuclides of concern is of most use for waste streams where many radionuclides may be present.

This information is used, along with facility experience, to produce a listing of facilities and the radionuclides for which workers in that facility should be monitored. This list, which appears in Procedure 5Q1-506 . . . , recommends bioassay programs that are in agreement with those given in most radiological work permits (RWP) that are issued in a facility. However, it must be stressed that the radiological requirements for a task, including the bioassay program, are specified in the RWP. Thus, the requirements of the RWP supersede the requirements of 5Q 1.1-506. [(WSRC, 1997, p. 3-4)]

As noted previously, this sitewide, detailed guidance for comprehensive facility characterization was not in place during the DuPont era at SRS. If workplace radiological characterization was not adequately and consistently performed at SRS facilities, as found by the 1990 DOE assessment, bioassays would not necessarily have been performed when required based on the potential exposures present and for the sampling frequencies necessary for an adequate measurement.

Farrell and Findley (1999), which constituted the third consideration and “final authority” for determining facility radionuclides in RPRT-0092, was issued “In response to a concern over prescribing the correct urine bioassay sampling program[s] on radiological work permits” (WSRC, 1998, p. 1). For building 773-A (encompassing the Savannah River Technology Center) and associated operations, it observed:

Additionally, certain facilities such as the Savannah River Technology Center (SRTC) and the solid waste disposal facilities handle a wide array of radioactive materials, some of which may not be encountered in the typical radiological work environment by workers in those areas. For facilities such as 221-FB-Line, where the source term is well defined and not subject to change, this is not a concern unless there is a major change in the facility mission. To ensure that the proper radionuclide(s) is identified for the RWP urine sampling program it may be necessary to perform a thorough characterization of the work environment. It is important also that this characterization be performed on a routine basis to stay current on the source term present. [Emphasis added.] [(WSRC 1998, p. 2)]

Such a routine, comprehensive characterization was not standardized practice during the DuPont era into the early WSRC era, except at specific facilities such as the Naval Fuel facility cited by DOE in its Tiger Team Assessment finding above. Given the complexity of operations in 773-A, the multiple source terms, the noted inadequacies of the DuPont bioassay procedures (particularly the absence of a sitewide defined job-specific bioassay program managed on a facility-by-facility basis), and finally the lack of a rigorous workplace radiological characterization process, it is questionable whether, based on DPSOL procedures alone, a particular “radionuclide of interest” could be designated for a specific job plan, as undertaken by RPRT-0092 (and reflected in attachment D).

From Farrell and Findley (1999), supplemented by DuPont bioassay type and frequency tables, primary source terms for 773-A were deemed to be plutonium, americium, and fission products, for which bioassay matches were tracked in attachment D of RPRT-0092. However, given the noted complexity of laboratory operations in 773-A and the changing nature of experimental and operational support studies, DuPont procedures, together with Farrell and Findley (1999), would not necessarily reflect source terms of relevance for bioassay requirements. For example, for the Actinide Technology Center, neptunium-237 (Np-237) and various uranium isotopes were handled, in addition to plutonium and americium. For the Analytical Development Section, uranium, neptunium, and curium¹² figured in operations, in addition to plutonium and fission

¹² SC&A acknowledges that curium was measured as part of the trivalent bioassay method, which measured americium, curium, and californium coincidentally.

products (La Bone, 1996). From a review of radiological survey data and logsheets for 773-A from 1975 to 1986, SC&A found a number of instances of the handling and contamination surveying of neptunium and curium in various operations at 773-A (e.g., DuPont, 1975, 1977, 1981a). While the primary radionuclides (plutonium, americium, fission products) may have constituted the majority of the routine potential dose, these and other source terms, particularly those of an experimental or operational support nature, would have figured in permitted nonroutine, job-specific work that should have been evident from the RPRT-0092 sampling conducted.

Finding 2: “Radionuclides of interest” assumed for sampled permits in RPRT-0092 are of questionable accuracy given cited lack of adequate radiological source term characterization prior to 1990.

4.3 Representativeness of SRS facilities in RPRT-0092 sampling

The SRS work permit sampling plan has as its primary goal to “randomly select radiological workers from the **various areas at the Savannah River Site (SRS)**, such that an evaluation of monitored and unmonitored workers can be conducted” (emphasis added) (NIOSH, 2018a, p. 1). However, as noted later in the plan (and repeated in RPRT-0092), following an initial inventory search conducted of the estimated number of RWPs per year by area, it was concluded that “the only clear information that we have been able to glean from this search is that SWP and Job Plans are only available for one area during the 1972-1989 time period” (NIOSH 2018a, p. 6). This was attributed to the possibility that “SWPs and/or Job Plans for other areas may have been destroyed,” although it was noted that “we likely will never know” (NIOSH 2018a, p. 6).

Given the lack of identified permit records for SRS areas and facilities other than 773-A,¹³ NIOSH chose to depart from its detailed and statistically based random sampling of permits for 1972–1989 and simply use all of the subcontractor work data it had collected, as noted below:

Because of the low number of boxes identified for 1972 through 1990 in the sampling plan, the team was charged with collecting all subCTW work data from Job Plans that required bioassay or respiratory protection. The team reviewed folders from physical boxes and EDWS identified in the box inventory. Job Plans and SWPs covered portions of 1972, 1973 through 1976, and 1979 through 1988 for work done in Building 773-A. [(NIOSH, 2019a, p. 47)]

However, by diverging from its sampling plan and conducting its subcontractor job-specific bioassay review for only one SRS facility (773-A), NIOSH neither met its stated primary goal for the RPRT-0092 assessment to sample “various areas at SRS,” nor satisfied the following criteria in NIOSH’s “Draft Criteria for the Evaluation and Use of Coworker Datasets” (NIOSH, 2015):

¹³ SC&A’s review of available CTW permits identified by NIOSH in its search of various records sources (i.e., Federal Records Center, Electronic Document Workflow (Records) System (EDWS), Site Research Database (SRDB)), as listed for 1972–1989 in SRDB 173828, determined that with only a few exceptions (e.g., 776-A), permits were only identified for 773-A. This circumstance is apparently acknowledged by NIOSH by the interchangeable use of “A Area” and “773-A” as the cited scope of facility permits in RPRT-0092.

the amount of available monitoring data must be evaluated to determine if there are sufficient measurements to ensure that the data are either bounding or representative of the exposure potential for each job/exposure category at the facility. This analysis should look, not only at the total amount of data that are available, but also consider any temporal trends in data availability. [(NIOSH, 2015, p. 5)]

The scope of permit sampling conducted for 1972–1988 for the one facility, 773-A, has expanded the existing subcontractor completeness review for 773-A conducted by NIOSH in ORAUT-RPRT-0083 (NIOSH, 2017a). In that review, job plans and SWPs for 1979–1986 for 773-A were identified, generating an initial random sample of 110 subcontractors without bioassay, which was evaluated and culled down to 88 subcontractor CTW-job pairings monitored by bioassay (based on respirator requirements). The RPRT-0092 review has added additional pairings of permits with bioassay results (likewise based on respirator requirements), e.g., for 1972–1979 and 1987–1988.

It is clear that assessing the work permits for only one of 30 plus facilities at SRS and, even then, for only intermittent periods (1972, 1973 through 1976, and 1979 through 1988), does not provide for a representative SRS-wide validation that subcontractor job-specific bioassays were performed for permit-related radiological work for representative SRS facilities. These other facilities include (with key operational radiological source terms cited) as described in La Bone (1996):

- F and E Areas:
 - 221 FB-Line, A-Line, 221-F Canyon, Solid Waste Disposal Facility, Pu Storage Facility, F/H Area Tank Farms, F Area Outside Facilities, PuFF and PEF facilities, Effluent Treatment Facility
 - Source terms:¹⁴ Pu-239, Pu-238, uranium-235 (U-235), U-238, cerium-144 (Ce-144), ruthenium-106 (Ru-106), strontium-90 (Sr-90), cesium-137 (Cs-137)
- H Area:
 - H Canyon, Pu Oxide Facility, 211-H Outside Facilities, Receiving Basin for Offsite Fuel facility, Resin Regeneration Facility
 - Source terms: Pu-239, Pu-238, Np-237, U-235, Ce-144, Cs-137, Ru-106, Sr-89, Sr-90
- M Area:
 - Uranium Target Fabrication Facility, Fuel Fabrication Facility, 320-M, 322-M, 341-M
 - Source terms: U-235, U-236, U-238

The magnitude of these historic operations, with their diverse and substantial radiological hazards, history of contamination and intakes, and large worker populations, makes their absence

¹⁴ This is a representative listing by area and is not all inclusive of full range of facility radiological source terms.

from NIOSH's sampling in RPRT-0092 a fundamental concern. For example, the F/H Area Tank Farms had radiological jobs that were regularly supported by CTWs, including subcontractors, and were associated with a history of serious contamination incidents, intakes, and uptakes of fission products (e.g., Cs-137), plutonium and other high-level waste constituents (e.g., DuPont (1981b), DuPont (1982)).¹⁵ Likewise, the F and H Area Canyons were the major fuel reprocessing facilities for the site and were associated with a similar radiological history of contamination, intakes, and confirmed uptakes, as indicated by the review of incidents for 1985–1990 in RPRT-0092 and also by SC&A's review of the same and similar incidents (e.g., DuPont (1973b), DuPont (1974), DuPont (1984)).¹⁶ Based on a review of available operational logbooks, facility descriptions, and incident reports, operations in these and other facilities involved many high-hazard radiological jobs for which contamination was present and respirators required.

This raises several fundamental questions, including the following:

- What was the implementation experience involving job-specific bioassay performance for SWPs and job plans for all of these key operations?
- How did various facility managers and local area health physicists for these specific operations apply work planning requirements, and how was bioassay mandated and carried out where known contamination existed and respirator protection was required?
- Can the original concerns surrounding the completeness of job-specific bioassays that surfaced in the 1997–1998 WSRC self-assessments and DOE enforcement action be addressed without permit records for other significant radiological operations at SRS for 1972–1990?

SC&A believes that the answer to the last question is “no,” and the response to the other two is that there is no way to know given the lack of available records cited in RPRT-0092.

As a potential qualifying consideration, NIOSH noted the following regarding the relative number of subcontractors in the SRS workforce for this earlier period:

The number of individual subCTWs employed at SRS from 1972 to 1989 further complicates the analysis for that period. At SRS during this period DuPont primarily used in-house CTWs. A large majority of work performed under Job Plans and reviewed by the team for A Area was done by DuPont construction workers. SRS employed relatively small numbers of subCTWs during that time, and not all work by subCTWs was on jobs that required bioassay. [(NIOSH, 2019a, pp. 47–48)]

SC&A agrees with NIOSH that subcontractors figured less prominently in the SRS workforce prior to the Westinghouse era (1990), and that DuPont tended to use in-house CTWs side by side with its own employees. However, as SC&A pointed out in its comments on the sampling plan, this did not negate the importance of establishing “that those subcontractors were doing the same

¹⁵ As cited in various DuPont incident reports involving skin contaminations, fission product intakes, and Cs-137 uptakes (assimilations) at the 241-F/H Tank Farms for 1975, 1980, 1981, and 1982.

¹⁶ As cited in various DuPont incident reports involving skin and clothing contaminations and uptakes (assimilations) of Pu-238, tritium, and fission products.

work as the in-house CTWs” (SC&A 2018b, p. 5). Further, SC&A reconfirmed the need to conduct a representative sampling of subcontractors in 1972–1989:

As a followup to last Friday’s teleconference regarding SRS path forward, we have discussed this within SC&A, and propose that NIOSH pursue pre-1989 RWPs/SWPs in terms of obtaining a representative sample from which a bioassay completeness assessment can be performed for that earlier period. This assessment would need to reflect the availability of RWPs/SWPs for 1972–1988, and encompass a sufficient scope of facilities and timeframe. Based on Tim’s presentation, it appears that 11 boxes have been identified to date that contain records of this kind for that period; presumably, additional boxes will be identified as the ongoing NIOSH review is completed. It would be important that NIOSH include a sampling approach for the pre-1989 period based on what is found in the boxes. The work group, supported by SC&A, would review these sampling plans (including one for the latter period) and provide any comments to NIOSH, as noted [in] Friday’s call. **Given the relatively fewer number of transient subcontractors (and subcontractors, in general) and RWPs during the 1970s and 1980s, it is understood that NIOSH’s sampling approach may differ from what is done for the 1990s.**

We believe this approach to be the most efficient one that can provide the best assessment on the subcontractor completeness at this point. [(SC&A, 2018b, p. 5)]

While SC&A acknowledges that “NIOSH’s sampling approach [for 1972–1989] may differ from what is done for the 1990s,” SC&A also pointed out that the number of subcontractors identified even for the one facility, 773-A, differed widely between March 1973 (“0” subcontractors, compared with 35 DuPont CTWs and 185 operations employees) and the period 1981–1986. For that latter period, table 2-2 of ORAUT-RPRT-0083 (see table 1 below, which is reproduced from that table), shows a total of 650 subCTWs at 773-A, with as many as 172 subCTWs in the year 1985 alone (NIOSH, 2017a).

Table 1. Total identified workers by year, building 773-A

Year	DuPont CTW	DuPont CTW with potential for intake	Subcontractor CTW	Subcontractor CTW with potential for intake
1980	60	48	8	8
1981	47	41	82	47
1982	68	55	80	20
1983	70	43	99	57
1984	60	49	122	65
1985	49	44	172	115
1986	43	25	87	38
Totals	397	305	650	350

Source: Reproduced from table 2-2 of ORAUT-RPRT-0083 (NIOSH, 2017a)

As SC&A pointed out, “it is clear that the particular year and SRS facility chosen to be sampled (at least for Radiation Survey Logsheet surveys) will influence the number of subcontractor CTWs identified” (SC&A, 2018b, pp. 5–6).

Finally, SC&A further emphasized:

It is important to sample what pre-1989 RWPs are available to validate that the two worker cohorts (DuPont CTW and subCTW) are similar in terms of work and exposure potential. This would add further basis for confirming that conclusion, given the initially ambiguous findings of the recent NIOSH/OCAS Claims Tracking System (NOCTS) comparison. This would argue for a sampling regime focused on the SWPs identified for A Area facilities, for which permits were identified in the 1972–1989 timeframe (although SWPs appear to have been phased out by 1976). It would also argue for continued scrutiny for any additional boxes of permit records that may apply for pre-1989 facilities beyond just A Area. [SC&A, 2018b, p. 6]¹⁷

From RPRT-0092, it is evident that SWPs were, in fact, only identified for the 1970s (although a few were noted for 1980–1985), and none of those had a job-specific bioassay requirement checked off. Further, additional searches conducted by NIOSH did not surface any pre-1990 job plan records for SRS facilities other than for 773-A/776-A.

While the NOCTS in vitro and in vivo bioassay data that support the OTIB-0081 coworker model for CTWs do include a spectrum of SRS facilities,¹⁸ it has not been demonstrated to be the case for the RPRT-0092 bioassay sampling of subcontractor data for 1972–1990. With completeness of subcontractor bioassay data being gauged as a basis for validating the coworker model (OTIB-0081), this becomes particularly important, as acknowledged in the 2015 “Draft Criteria for the Evaluation and Use of Coworker Datasets,” because of the need to ensure, “as part of this analysis, [that] the number of monitoring samples for each identifiable job category should be compared to the total number of workers who were potentially exposed in that job category,” including “any temporal trends in data availability” (NIOSH, 2015, p. 5). That is not feasible with RPRT-0092’s sampling only addressing one of more than 30 SRS radiologically significant facilities, with only 773-A subcontractor data being used as a representative sampling for SRS, and even for that set, having incomplete time periods of permit-related sampling.

Finding 3: The scope of permit sampling for 1972–1990 at SRS is essentially limited to one facility, 773-A, falling short of achieving NIOSH’s sampling objective and the representativeness called for in NIOSH’s coworker guidelines.

¹⁷ The “recent NIOSH/OCAS Claims Tracking System (NOCTS) comparison” refers to a NIOSH analysis of DuPont CTWs vs. subcontractor CTWs for plutonium urinalysis, 1956–1988, as a means to compare 95th percentile urinary excretion rates in support of subcontractor CTWs being included in the same cohort as CTWs for stratification purposes in the coworker model (NIOSH, 2017c). SC&A has reviewed the white paper (NIOSH, 2019d), issued as a further review of this issue, and has issued a memorandum report in response.

¹⁸ As part of this review, SC&A conducted a validation review on this question (see appendix 1 of this report).

4.4 Inclusion of incident-based bioassays to supplement permit-related job-specific bioassays

NIOSH's subcontractor completeness review for 1972–1989 includes bioassay results from incident reports in the late 1980s, as noted in RPRT-0092:

As a reminder, the data in Tables 5-6 through 5-11 represent work in A Area Building 773-A only. While the team was not able to capture job-specific data for other areas, it did capture incident reports for the latter portion of the 1980s for F and H Areas (DuPont 1983–1989, 1989–1992). The reports include listings of DuPont CTWs and subCTWs. Often, the same incidents involved both sets of workers. The team identified 45 subCTWs in those reports who received head-area contamination occurring from 1985 through 1990 to determine if HP followed up with the workers with bioassay. The team assumed required bioassay radionuclides based on the location of work and description of the incident. [(NIOSH, 2019a, p. 54)]

From a review of these incident reports (for DuPont 1989–1992¹⁹), it can be confirmed that most of them required “special bioassays” to be performed; others, while not explicitly citing the form of followup bioassay, would have likely involved this particular bioassay program.

Incident or intake-driven “special bioassays” are not routine bioassays. While routine bioassays encompass regular radiological work monitoring, verification, and termination, special bioassays are initiated for the following reasons (WSRC, 1997, p. 4-1, PDF p. 15):

- in response to an incident to determine if an intake has occurred,
- as follow-up to a known intake to quantify the intake and monitor the status of the person, and
- as a follow-up to a positive routine bioassay.

Little is referenced in DPSOLs for job-specific bioassays, other than general guidance that provides latitude to line supervisors to specify them, as necessary. However, special bioassays are accorded particular emphasis and detailed procedures. For example, as illustrated by DPSOL 193-302, revision 7 (DuPont, 1976), detailed instructions are provided and responsibilities assigned to the health physics supervisors for determining when special samples (and in vivo counts) are needed, for notifications of medical and line supervisors, for sample collection and handling (including various reports and forms), and sample delivery verification.

Clearly, job-specific bioassay sampling, when and if it occurred, was considered “verification” monitoring and was determined and approved by line supervisors based on their judgment of need for specific radiological jobs. Special bioassay sampling, however, was mandated whenever a known or suspected intake was determined and was the responsibility of the health physics

¹⁹ SC&A's review of DuPont (1983–1989) found it to be a collection of job plans for this period, not incident reports. In addition, the citation for DuPont (1989–1992) in RPRT-0092 refers to a collection of incident reports titled “Contamination Statistics and Monthly Reports 1983–1988” in the SRDB. For continuity between RPRT-0092 and this review, the citation remains unchanged in this report.

organization. As such, the relative level of oversight and accountability for these respective bioassay sampling programs can be seen as considerably different, with the special bioassay program being given a high level of followup attention by management and health physics.

Given the detailed procedures, the assigned management responsibilities, and higher level of accountability for ascertaining whether uptakes occurred and radiological limits were exceeded, it can be expected that almost all of the 45 subCTWs involved in the incidents cited by NIOSH for 1985 through 1990 would have had special bioassays conducted in a timely manner. That NIOSH found only 83 percent (100 percent for H Area and 78 percent for F Area), may be as much attributable to some of the workers being assigned to more routine followup given the circumstances of their contamination (that was found in a few cases reviewed by SC&A), with attendant delinquency issues.

The stark difference between the handling of job-specific bioassays in the DuPont era in the absence of a formal RWP program²⁰ and the much more prescriptive special bioassay program makes the inclusion of the incident-driven bioassays for F and H Area inconsistent with what was actual DuPont policy and practice. One does not complement the other, and the resulting comparison should not be considered together as a common measure of subcontractor bioassay completeness. While SC&A acknowledges the lack of available permits identified by NIOSH for SRS facilities other than for 773-A, the use of incident-driven bioassays as a means of comparison to supplement the job-specific bioassay evaluation in RPRT-0092 is not appropriate.

Finding 4: SRS incident-based/special bioassays were provided by workers on a more stringent procedural basis and should not be used to supplement the evaluation of permit-related, job-specific bioassays for 1972–1989 as a measure of historic data completeness.

4.5 Incompleteness of SRS dose records

In its RPRT-0092 review, NIOSH identified and inventoried permits from 126 physical boxes and 70 electronically stored boxes, the former aided by the discovery of 852 boxes of records identified at an offsite Federal Records Center, and the latter through online searches of SRS's EDWS online document inventory. Applying sampling criteria to identify "folders of interest" containing suitable subCTW permits for review, NIOSH found that "only one area (A Area) appears to have routinely used SWPs and/or Job Plans in the 1972 through 1989 era (DuPont era)" (NIOSH, 2019a, p. 14).

SC&A disagrees with this finding.²¹

²⁰ The RWP program was discontinued in the 1960s by DuPont in favor of applying internal DPSOL procedures, but as a DOE assessment pointed out, a requirement for RWPs and SRWPs for any work within a radiologically controlled area (RCA) was carried forward as cited in Special Hazards Bulletins in DPSOP 40, revision 82, September 1989. As DOE observed, "Radiation Work Permits or Standing Radiation Work Permits are not used even though required by Westinghouse Savannah River Company procedures and accepted industry standards" (DOE, 1990, p. 4-307).

²¹ A later statement in RPRT-0092 modifies this finding by stating, "the only clear information the team was able to glean from this search is that SWP and Job Plans are only available for one area during the period from 1972 to 1990" (NIOSH, 2019a, p. 15), which SC&A believes is the accurate assessment.

As NIOSH itself acknowledges in RPRT-0092, “current and former employee interviews indicated that some records were destroyed in the late 1980s or early 1990s,” and “the SWPs or Job Plans for other areas might have been destroyed as part of that effort” (NIOSH, 2019a, p. 15). The following is a summary of the interviews in question:

There were all kinds of records destroyed from the offices of subcontractors after they left the plant. In 1989, the subcontractors started leaving the job as their contracts expired. The personnel were transferred to BSRC [Bechtel Savannah River Company]. The crafts were transferred at various times starting in September 1989. In 1989, the electricians changed from Miller Dunn to BSRC. In the early 1990s, the fitters changed to Bechtel. Sometime in the early 1990s, crews of 6–8 laborers went around to the office buildings that the general contractors had left. It was the records in their offices that were destroyed. Laborers went in and shredded the records; they loaded the stuff on pickup trucks and left. The interviewee is not sure whose laborers were doing the shredding; they were either DuPont construction laborers or Bechtel construction laborers. They shredded all kinds of records (**e.g., monitoring records, time cards**) after the subcontractors left the plant. The interviewee observed this when [the interviewee] had a maintenance crew out there to fix the electricity for the building. [The interviewee] went out to see why the electricity was out. There were laborers in there cleaning out file drawers to be shredded. If the interviewee is not mistaken, it was the heavy equipment office [where [the interviewee] observed this occurring], but [the interviewee] is not positive. The interviewee asked the laborers what they were doing, and they said they were shredding records. [Emphasis added.] [(SC&A, 2012, p. 55)]

As indicated by these interviewed workers, the destruction of records during DuPont’s departure as SRS operating contractor in early 1990 was extensive and apparently involved a wide range of records, including radiation monitoring records. It will never be clear what records were destroyed and for what years, but the extent of this reported records destruction renders any later survey or compilation of subcontractor records dating prior to 1990 as suspect and presumptively incomplete.

In about the same timeframe (early 1990), DOE headquarters conducted a Tiger Team assessment of SRS and made the following finding.

Comprehensive records related to occupational radiation exposure are not retained consistent with ANSI N13.6. There are many personnel files where radiation dose data are missing for many years. [(DOE, 1990, p. 4-193, PDF p. 530)]

The DOE assessment team found that SRS radiation records did not satisfy the Department’s performance requirement that “records related to occupational radiation exposure should accurately document exposures received and be readily retrievable” (DOE, 1990, p. 4-202, PDF p. 539). Their findings included the following (DOE, 1990, p. 4-202, PDF p. 539):

- Radiation exposure history records are maintained in the dosimetry files in Bldg. 735A. All other records are boxed, inventoried, and sent to the

Federal Repository in Atlanta, after an interim storage period of up to 2 years onsite. . . .

- Prior to 1989, not all of the required records were compiled and retained in a readily retrievable system. Consequently, there are many personnel files where radiation exposure data are not easily assembled. . . .
- Radiation records related to status of work areas, e.g., radiation survey reports, air sample results, etc., are not retained onsite beyond the interim storage period. The records sent to the Federal Repository are readily retrievable, but complete records are not easily compiled.

In its action plan response, WSRC noted the following:

Radiation Work Permits (RWP's) have been developed and their use is being phased in across the site. The RWP's will tie the worker(s) and the job conditions together in a database in each area. Once the RWP program is in place, the record program will meet the requirements in ANSI N13.6. [(WSRC, 1990a, p. 3C-66, PDF p. 439)]

This response seems to acknowledge²² that, while the routine internal and external dosimetry program maintained relatively complete and accessible dose data, the nonroutine job-specific dosimetry data were not being consistently obtained from workers and retained in retrievable form. The establishment of an RWP program to monitor and record job-specific radiation exposures was coupled with formal and explicit responsibilities assigned to facility management for ensuring bioassay samples were collected, as follows:

As part of the 1990 SRS Radiological Improvement Plan, the site management has placed the responsibility for the radiological protection of the employees on line management. This responsibility includes monitoring the submission of routine and non-routine bioassay samples and followup on delinquent samples. Line management assures the same responsibility for facility visitors. In addition, the Radiation/Contamination Control Manual, 5Q, is being revised to explicitly state the employee's responsibility to submit requested bioassay samples or be subject to disciplinary action. [(WSRC, 1990a, p. 3C-61, PDF p. 434)]

The cited inability to readily compile radiation exposure data obtained prior to 1990, as well as key radiation control records (e.g., SWPs and job plans), is traceable to a longstanding SRS policy in the DuPont era that limited onsite retention of all but exposure histories. Records were only retained for up to 2 years and then shipped to the Federal Repository, for which retrieval of complete records can be difficult, as noted by the DOE assessment team and illustrated by NIOSH's survey results for the 852 boxes retrieved.

The issue of incomplete records is clearly compounded by evidence that SRS workers did not consistently submit required bioassay samples, and facility managers and SRS management did

²² SC&A has not yet found information about the WSRC action plan that explains why and how the new RWP program would be the key link for ensuring the completeness and retrieval of onsite radiological records at the time.

not hold them accountable for doing so, an issue that was the subject of the 1998 DOE enforcement action. This concern was, likewise, cited in the 1990 DOE Tiger Team assessment, which determined that scheduled/routine bioassays were not being provided by some SRS employees:

Employees who fail to leave a scheduled bioassay sample for over 1 month are added to a delinquent list. The list also tabulates those who are 2, 3, and 4 months delinquent. A person who is 5 months delinquent is listed again as being 1 month delinquent. There is a policy to remove people from radiation work if they are 3 months delinquent on a bioassay sample. However, there is no enforcement of this policy and some employees ignore requests for bioassay samples. [(DOE, 1990, p. 4-198, PDF p. 535)]

DOE concluded that “when scheduled bioassay samples are not provided, it is impossible to do an accurate dose assessment” (DOE, 1990, pp. 4-198–4-199, PDF pp. 535–536). WSRC responded in its action plan that “when routine or special bioassay samples are not . . . provided at all, the related dose assessments must be made using available data. . . . these assessments [are made] on a reasonable but conservative basis” (WSRC, 1990a, p. 3C-60, PDF p. 433). However, apart from the need to rely on “conservative” dose assessment techniques to bridge bioassay gaps, for transient construction workers it may not be feasible to adequately monitor job-specific doses between jobs and for intermittent work at SRS. Given that DOE and WSRC both found that some routine and special bioassays were “not provided at all,” and that DOE established that management (both facility and health protection organization) was not holding workers accountable and enforcing bioassay sampling policies, these resulting gaps clearly become a contributor to bioassay data incompleteness before 1990.

The lack of complete personnel records, including radiation exposure records, is corroborated by interviews with SRS workers, who provided the following accounts:

A worker representative has sent hundreds of records requests to SRS on behalf of workers. When they would get the records, they would see there were gaps in the records. They would get a summary, but would not see the details. There would be an indication that a sample was given, but nothing in the records as to the result. NIOSH has requested records, and they have more records than are made available to the claimants, but they are still not complete. Even now, people who worked for the contractors have no records of employment out there. They want to know how they can verify that they worked there. Some of them have income tax records, or they can get signed affidavits from someone who knew that they worked out there. In one case, an individual was at SRS off and on from the early 1980s to about 2002. When he returned to SRS, they did not seem to have records of where he had worked. They said they could not find when he was there.

[SC&A observed that one interviewee’s DOE records (collected by NIOSH) did not include any data for several years scattered over a 15-year period when the worker was employed at SRS (late 1950s through mid-1970s.) The worker reported no significant changes in work activities that would explain these gaps. The interviewee was still entering radiological areas during these years, and does

not know why there are no data. Worker representatives are concerned that NIOSH does not have all the records. If they do have all the records, then the monitoring information is incomplete. [(SC&A, 2012, pp. 54–55)]

The lack of retention of radiation monitoring records and the inability to efficiently access a complete file from a central offsite records repository poses a barrier to assuring an adequately complete work history, work permit record (relevant to RPRT-0092), and personnel exposure file to support a representative coworker model and dose reconstruction. This circumstance is analogous to that of Sandia National Laboratory prior to 1994, where program and dose records, in paper form, were stored in an offsite repository in “record storage boxes which are not easily nor routinely searched” (NIOSH, 2011, p. 27). The inability to readily access complete records from the offsite repository was a key stated basis for the Special Exposure Cohort (SEC) class being defined for Sandia for 1963–1994 (NIOSH, 2011).

In summary, an extensive onsite and offsite search for SRS records of SWPs and job plans for 1972–1989 identified only those for one facility, 773-A. No permits were identified for the other major SRS areas and facilities (leaving out the production reactors).

As acknowledged by NIOSH, the lack of such documentation may stem from the reported destruction of records in 1990. It is also likely due to the inability to retrieve records that were transferred for storage at the Federal Records Center without an effective means to search and retrieve them. That both of these shortfalls may have led to missing radiation monitoring and work records brings into question the completeness of radiation dose records necessary for a representative coworker model and NIOSH’s ability to establish the completeness of subcontractor job-specific bioassay records for 1972–1990, as stipulated in RPRT-0092.

Finding 5: The incompleteness of SRS dose records for 1972–1990 is substantiated by the acknowledged destruction of subcontractor records and firsthand worker accounts, coupled with DOE findings of missing occupational radiation dose data from many SRS personnel files, as well as systemic bioassay delinquencies, and wide gaps in NIOSH’s capture of permit documentation.

4.6 SRS internal dosimetry policy and procedural changes, 1972–1998

The notable difference between how internal exposures were monitored and controlled at SRS between the DuPont era of the 1970s and 1980s and the WSRC era that began in early 1990 mirrors the overall policy shift in radiation protection at DOE facilities between those timeframes. From a policy standpoint, the Savannah River Plant under DuPont implemented DOE Order 5480.1, Chapter XI, for which the requirements for radiological monitoring were as follows:

- (d) Monitoring Requirements. Monitoring is required where the potential exists for the individual to receive a dose or dose commitment in any calendar quarter in excess of 10 percent of the quarterly standards stated in paragraphs 4a(1) and 4a(2)(a)2 above. Monitoring requirements as specified for the following conditions shall include:

1 External Radiation. Personnel monitoring equipment for each individual.

2 Internal Radiation. Periodic (monthly, quarterly, annually, etc.) bioassay analysis or in vivo counting or evaluation of air concentration to which the individual is exposed, or a combination of all methods. [(DOE, 1981, PDF p. 162)]

This DOE order stipulated that these and other radiation protection requirements were the sole responsibility of the headquarters and field line organizations, who developed their own facility requirements and procedures to implement them. DuPont's procedures satisfied DOE orders by (1) stipulating a standard type and frequency for the primary radionuclides encountered in the SRS operations, and (2) allowing facility managers and health physicists to require bioassays for "other radionuclides," as necessary.

In contrast, DOE Order 5480.11, which was issued on December 21, 1988 (with required implementation a year later), required the following (DOE, 1988):

9.f (1) Combining Internal and External Dose Equivalent. The annual effective dose equivalent to an individual shall be determined by summing the annual effective dose equivalents from internally deposited radionuclides and from external exposure to radioactive material and/or radiation generating devices resulting from DOE activities. **When in-vivo and/or in-vitro measurements confirm the retention of radionuclides in the body, with respect to evaluating conformance with the limiting value for occupational exposure, the annual effective dose equivalent due to all radionuclides retained in the body from these intakes shall be assessed for as long as the annual effective dose equivalent is 10 mrem or greater.** Exposures to the skin, extremities, and lens of the eye are not included in the determination of the annual effective dose equivalent. For uniform external Irradiation of the whole body, a weighting factor (W_t) equal to one may be used. This whole body dose is to be measured in accordance with the provisions in paragraph 99(1). Non-uniform external and internal irradiation values of W_t for organs and tissues are defined in paragraph 8e(12). [Emphasis added.] [(DOE, 1988, p. 13)]

A programmatic requirement was also included for internal dosimetry in paragraph 9.g(2):

Internal Radiation. Internal dose evaluation programs (including routine bioassay programs) shall be adequate to demonstrate compliance with the radiation protection standards in paragraph 9b.^[23] Such programs are required for radiation workers exposed to surface or airborne radioactive contamination **where the worker could receive 0.1 rem (0.001 sievert) annual effective dose equivalent from all intakes of all radionuclides from occupational sources**, or if any organ or tissue dose equivalent could exceed 5 rem (0.05 sievert) annual dose equivalent. [Emphasis added.] [(DOE, 1988, p. 17)]

²³ These standards provide internal dose limits for stochastic effects of 5 rem (annual effective dose equivalent), and for non-stochastic effects, a limit for organ or tissue of 50 rem (annual dose equivalent)] (DOE, 1988).

These provisions (particularly combining internal and external dose equivalent, and the required 100-millirem (mrem) threshold for monitoring), coupled with a formal DOE 5480.11 requirement for implementing and monitoring “as-low-as-reasonably-achievable” (ALARA) objectives in the workplace and formal independent review by DOE,²⁴ had a decided effect on how bioassay programs would be implemented between the late 1980s and early 1990s. These policy changes would be amplified by (1) the first change in operating contractors for the SRS site since its inception in 1951 and (2) a Tiger Team assessment, both occurring in early 1990. In SC&A’s judgement, it is not plausible to apply the same completeness review, with the same evaluation criteria and assumptions, over a 25-year span of SRS operations without accounting for these fundamental changes in internal dosimetry policy, procedures, and practice that occurred simultaneously in 1989–1990.

Observation 1: The back application of assumptions regarding work permits, job-specific bioassays, and target radionuclides to conduct a completeness review for 1972–1998 is not plausible given the significant changes in radiological policies, procedures, and practices that occurred in the early 1990s.

²⁴ Including a provision to elevate ultimate interpretation of requirements to the Secretary of Energy and approval of exemptions to the headquarters Assistant Secretary for Environment, Safety and Health (DOE, 1988).

5 Analysis of Pre-1990 Subcontractor Data

Section 5 of RPRT-0092 presents the NIOSH evaluation of subcontractor internal monitoring data based on the assumed job plan requirements,²⁵ primarily for building 773-A. The evaluation was restricted to A Area because this was the only SRS location for which job plans could be identified for the site. The RPRT-0092 analysis was separated into three time periods based on the observed job plan availability:

- 1972–1974 (see NIOSH (2019a), section 5.1)
- 1975–1979 (see NIOSH (2019a), section 5.2)
- 1980–1989 (see NIOSH (2019a), section 5.3)

Notably, no job plans were identified for 1975–1979; thus, no evaluation of subcontractor internal monitoring was feasible for this period. The compiled dataset used in the NIOSH analysis can be found in tables D-2 and D-3 of RPRT-0092 for the 1972–1974 and 1980–1989 periods, respectively. Internal monitoring was evaluated for the assumed exposure potential to americium, plutonium, and mixed fission products, although americium exposure potential and monitoring practices were only assessed if the job plan was located in the F-Wing of 773-A.

SC&A's evaluation of the NIOSH dataset focused on two main facets:

1. the total number of workers monitored for each radionuclide of interest in the identified job plans (including both in vivo and in vitro monitoring results)
2. the percentage of monitored workers who would theoretically be included in the coworker model formulation and thus can be considered representative of unmonitored workers on the same job plan

While facet 1 simply reflects the workers for whom monitoring should have been required, internal monitoring was performed, and the subsequent results are available, facet 2 addresses the question of the applicability and representativeness of available subcontractor internal monitoring to the unmonitored worker. A key aspect in evaluating the applicability and representativeness of the subcontractor monitoring data is whether unmonitored workers worked side by side on the same jobs as the monitored workers who are theoretically included in the coworker model formulation.

RPRT-0092 introduced the concept of “effective monitoring,” which it defined as the total number of workers who were either monitored directly or who were working side by side with a worker who was monitored directly. However, SC&A believes that an unmonitored worker can only be considered “effectively monitored” if they worked side by side with a worker whose

²⁵ NIOSH assumed an internal monitoring requirement if the job plan prescribed respiratory protection during the job, as discussed in section 4.1 of this report.

internal monitoring result *would hypothetically be included in the development of the SRS coworker model in OTIB-0081.*²⁶

As a simplified example, consider a job plan that lists three subcontractors with the same job type, period of work, and potential exposure to a contaminant for which a coworker model has been developed using urinalysis. In this hypothetical example:

- Subcontractor 1 was monitored via urinalysis.
- Subcontractor 2 was monitored via in vivo counting.
- Subcontractor 3 was unmonitored.

This example would result in about 66 percent direct internal monitoring coverage (subcontractors 1 and 2 were monitored) with 100 percent “effective monitoring” coverage because the unmonitored worker (subcontractor 3) is represented by the coworker who submitted urinalysis (subcontractor 1). However, consider an alternate situation in which both monitored subcontractors had undergone in vivo monitoring. In this alternate situation, subcontractor 3 would no longer be represented in the coworker model because no in vitro samples were taken that reflect the job plan. Thus, the “effective monitoring” coverage would remain at 66 percent (two subcontractors directly monitored and one subcontractor unmonitored and not represented). This example illustrates the importance of the identified method of internal monitoring (in vitro or in vivo) in establishing whether the unmonitored worker is truly represented.

Further complicating the evaluation of subcontractor bioassay is the establishment of an acceptable time limit between the end of a given job plan and the subsequent direct monitoring result. Section 4.1.3 of RPRT-0092 quotes ORAUT-OTIB-0060, revision 02 (NIOSH, 2018b, pp. 24–25), as follows:

A long-lived, long-retained nuclide (e.g., plutonium and uranium) can be retained for decades with continuous excretion of small amounts. One result after many years of employment can contain activity from all previous intakes and provide information for determining an intake amount for all previous years and, in such a situation, a lack of bioassay samples for several years would not be considered unmonitored because an upper bound can be placed on the intake. This is not true for nuclides that are eliminated relatively rapidly from the body (e.g., ¹³⁷Cs). . . .

Long-lived, long-retained nuclides include all absorption types of plutonium, uranium, and americium, **unless the only monitoring method is chest counting**. Types F and M are not retained for significant periods in the lungs and the rules for short-retained radionuclides must be followed.

For short-lived or short-retained radionuclides (including ¹³⁷Cs and ⁹⁰Sr) during potential exposure periods: Missed dose is calculated in the intervals where there are bioassay results; other periods are considered to be unmonitored. **Gaps of**

²⁶ Several of the coworker models developed in OTIB-0081 do not use the full scope of SRS internal monitoring data but rather rely on the subset of claimant data to develop coworker intakes. Thus, not all directly monitored workers evaluated in RPRT-0092 are necessarily included in the OTIB-0081 coworker formulation.

greater than 2 years between results are considered to be unmonitored.

[Emphasis added.] [(NIOSH, 2019a, p. 34)]

Therefore, SC&A only considered monitoring results for fission products valid if they occurred within 2 years of the end of the job plan. Similarly, chest counts for americium and plutonium are only considered valid if they occurred within 2 years, per the guidance above. SC&A notes that in the original sampling plan, the acceptable time limit was originally restricted to one year regardless of the biological half-life of the contaminant:

A CTW being monitored means the worker was bioassayed per the RWP requirement. For a pulled CTW, the ORAU team would use available bioassay data including NOCTS to **determine if worker was bioassayed within one year from date of RWP sign-in, either by urinalysis or *in vivo* analysis for all radionuclides listed on the RWP other than tritium (H3).** [Emphasis added.] [(NIOSH, 2018a, p. 2)]

Finally, when establishing an appropriate representative coworker, the majority of matches indicated by NIOSH included workers on the same job plan, with the same craft designation and the same date/time. This characterization of a coworker is reflected in the example provided in NIOSH (2018c):

RWP#4 had an unmonitored subcontractor CTW, on a work crew of five CTWs, in which 3 DuPont CTWs were monitored. This results in either an unmonitored subcontractor CTW with no surrogate, or 60% monitoring of the work crew if considered as a whole and depends on the point of view. . . .

if the whole crew were pipefitters and the subcontractor was simply brought in as an additional worker then the criteria noted in [NIOSH] (2015) would be appropriate and 60% would be considered a success. **If the DuPont CTWs were Electricians that did electrical work in the morning and the subcontractor CTW was a pipefitter who worked in the afternoon doing a separate task then the DuPont CTWs would not be an appropriate co-worker.** [Emphasis added.] [(NIOSH, 2018c, p. 17)]

In a few cases, NIOSH appears to identify workers as “appropriate coworkers” when they were on the same job plan but may not have had the same craft designation or worked on the same date/time. SC&A did not remove these matches from its own analysis; however, they are noted (where applicable) in the evaluation subsections below. Where feasible in these circumstances, SC&A attempted to identify a more appropriate coworker designation (i.e., another coworker on the same job plan with the same craft/date/time) and made the correction prior to reporting the totals below. However, SC&A did remove coworker matches from its calculated totals in a few rare cases where the NIOSH coworker match was based on workers who were on completely different job plans. As discussed above, suitable coworkers were only recognized by SC&A in the “effective monitoring” totals if they were monitored via the same method used in coworker model development (i.e., urinalysis for americium/plutonium and *in vivo* counting for fission products).

5.1 1972–1974

5.1.1 Americium (1972–1974)

Only a single worker was identified in RPRT-0092 as requiring americium monitoring as a result of their job plan specifications, and the worker was not monitored either by in vitro or in vivo methods. The job plan description involved the installation of an air sampling line in the F section valve pit. Although RPRT-0092 concludes that americium exposure potential only occurred in the F-Wing area of 773-A, table D-1 of attachment D indicates americium monitoring was required for a second job plan occurring in the high-level caves (Job Plan 47). The job plan indicates the work was to pick up regulated tools and transfer them to radiation control for surveying. The work required two sets of coveralls, shoe covers, gloves, and a hood.

Observation 2: During the 1972–1974 period, RPRT-0092 only evaluates one job plan/worker combination (Job Plan 46) for potential americium exposure. However, attachment D, table D-1 indicates at least one other job plan (Job Plan 47) requiring americium monitoring during this period. Neither of the workers were directly monitored nor had an appropriate coworker monitored for americium.

5.1.2 Plutonium (1972–1974)

Table 2 shows the results of SC&A’s independent assessment of the available monitoring data provided by NIOSH for plutonium (1972–1974). When evaluating the available job plans, SC&A found that about 63 percent of the job plans had at least one worker with valid internal monitoring identified. SC&A’s evaluation of the total number of monitored workers (independent of job plan) was slightly less than NIOSH’s evaluation (50 percent versus 51 percent) due the removal of a chest count occurring more than 2 years after the end of the job plan. When evaluating appropriate coworkers, SC&A removed five matches from the original NIOSH analysis due to the coworker matches occurring on different job plans. This results in an effectively monitored total of 64.7 percent rather than the 69 percent reported in RPRT-0092.

SC&A notes that, in one case, the coworker match was on a different date but the same job plan and craft. One additional coworker match was from a different craft but the same job plan and date/time. Finally, three coworker matches were from a different time of day (e.g., one worker entered the area in the morning and the other entered in the afternoon) but were on the same job plan and date and were designated as the same craft. Removal of these entries from consideration would further reduce SC&A’s estimate of the total effectively monitored workers to approximately 61 percent.

Table 2. Summary of SC&A evaluation of plutonium monitoring data (1972–1974)

Category	SC&A total (%)	RPRT-0092 total (%)*	SC&A comment
Total job plans for review	59	NR	—
Job plans with internal monitoring	36 (61.0%)	NR	—
Total workers for review	136	136	—
Total workers monitored internally	68 (50%)	69 (51%)	SC&A removed one chest count result that was more than 2 years from the end of the job plan (2,779 days).
Coworker match by urinalysis	20 (14.7%)	25	SC&A rejected 5 coworker matches because they were on different job plans. SC&A's total does include 1 coworker match on a different date, 1 coworker match from a different craft, and 3 coworker matches from a different time of day. Removal of these entries would decrease the total to 15 (11.0%).
Total effectively monitored workers	88 (64.7%)	69%	Removal of the coworker matches described above reduces this total to 83 (61.0%).

*NR = Not reported

5.1.3 Fission products (1972–1974)

Table 3 shows the results of SC&A's independent assessment of the available monitoring data provided by NIOSH for fission products (1972–1974). When evaluating the available job plans, SC&A found that nearly 90 percent had at least one worker with valid internal monitoring identified. As seen in the table, SC&A's evaluation of the directly monitored workers was slightly less than NIOSH's evaluation (~70 percent versus 74 percent). The difference is partially due to four entries containing urinalysis results that were more than 2 years after the end of the job plan. The monitoring records could not be located by SC&A for the two remaining case discrepancies (CTW-700 and CTW-838) in the documentation provided by NIOSH.

When evaluating appropriate coworkers, SC&A's total was very close to that reported by NIOSH (26 for SC&A, 27 for NIOSH). However, the coworker matches were based on monitored workers with in vitro samples, while the SRS coworker model in OTIB-0081 is based on in vivo monitoring. Therefore, monitoring results associated with urinalysis are not representative of the unmonitored worker and should not be included in the effectively monitored total. As there were no appropriate chest counts identified for the workers during this period, the effectively monitored total is simply the number who were directly monitored (i.e., around 70 percent).

Table 3. Summary of SC&A evaluation of fission product monitoring data (1972–1974)

Category	SC&A total (%)	RPRT-0092 total (%)*	SC&A comment
Total job plans for review	59	NR	—
Job plans with urinalysis sampling	53 (89.8%)	NR	—
Job plans with chest count sampling	0 (0.0%)	NR	—
Job plans with internal monitoring	53 (89.8%)	NR	—
Total workers for review	136	136	—
Workers with urinalysis	95 (69.9%)	NR	—
Workers with chest counts	0 (0.0%)	NR	—
Total workers monitored	95 (69.9%)	101 (74%)	SC&A rejected four entries because the urinalysis value was more than 2 years after the job plan. The records for two additional entries could not be found by SC&A in the supporting files provided by NIOSH.
Coworker match by urinalysis	26 (19.1%)	27	OTIB-0081 coworker intakes are based on in vivo monitoring, not in vitro, so these coworker matches are not appropriate for inclusion in the effectively monitored total.
Total effectively monitored workers	95 (69.9%)	94%	SC&A total includes only those workers directly monitored via urinalysis.

*NR = Not reported

5.2 1980–1989

5.2.1 Americium (1980–1989)

Table 4 shows the results of SC&A’s independent assessment of the available monitoring data provided by NIOSH for americium (1980–1989). RPRT-0092 identified 145 total job plans during the time period of interest; however, only 35 of those job plans (about 24 percent) were identified as having workers required to be internally monitored for americium. Furthermore, no job plans were available for 1980 or 1988–1989. The identified job plans for americium evaluation cover 151 total worker/job plan combinations. Approximately 63 percent of the job plans had at least one worker with associated internal monitoring (37.5 percent via urinalysis sampling and 25.7 percent via in vivo monitoring).

Table 4. Summary of SC&A evaluation of americium monitoring data (1980–1989)

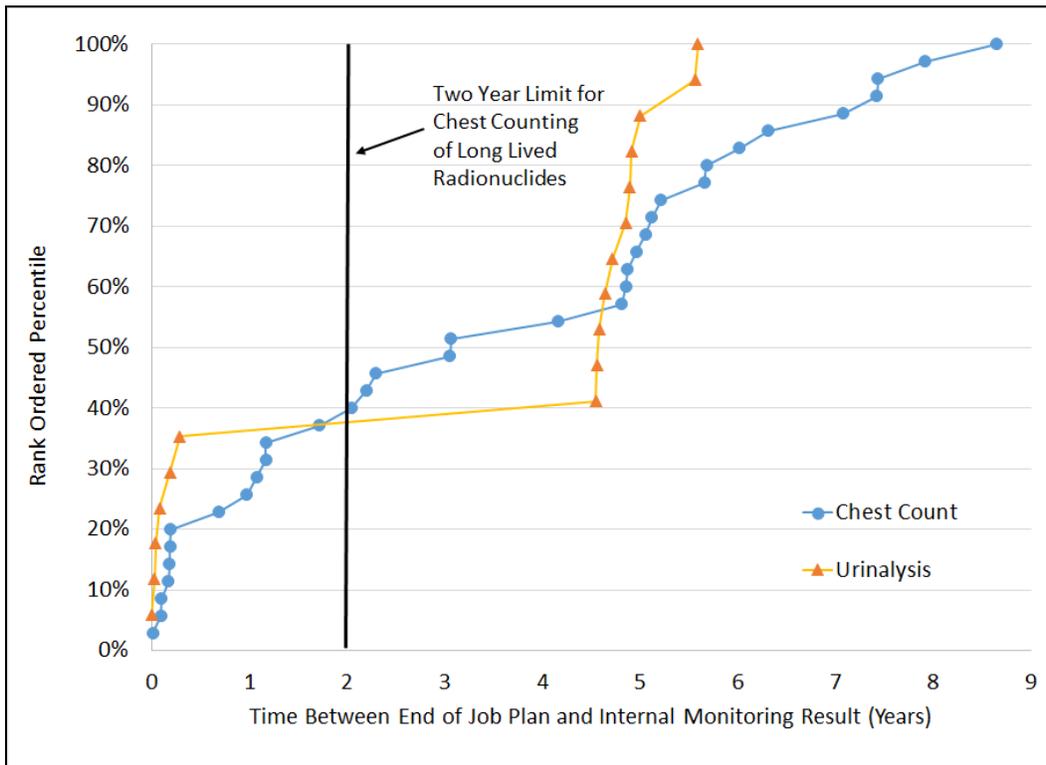
Category	SC&A total (%)	RPRT-0092 total (%)*	SC&A comment
Total job plans for review	35	NR	This constitutes just 24% of the total job plans reviewed for 1980–1989.
Job plans with urinalysis sampling	13 (37.5%)	NR	—
Job plans with chest count sampling	9 (25.7%)	NR	Five job plans were discounted due to the chest count occurring more than 2 years after the job plan.
Job plans with internal monitoring	22 (62.9%)	NR	—
Total workers for review	151	151	—
Workers with urinalysis	17 (11.3%)	NR	Represents the number of workers with urinalysis values used in coworker model development. The 17 urine samples identified were taken from only 3 workers. Eleven of 17 were taken from a single worker who was sampled in April 1991 (note: 1991 data are not currently used in the SRS coworker model).
Workers with chest counts	13 (8.6%)	NR	Twenty-two chest count results were discounted due to the chest count occurring more than 2 years after the job plan.
Total workers monitored	30 (19.9%)	52 (34%)	—
Coworker match by urinalysis	20 (13.2%)	NR	One of 20 matches involved a different craft and date. Removal of this sample would decrease the total to 19 (12.6%). Ten of the 20 matches were to a urinalysis result in 1991 that is not currently used in the coworker model.
Coworker match by chest count	35 (23.2%)	NR	Sixteen of 35 matches involved different craft designations. One of 35 matches involved a different date. Removal of these would decrease the total to 18 (11.9%). However, chest counts are not used in coworker development; thus, these matches are not relevant to establishing the effectively monitored worker totals.
Total coworker matches	55 (36.4%)	63 (NR)	The difference between SC&A's total (55) and NIOSH's total (63) is the removal of coworkers who were tied to chest counts more than 2 years. Where possible, SC&A matched these entries to appropriate workers with urinalysis. Additional removal of coworker entries described in two preceding rows would decrease the SC&A total to 37 (24.5%).

Category	SC&A total (%)	RPRT-0092 total (%)*	SC&A comment
Total effectively monitored workers	50 (33.1%)	NR (76%)	Represents the total monitored workers plus those represented by coworker urinalysis values. Removal of the coworker match involving a different craft and date would decrease the total to 49 (32.5%). Removal of 10 coworker matches to the 1991 result that is not currently used in coworker modeling would reduce this total to 40 (26.5%).

*NR = Not reported

Although nearly two-thirds of the job plans had at least one worker with internal monitoring for americium, this reflects just 20 percent of the total identified americium workers. As noted in table 4, a large portion of the workers monitored via chest count were removed due to the chest count occurring more than 2 years after the end of the job plan. This is in accordance with ORAUT-OTIB-0060, revision 02 (NIOSH, 2018b), and restated in RPRT-0092, which notes that long-lived nuclides monitored via chest count must be treated as a short-lived nuclide for which periods longer than 2 years are considered unmonitored (see section 5 of this report for the pertinent excerpt from RPRT-0092 quoting ORAUT-OTIB-0060). Figure 3 plots the time elapsed between the identified internal monitoring results and the end of the job plan.

Figure 3. Number of years elapsed between end of job plan and internal monitoring result



Although long-lived urinalysis results for americium are considered valid for the purposes of internal monitoring, it is clear that the majority of urinalysis results were not associated with the actual job plan, as they were taken more than 4 years after the end of the work. Furthermore, the 17 identified urinalysis results shown in table 4 were taken from just three workers. Eleven of the 17 results were taken from [REDACTED] in 1991 and was sampled subsequent to [REDACTED] (i.e., neither the sample nor the reason for the sample occurred in the period of interest). The remaining two workers were involved in separate incidents [REDACTED].

Finding 6: For the period 1980–1989, only 20 percent of the identified subcontractor-job plan combinations identified by NIOSH as requiring americium sampling had internal monitoring performed within an acceptable timeframe (i.e., within 2 years for chest counting).

Observation 3: Only 13 percent of the subcontractor-job plan combinations (17 total) had americium urinalysis performed that could be considered relevant to coworker modeling. Eleven of the 17 urinalysis data points represented a single worker who had a single sample taken in 1991 [REDACTED] in a different area ([REDACTED]) during that year (i.e., representative of a different area and different period).

Per table 4, most of the coworker matches identified by SC&A were associated with chest counts, which are not considered in coworker modeling and thus cannot be considered representative of the unmonitored worker. In addition, in several cases the coworker chest count match was for workers with different craft designations²⁷ (e.g., carpenter matched with a sheet metal worker). SC&A was able to match 13 percent of the unmonitored workers (20 in total) to a coworker on the same job plan with a relevant urinalysis result.

Therefore, the total “effectively monitored” population for americium is just 33.1 percent (20 percent directly monitored and 13 percent represented by a suitable coworker). As noted in observation 3, the majority of urinalysis results were for a single worker [REDACTED] [REDACTED] sampled in 1991, which is outside the current coworker model period (i.e., the sample was *not* used in the current coworker model in OTIB-0081. If the coworkers matched to this individual are removed, then the effectively monitored population is reduced to 26.5 percent.

Finding 7: The total “effectively monitored” population for americium (those monitored directly or have a coworker on the same job plan with a urinalysis result) during the 1980–1989 period is approximately 33 percent. If a urinalysis sample taken during 1991 [REDACTED] in a different SRS location (and is not currently used in the SRS coworker model) is removed, the effective monitored population drops to 26.5 percent.

5.2.2 Plutonium (1980–1989)

Table 5 shows the results of SC&A’s independent assessment of the available monitoring data provided by NIOSH for plutonium (1980–1989). When evaluating the available job plans, SC&A found that nearly 98 percent had at least one worker with valid internal monitoring identified. As seen in the table, SC&A’s evaluation of the total monitored workers was slightly

²⁷ SC&A considered craft designations to be “different” if they were delineated with a separate entry in table 5-9, “SubCTW Americium Bioassay by Craft, 1980 to 1988” (NIOSH, 2019a).

less than NIOSH's evaluation (79.4 percent versus 80 percent) due to three chest count results occurring more than 2 years after the end of the job plan. However, when evaluating coworker matches, SC&A identified four additional matches that had not been included in the original NIOSH analysis. The net result is that SC&A's and NIOSH's estimate of the effectively monitored population is essentially identical (around 97 percent).

Table 5. Summary of SC&A evaluation of plutonium monitoring data (1980–1989)

Category	SC&A total (%)	RPRT-0092 total (%)	SC&A comment
Total job plans for review	145	NR	—
Job plans with urinalysis sampling	141 (97.2%)	NR	—
Job plans with chest count sampling	1 (0.7%)	NR	—
Job plans with internal monitoring	142 (97.9%)	NR	—
Total workers for review	591	591	—
Workers with urinalysis	442 (74.8%)	NR	—
Workers with chest counts	27 (4.6%)	NR	—
Total workers monitored	469 (79.4%)	472 (80%)	SC&A rejected 3 entries due to the chest counts being more than 2 years from the job plan date.
Coworker match by urinalysis	104 (17.6%)	NR	—
Coworker match by chest count	2 (0.3%)	NR	—
Total coworker matches	106 (17.9%)	102	SC&A identified four additional coworker matches.
Total effectively monitored workers	573 (97.0%)	97%	—

*NR = Not reported

5.2.3 Fission products (1980–1989)

Table 6 shows the results of SC&A's independent assessment of the available monitoring data provided by NIOSH for fission products (1980–1989). When evaluating the available job plans, SC&A found that over 99 percent had at least one worker with valid internal monitoring identified. As seen in the table, SC&A's evaluation of the total monitored workers was slightly less than NIOSH's evaluation (about 73 percent versus 78 percent). The difference is mainly due to 23 entries containing internal monitoring results that were more than 2 years after the end of the job plan. The remaining discrepancies are due to 11 entries for which SC&A could not locate the source dosimetry file or the specific entry indicated in the NIOSH documentation was not found within the provided dosimetry file.

When evaluating appropriate coworkers, SC&A identified 18 additional matches compared to the total reported by NIOSH (138 for SC&A, 120 for NIOSH). However, it should be noted that only a small portion of the coworker matches (8 of 138) were represented by in vivo monitoring,

which is used in the formulation of the SRS fission product coworker model (NIOSH, 2019c). Therefore, SC&A’s assessment of the total “effectively monitored” population is significantly lower (around 74 percent) when compared to the value reported in RPRT-0092 (99 percent).

Table 6. Summary of SC&A evaluation of fission product monitoring data (1980–1989)

Category	SC&A total (%)	RPRT-0092 total (%)	SC&A comment
Total job plans for review	145	NR	—
Job plans with urinalysis sampling	126 (86.9%)	NR	—
Job plans with chest count sampling	18 (12.4%)	NR	—
Job plans with internal monitoring	144 (99.3%)	NR	—
Total workers for review	591	591	—
Workers with urinalysis	406 (68.7%)	NR	—
Workers with chest counts	23 (3.9%)	NR	—
Total workers monitored	429 (72.6%)	463 (78%)	SC&A rejected 23 entries because the monitoring occurred more than 2 years after the job plan. SC&A could not verify an additional 11 entries because either the dosimetry file was not available, or the specified result could not be located in the provided dosimetry file.
Coworker match by urinalysis	130 (22.0%)	NR	—
Coworker match by chest count	8 (1.4%)	NR	OTIB-0081 coworker intakes are based on in vivo sampling.
Total coworker matches	138 (23.4%)	120	—
Total effectively monitored workers	437 (73.9%)	99%	—

*NR = Not reported

5.3 Summary conclusions for pre-1990 time period

As described in section 5 and presented in sections 5.1 and 5.2, SC&A reevaluated the available data provided by NIOSH to correct for three identified issues:

- Remove identified internal monitoring that is outside the acceptable timeframe between the end of the job plan and the internal monitoring result.
- Remove coworker matches that involved two workers who were associated with different job plans.
- Adjust the “effectively monitored” population to reflect only coworker matches with the type of internal monitoring used in coworker model development (i.e., in vivo for fission products and in vitro for americium/plutonium).

Table 7 summarizes the results of SC&A's reevaluation of the subcontractor data in comparison to the RPRT-0092 reported values. As seen in the summary table, SC&A's evaluation of the plutonium data showed reasonably good agreement with the RPRT-0092 values. Similarly, the total number of monitored workers for fission products was similar to RPRT-0092, although it was slightly lower in SC&A's analysis due largely to the exclusion of bioassay samples taken more than 2 years after the end of the evaluated job plan. The differences in the "effectively monitored" population for fission products was largely due to the exclusion of coworker matches based on urinalysis results that are not used in the formulation of the SRS coworker model in OTIB-0081.

Table 7. Summary of SC&A evaluation of pre-1990 subcontractor data for total monitored versus RPRT-0092 values

Radionuclide (time period)	Years with available data	SC&A monitored	RPRT-0092 monitored	Ratio (SC&A /RPRT -0092)	SC&A effectively monitored	RPRT-0092 effectively monitored	Ratio (SC&A /RPRT -0092)
Americium (1972–1974)	1973	0%	0%	N/A	0%	0%	N/A
Plutonium (1972–1974)	All	50%	51%	0.986	64.7%	69%	0.936
Fission products (1972–1974)	All	69.9%	74%	0.941	69.9%	94%	0.742
All radionuclides (1975–1979)	None	N/A	N/A	N/A	N/A	N/A	N/A
Americium (1980–1989)	1981–1987	19.9%	34%	0.577	33.1%	76%	0.435
Plutonium (1980–1989)	All	79.4%	80%	0.994	97.0%	97%	0.998
Fission products (1980–1989)	All	72.6%	78%	0.927	73.9%	99%	0.750

N/A = Not applicable

Finding 8: Many of the workers (around 70–73 percent) who should have been monitored for fission products underwent appropriate internal sampling during the two periods evaluated prior to 1990 (1972–1974 and 1980–1989). However, very few of these monitored workers underwent in vivo counting for fission products. Thus, they are not included in the coworker model developed for SRS and are not considered representative of the unmonitored worker.

The largest observed differences between SC&A's analysis and the values reported in RPRT-0092 were for americium during the 1980–1989 time period. SC&A's estimations of the monitored and effectively monitored population were approximately half those presented in RPRT-0092. The reported differences are largely due to the exclusion of chest count results that are more than 2 years from the end of the job plan, as well as only including coworker matches that involve a worker monitored via urinalysis.

It should be reiterated that evaluation of americium monitoring practices for subCTWs is severely limited for the pre-1990 time period. The only years in which job plans were identified for analysis were 1973 (two workers who were unmonitored) and 1981–1987. Nonetheless, SC&A’s analysis of this limited sample indicates that fewer than 20 percent of the workers who should have been monitored for americium exposure actually underwent appropriate internal monitoring. If we include the unmonitored workers who are represented by a monitored coworker via urinalysis on the same job plan (the “effectively monitored” population), the total percentage rises to just over 33 percent.²⁸

Finding 9: SC&A does not find that the data collected as part of the RPRT-0092 review support the premise that subcontractors on job plans that should have required internal monitoring for americium were either directly monitored (around 20 percent) or, alternately, appropriately represented in the derived coworker models for SRS (around 13 percent).

Finally, section 6.3 of RPRT-0092 provides summary table 6-4, “Rates of Monitoring of subCTW for at Least One Radionuclide, 1981 to 1998” (NIOSH, 2019a, p. 59). The table contains both direct monitoring and effective monitoring rates “for at least one” radionuclide assumed with the evaluated job plans. SC&A believes such a metric can be misleading. For example, a worker who should have been monitored for plutonium, fission products, and americium on a given job but was only monitored for fission products would be considered a “success” and counted toward the monitored totals in this summary table even though they were not monitored for two other key radionuclides (plutonium and americium). SC&A believes a much more informative metric would look at the rates of monitoring of subCTW for *all* radionuclides contained in the respective job plan. Table 8 provides a comparison of this latter metric to the table 6-4 data in RPRT-0092. Not surprisingly, when considering all radionuclides that should have been monitored (as opposed to “at least one”), the percentages drop considerably. For 1972–1974, the percentage of directly monitored workers reported drops from 76 percent to 47.1 percent, and the effectively monitored workers drops from 85 percent to 55.1 percent. For 1980–1989, the percentage of directly monitored workers reported drops from 90 percent to 51.3 percent, and the effectively monitored percentage drops from 99 percent to 65.5 percent.

Table 8. Comparison of monitoring percentages involving at least one radionuclide (RPRT-0092 value) versus all radionuclides on work permit (SC&A value)

Time period	RPRT-0092 directly monitored for at least one radionuclide	SC&A directly monitored for all radionuclides on work permit	RPRT-0092 effectively monitored for at least one radionuclide	SC&A effectively monitored for all radionuclides on work permit
1972–1974	76%	47.1%	85%	55.1%
1975–1979	No data	No data	No data	No data
1980–1989	90%	51.3%	99%	65.5%

²⁸ This percentage includes the 11 urinalysis values that were taken in 1991 [Redacted] during that year in a different SRS location.

6 Evaluation of RPRT-0092 1990–1998 Data

6.1 RPRT-0092 RWP data per SRS area (1990–1998)

In view of the lack of representativeness of the various areas at SRS in RPRT-0092 concerning the 1972–1989 job plan and SWP data (which were limited to Area A) and temporal gaps in those data (i.e., no evaluation was possible for 1975–1979 or 1989), SC&A analyzed the area and temporal representativeness of the 1972–1989 bioassay data used in coworker modeling in OTIB-0081 and the 1990–1998 RWs data NIOSH sampled in RPRT-0092. A summary of the results using the 1972–1998 data in OTIB-0081 is provided in appendix 1 of this report. For the 1990–1998 data used in RPRT-0092, SC&A analyzed the data NIOSH used to derive table 4-4 using the file “Table C-3 Final.xlsx” in the folder G, labelled “Report Tables,” provided by NIOSH, which does not have a corresponding table in attachment C of RPRT-0092. The results are summarized in figure 4.

Figure 4. Number of RWPs per SRS area per year (1990–1998)

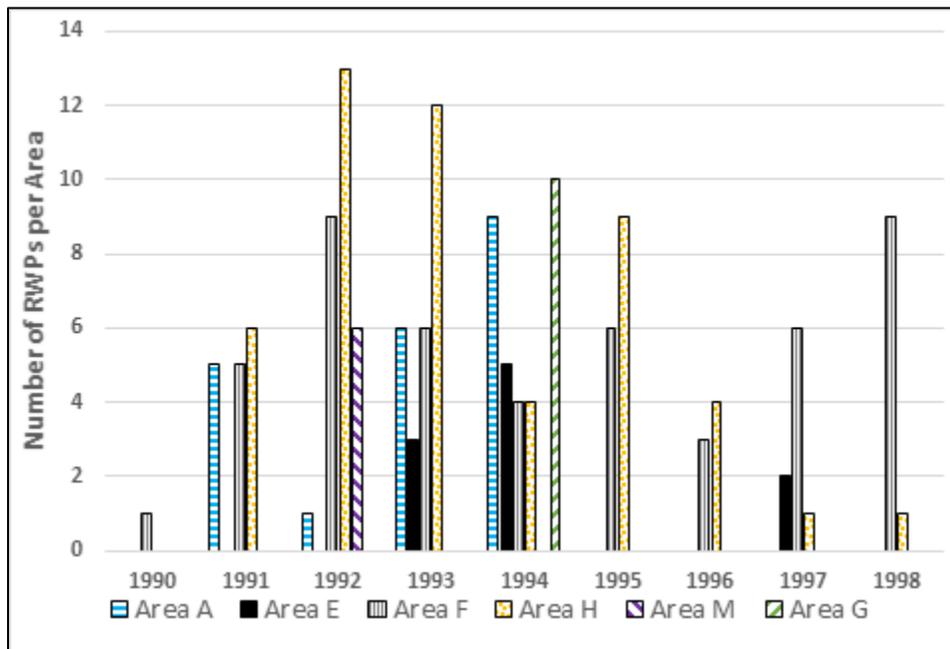


Figure 4 indicates that, of the 146 RWPs analyzed, the main concentration of the RWPs was during the period 1992–1994, with Areas F and H containing the largest fraction of the total number of RWPs.

There was only one RWP with one unmonitored subCTW listed for 1990. This does not appear to warrant bundling 1990 with 1991 and treating it as part of the period when additional data became available. The year 1990, with one RWP, is not much better than 1989 (no job plans identified) or any other previous year. Although there were corporate changes taking place at that time, there was a lag time in policy implementation; therefore, it would be more appropriate that the time intervals should be broken up into 1972–1990 and 1991–1998, so that 1990 is considered in the era with very limited data.

Finding 10: Data for 1990 are lacking. Therefore, 1990 should be included with the period of limited data, 1972–1989, and not bundled in with the year 1991.

6.2 Procedural check of RPRT-0092’s analyses of bioassay data (1990–1998)

SC&A reviewed the data in attachment C of RPRT-0092 to determine if the procedures, as prescribed in sections 2, 3, and 4 of RPRT-0092, for analyzing bioassay data for the period 1990–1998 were followed. This current review does not indicate SC&A’s concurrence with the assumptions and methods used by NIOSH, but only a check to see if the stated procedures were followed.

6.2.1 Spot check of RPRT-0092 data analyses

SC&A performed a limited review of the data in files provided by NIOSH to spot check the processes that were used in RPRT-0092 for the period 1990–1998. The steps SC&A used in the analysis are provided in appendix 2 of this report. SC&A used the information obtained from their analysis to manually spot check some of the individual subCTW’s bioassay records to verify if the information in tables C-3 through C-7 were correct. SC&A checked 13 RWPs, which contained a total of 74 bioassay data points involving five radionuclides (plutonium, strontium, uranium, americium, and neptunium) for 22 different subCTWs. From the limited analysis SC&A performed, SC&A found:

- Four examples of incorrect dates in tables C-3 through C-7 of RPRT-0092. Some date errors amounted to a few days, other to a year or more.
- Two errors on page 139 of RPRT-0092:
 - The referenced coworker for CTW-████ on sample identification (SID)-████, dated █████ 1995, is listed as CTW-████ (i.e., it referred to a coworker that is the CTW itself).
 - The referenced coworker for CTW-████ on SID-████, dated █████ 1995, is listed as CTW-████, who is not signed in on SID-████, and CTW-████ is listed as needing a coworker because it was not monitored on SID-████.
- Page 103 of RPRT-0092 lists CTW-████ as a coworker for unmonitored CTW-████ on SID-████. However, the file, “Master list of Employees to CTW number for Report Final.xlsx” (obtained from NIOSH’s folder G, “Report Tables”), on line 182 of the spreadsheet, lists CTW-████ as “UNASSIGNED #.”

From this relatively small sampling of the data, SC&A did not locate major errors in the data analyses in RPRT-0092 but did locate some data errors, or inconsistencies, that could have some effect on the reported total percentage of subCTWs monitored.

6.2.2 Overall adherence to sampling plan

In an evaluation of implementation of procedures, SC&A found that there appears to be an inconsistency in the sampling plan defined in section 2.1 and in the process used to generate the summary tables in sections 4 and 6 of RPRT-0092. Section 2.1 states:

SubCTW being monitored. Worker was monitored by bioassay, which could include routine sampling, according to the RWP requirements. For a pulled subCTW, the ORAU Team used available bioassay data, including DOE data already in the NIOSH-Division of Compensation Analysis and Support Claims Tracking System (NOCTS), to determine if a worker was monitored **within a frequency specific to the sampled radionuclide from date of RWP sign-in**, either by urinalysis or in-vivo analysis, for **all radionuclides listed on the RWP** other than tritium (^3H). [Emphases added.] [(NIOSH, 2019a, p. 12)]

However, when NIOSH analyzed the data, apparently a recorded bioassay for any one required radionuclide at any time was counted as fulfilling the RWP requirements and included in tables 4-1, 4-3, 4-4, and 6-4, regardless of the number and types of radionuclides and bioassays required by the RWP or the delay time between the RWP date and the bioassay. RPRT-0092 states:

The team calculated percentages of subCTWs monitored by year having at least one required bioassay, even though a subCTW could have more than one; results are provided in Table 4-1. For example, a subCTW bioassay required for **plutonium and strontium** would be counted in this tabulation if the subCTW had been sampled for **either**. [Emphases added.] [(NIOSH, 2019a, p. 35)]

The captions for tables 4-1 and 4-3 use the term “with at least one bioassay for any radionuclide,” and tables 4-4 and 6-4 use the term “with at least one bioassay.” These statements are contrary to the statement quoted above from section 2.1 of RPRT-0092, which requires that all radionuclides listed on the RWP must be sampled and within a specified frequency (i.e., time interval between RWP sign in and bioassay). Therefore, some of the percentages of the subCTWs monitored in the tables in sections 4 and 6 of RPRT-0092 are misleading. For example, table 4-6 for plutonium in RPRT-0092 indicates a 1990–1998 average directly monitored subCTW rate of 88 percent and an effective subCTW monitoring rate of 95 percent. However, this does not address the fact that, in addition to the required plutonium bioassay, there could have been other required bioassays that were not performed, which would result in the subCTW not being adequately monitored.

When SC&A recreated and compared data from table 4-1 (“SubCTWs with at least one bioassay for any radionuclide, 1990 to 1998”) from RPRT-0092 to that obtained when considering all required radionuclides on an RWP (with a 2-year time limit on chest counts), it was found that the results adjust downward to lower percentages. For the period 1990–1998 in table 4-1 and table 6-4, the percentage with *at least one bioassay* directly monitored as required on the RWP is cited as 96 percent, while SC&A’s recalculated percentage with bioassay *for all required radionuclides* directly monitored as specified on the RWP is 77 percent. The values from table 4-1 and table 6-4 of percentage effectively monitored for at least one bioassay on the job plan is 98 percent, while SC&A’s recalculated percentage effectively monitored for all required radionuclides specified on the RWP is 89 percent. The results of SC&A’s analysis for direct monitoring are summarized in tables 9 and 10, and for effective monitoring in tables 11 and 12, which included bioassays for plutonium, fission products, uranium, americium, and neptunium, as required by the RWP, for 1990–1998.

Table 9. Summary of using all required radionuclides compared to using only at least one required radionuclide for subCTWs directly monitored

Category	SC&A total or %	RPRT-0092 table 4-1 and table 6-4 total or %	SC&A comment
Total subCTWs requiring bioassays	660	662	SC&A eliminated two 1994 entries because RPT-0092, page 94 states Pu only, while page 112 states Pu not applicable.
SubCTWs with direct bioassays	505	633	SC&A required that all required radionuclides be monitored for the bioassay to be complete (with chest counts limited to 2 years). RPRT-0092 only required at least one required radionuclide to be monitored at any time for the bioassay to be complete.
SubCTWs without complete bioassays	155	29	SC&A removed 155 entries that were not monitored for all required radionuclides or the chest count was more than 2 years (of which there were 19). RPRT-0092 remove 29 entries that had no bioassays.
SubCTWs directly monitored	77%	96%	19% decrease in the number of subCTWs directly monitored.

Table 10. Breakdown by year of using all required radionuclides compared to using only at least one required radionuclide for subCTWs directly monitored

Year	SC&A percent directly monitored	SC&A total subCTWs requiring bioassays	RPRT-0092 table 4-1 percent directly monitored	RPRT-0092 table 4-1 total subCTWs requiring bioassays
1990	0%	1	NA	NA
1991	72%	81	99%	82
1992	91%	106	97%	106
1993	70%	173	97%	173
1994	73%	138	94%	140
1995	68%	57	95%	57
1996	75%	24	83%	24
1997	95%	55	98%	55
1998	80%	25	92%	25

Table 11. Summary of using all required radionuclides compared to using only at least one required radionuclide for subCTWs effectively monitored

Category	SC&A total or %	RPRT-0092 table 4-1 and table 6-4 total or %	SC&A comment
Total subCTWs requiring bioassays	660	662	SC&A eliminated two 1994 entries because RPT-0092, page 94 states Pu only, while page 112 states Pu not applicable.
SubCTWs with direct bioassays	505	633	SC&A required that all required radionuclides be monitored for the bioassay to be complete (with chest counts limited to 2 years). RPRT-0092 only required at least one required radionuclide to be monitored at any time for the bioassay to be complete.
SubCTWs without complete bioassays	155	29	SC&A removed 155 entries that were not monitored for all required radionuclides or the chest count was more than 2 years (of which there were 19). RPRT-0092 remove 29 entries that had no bioassays.
Monitored coworker matched to unmonitored subCTW	81	19	SC&A matched coworkers as listed in the tables in attachment C of RPRT-0092, except SC&A did not use coworkers with chest counts more than 2 years.
Percent of subCTWs effectively monitored	89%	98%	9% decrease in the number of subCTWs effectively monitored.

Table 12. Breakdown by year of using all required radionuclides compared to using only at least one required radionuclide for subCTWs effectively monitored

Year	SC&A percent effectively monitored	SC&A total subCTWs requiring bioassays	RPRT-0092 table 4-1 percent effectively monitored	RPRT-0092 table 4-1 total subCTWs requiring bioassays
1990	0%	1	NA	NA
1991	88%	81	100%	82
1992	96%	106	100%	106
1993	83%	173	99%	173
1994	90%	138	96%	140
1995	83%	57	100%	57
1996	83%	24	83%	24
1997	98%	55	100%	55
1998	96%	25	100%	25
SubCTWs effectively monitored	89%	660	98%	662

The percentage values listed in the tables in sections 4 and 6 of RPRT-0092 are sometimes misleading because they do not incorporate the need for the subCTW, or the coworker, to be monitored for all required radionuclides, with the chest count limited to 2 years. As shown in

SC&A's analysis, this results in a noticeable difference in both the directly monitored and effectively monitored subCTW percentages. For example, for 1993, table 4-1 lists a value of 97 percent for directly monitored subCTWs by any one required bioassay, and table 4-6 lists 89 percent for required plutonium; however, if all required radionuclides are included, and the chest counts limited to 2 years, the value drops to 70 percent, as shown in table 10. This issue, which applies to both periods 1972–1989 and 1990–1998, is summarized in finding 11 in the “Conclusions” section of this report.

6.3 Analysis of coworker data needed to supplement CTW data

SC&A used the data from the tables in attachment C of RPRT-0092 to analyze the use of monitored coworker (CW) data for unmonitored subCTWs who were listed on an RWP along with a monitored worker. The percent of coworker data needed is an indication of the completeness or incompleteness of the subCTW bioassay data during the period 1990–1998. Table 13 summarizes the results.

Table 13. Summary of use of coworkers for subCTWs

Radionuclide	Attachment C table	Total number of subCTWs	Total number of CWs used	Percent of time CW data used
Plutonium	C-3	644	47	7.3%
Strontium	C-4	429	12	2.8%
Uranium	C-5	225	17	7.6%
Americium	C-6	180	25	13.9%
Neptunium	C-7	91	13	14.3%
Total or weighted average	NA	1569	114	7.3%

These results indicate that in RPRT-0092, on average, subCTW bioassay data were supplemented with coworker bioassay data approximately 7 percent of the time for the period 1990–1998.

SC&A further analyzed the plutonium data in table C-3 of RPRT-0092 for the 47 subCTWs that had coworkers listed to determine if there were indications that the coworker exposure could reasonably represent the exposure to the unmonitored subCTW. To perform this task, SC&A determined if the monitored coworker and unmonitored subCTW (1) were both signed in on the same RWP number, (2) were both signed in on the same date, and if so, (3) both worked during the same time interval, and (4) both had the same job or craft title. Additionally, the results were then analyzed to determine if the coworker met all four of these criteria, which would be needed to represent a condition where a monitored coworker and an unmonitored subCTW were working side by side performing similar tasks at the same time, resulting in similar intakes. Table 14 summarizes the results.

Table 14. Summary of use of monitored coworkers for unmonitored subCTWs for plutonium

Criterion	Percent of workers that meet criterion
CW listed on same RWP	96%
CW signed in on same RWP and date	77%
CW signed in on same RWP, date, and time	66%
CW signed in on same RWP, date, time, and craft	45%

These results indicate:

- The unmonitored subCTW and the coworker were both generally listed on the same RWP (96 percent of the time).
- The unmonitored subCTW and the coworker only performed work under a given RWP on the same date 77 percent of the time; different dates could mean different tasks and, therefore, different exposure potentials.
- The unmonitored subCTW and the coworker both signed in on the same RWP and same date and worked during the same time interval 66 percent of time. Different times of the day or different time intervals could mean different exposure potentials.
- The coworker only met all four of the required criteria 45 percent of the time to indicate a coworker and the unmonitored subCTW were working side by side performing similar tasks (i.e., same craft designation) on the same date at the same time.

SC&A found that the unmonitored subCTW and the monitored coworker had the same job title 60 percent of the time when signed in on the same RWP (regardless of sign in date or time). Different craft could mean different exposure potentials.

Observation 4: SC&A’s analysis indicates that identified coworker matches may not be sufficiently representative of the subCTW intakes in all cases unless strict criteria are applied, such as the same craft designation as well as the same date and time of the work performed.

6.4 Implementation in the field was not a step function beginning in 1990

Although corporate and policy changes were initiated in 1990, those changes did not take place immediately. It took well into the 1990s to implement changes in the field, and to obtain better bioassay participation and record storage and retrieval. Some of the relevant issues and deficiencies that extend into the 1990s have been previously discussed in detail in this report while evaluating the 1972–1989 data. If the necessary changes had been implemented relatively quickly, then there would not have been issues that were being identified and addressed in the 1990s. Most of these 1990s issues have previously been discussed by the SRS work group. Examples of issues that extended into the 1990s are contained in the DOE 1998 occurrence report, “Inadequate Participation in the Job-Specific Bioassay Program” (DOE, 1998a); the 1998 “Root Cause Analysis for Corrective Action Report #97-CAR-07-0001” (Kornacki et al., 1998); and the 1999 WSRC interoffice memorandum, “Response to the Compilation of PAAA Internal Dosimetry Issues” (Morgan, 1999).

SC&A analyzed the data in table C-1 of RPRT-0092 to determine when RWPs began to state that a bioassay was required, and the types of radionuclides that should be bioassayed for. SC&A sorted the data in table C-1 according to the year of the RWP (1990–1998) and determined the total number of bioassays required by adding the number required by an RWP (represented by the symbol “R” in table C-1) plus the number assumed to be needed by NIOSH (represented by the symbol “A” in table C-1). The total number of RWP required bioassays (R) was then divided by the total number of required bioassays (R+A) to obtain the fraction of bioassays used in RPRT-0092 that were specifically required by the RWPs. This procedure was performed annually for each radionuclide. The results are summarized in table 15.

Table 15. Percent of RWP required bioassays compared to the total number of bioassays in RPRT-0092, table C-1

Year	Percent of Pu bios* required by RWPs	Total of RWP plus assumed Pu bios	Percent of Sr/FP bios required by RWPs	Total of RWP plus assumed Sr/FP bios	Percent of Am bios required by RWPs	Total of RWP plus assumed Am bios	Percent of U bios required by RWPs	Total of RWP plus assumed U bios	Percent of Np bios required by RWPs	Total of RWP plus assumed Np bios
1990	0%	1	0%	1	NA	0	0%	1	NA	0
1991	0%	16	0%	13	0%	4	25%	4	0%	1
1992	0%	23	0%	9	0%	12	0%	20	0%	2
1993	4%	27	0%	12	0%	13	9%	11	0%	11
1994	78%	32	72%	25	33%	9	33%	15	NA	0
1995	100%	15	100%	5	0%	2	100%	2	33%	3
1996	100%	7	100%	3	0%	2	NA	0	100%	1
1997	100%	9	100%	8	0%	1	NA	0	NA	0
1998	80%	10	71%	7	0%	1	NA	0	NA	0

Pu = plutonium, Sr/FP = strontium/fission products, Am = americium, U = uranium, Np = neptunium

* bios = bioassays

The results in table 15 indicate that RWPs began to specify that a bioassay was required for a certain radionuclide in the mid-1990s (1994 to 1995).

Observation 5: Bioassay data in the 1990s are not entirely free of the earlier data issues. The implementation of methods used to correct for the bioassay deficiencies seen in the 1970s and 1980s did not take place immediately with the change in the contracting company in 1990. It was not a step function that took place in 1990; instead, it took a number of years to identify, address, and effectively implement the changes. For example, there was only one RWP with one subCTW listed for 1990 in RPRT-0092, and specific radionuclides were not required on the RWPs until the mid-1990s.

7 Conclusions

SC&A reviewed ORAUT-RPRT-0092, revision 00, “Evaluation of Bioassay Data for Subcontracted Construction Trade Workers at the Savannah River Site,” from three vantage points:

1. **Sampling premise:** From the standpoint of sampling experience and results, were the guiding assumptions, upon which the evaluation was planned and conducted borne out for the time periods in question?
2. **Sampling execution:** From the standpoint of sampling execution, was its primary goal accomplished? In other words, did it “randomly select radiological workers from the various areas at the Savannah River Site (SRS), such that an evaluation of monitored and unmonitored workers can be conducted” (NIOSH, 2018a, p. 1)?
3. **Coworker datasets:** From the standpoint of NIOSH’s “Draft Criteria for the Evaluation and Use of Coworker Datasets” (NIOSH, 2015), did the evaluation satisfy its stated objective of demonstrating that “monitored subcontractor CTWs and unmonitored subcontractor CTWs worked side by side in the same radiological environment at the same time” (NIOSH, 2018a, p. 1)?

7.1 Sampling premise

For the first vantage point concerning the sampling premise, SC&A concludes that NIOSH’s guiding assumptions for sampling subcontractor bioassay data for 1972–1989 have neither been validated in practice nor adequately grounded in actual DuPont policies, procedures, and practice of that time period. In vitro and in vivo bioassays were linked to SWPs and job plans without clear evidence that the former stemmed from the latter and were not merely incidental. None of the SWPs and job plans for that period reviewed by SC&A contained any bioassay requirements, despite the vast majority of them requiring respiratory protection. The basis for identifying “radionuclides of interest” for sampled permits does not account for inadequate radiological characterization cited by DOE. The scope of sampling is limited to one SRS facility, 773-A, for incomplete operational periods, and is not representative of other critical SRS facilities. The inclusion of incident-driven bioassays is not appropriate, given the degree of procedural accountability provided special bioassays, as compared with that afforded the routine and job-specific bioassay program (for which DOE found a history of delinquent bioassays). The completeness of these and other radiological records is questionable, given the acknowledged destruction of subcontractor records, DOE findings of missing occupational dose data, and firsthand worker accounts regarding dose record gaps.

For the post-1989 period, SC&A concludes there were similar concerns until such time as the new contractor, WSRC, was able to develop, implement, and hold SRS line management accountable, as part of its Radiological Improvement Plan. This plan included a spectrum of new and updated radiation protection and bioassay policies and procedures, including (1) the late 1990 “Internal Dosimetry Technical Basis Manual” (WSRC, 1990b), (2) the implementation of a 1990 RWP program requiring a job-specific bioassay program (begun in 1991) that was required upon respirator use (WSRC, 1992b), and (3) manual 5Q1.1 “Radiation and Contamination Control Procedures” (WSRC, 1992b). However, it is not clear when effective implementation

was actually achieved, given the persistence of the former workplace practices, as illustrated by the significant job-specific bioassay gaps uncovered by WSRC and DOE in 1997–1998.

The underlying reason for these disparities lies in the difference in how job-specific permits and bioassays were apparently handled by DuPont in 1972–1989,²⁹ and the premise and assumptions applied by NIOSH, many of which were either founded on WSRC’s policies and practices of the 1990s, or were not grounded in contemporary policies, procedures, and practices of the DuPont era, as critiqued by DOE and WSRC, as the site transitioned from DuPont to Westinghouse. This fundamental difference between how the internal dosimetry program was defined and implemented between the two operational eras—1972-1989 and post-1989—along with the substantial absence of permit records for all but one facility, 773-A, makes the application of the same evaluation criteria and assumptions to survey both time frames unrealistic.

7.2 Sampling execution

For the second vantage point concerning sampling execution, SC&A concludes that for 1972–1989, NIOSH’s interpretation of “effective monitoring” to include coworker matches involving internal bioassay methods that are not used in the formulation of the coworker models presented in OTIB-0081 is technically inappropriate. Likewise, NIOSH’s consideration that “lack of bioassay samples for several years” would not be considered “unmonitored” for purposes of the job plan review is inconsistent with the essential purpose of permitted job-specific bioassays, as well as with documented NIOSH positions (e.g., NIOSH (2019a, 2018b)). Specifically, periods greater than 2 years for all fission product monitoring as well as chest counts for long-lived radionuclides (e.g., plutonium and americium) should be considered unmonitored. When SC&A revised the “matching” percentage in RPRT-0092 based on removing these two questionable adjustments, it was found that for americium, there was only one data point for 1973 (0 percent effectively monitored), and 33 percent effectively monitored for 1981–1987 (versus 76 percent in RPRT-0092). For plutonium, SC&A determined that 64.7 percent were effectively monitored for 1972–1974 (versus 69 percent in RPRT-0092), with agreement between both SC&A and NIOSH on 97 percent effectively monitored for 1980–1989. For fission products, SC&A determined that 69.9 percent of the worker population was effectively monitored for 1972–1974 (versus 94 percent in RPRT-0092) and 73.9 percent for 1980–1989 (versus 99 percent for RPRT-0092). While the question of “how complete is complete enough?” is a subjective policy-based decision, the removal of these two “adjustments” from the assessment lowers the bioassay monitoring percentages to a level comparable to that seen in SC&A’s 2017 subcontractor completeness review (SC&A, 2017a) and that cited by WSRC in its self-assessments of job-specific bioassays in 1997 (DOE, 1998b).

From its review of the americium data, SC&A does not find that the RPRT-0092 review supports the premise that subcontractors on job plans that should have required internal monitoring for americium were either directly monitored (approximately 20 percent) or, alternately, appropriately represented in the derived coworker models for SRS (about 13 percent).

Likewise, SC&A found that the many workers (approximately 70–73 percent) who should have been monitored for fission products underwent appropriate internal sampling during the two

²⁹ As noted earlier in this report, any conclusion for 1972–1989 would likely apply also to 1990 (albeit the job plans evaluated only extend to March 1988).

periods evaluated prior to 1990. However, very few of those monitored workers underwent in vivo counting for fission products. Thus, they are not included in the coworker model developed for SRS and not considered representative of the unmonitored worker.

For all periods evaluated, SC&A concludes that there is an apparent lack of adherence of the RPRT-0092 review to its sampling plan in that bioassays for all of the radionuclides listed on the RWP were not addressed in the corresponding data analyses for the specific time intervals. This was also the conclusion reached in section 6.2.2 of this report. Table 6-4 in the summary section of RPRT-0092 details the total percentage of workers “monitored for at least one radionuclide.” SC&A believes this is a misleading metric and that the appropriate metric would be “monitored for all radionuclides on the work permit/job plan.” A comparison of these values is shown below in table 16.

Table 16. Comparison of monitoring percentages involving at least one radionuclide (RPRT-0092 value) versus all radionuclides on work permit (SC&A value)

Time period	RPRT-0092 directly monitored for at least one radionuclide	SC&A directly monitored for all radionuclides on work permit	RPRT-0092 effectively monitored for at least one radionuclide	SC&A effectively monitored for all radionuclides on work permit
1972–1974	76%	47.1%	85%	55.1%
1975–1979	No data	No data	No data	No data
1980–1989	90%	51.3%	99%	65.5%
1990–1998	96%	77%	97%	89%

Finding 11: For both the 1972–1989 and the 1990–1998 periods, when considering all radionuclides requiring internal monitoring per work permit, as opposed to “at least one radionuclide” requiring monitoring, the percentage of monitored workers drops significantly (particularly in the earlier periods). Directly monitored workers ranged from 47 percent to 77 percent (in comparison to 76–96 percent in RPRT-0092), and effectively monitored workers ranged from 55 percent to 89 percent (in comparison to 85–99 percent in RPRT-0092).

SC&A also concluded that, because data are lacking for 1990 (only one RWP and one subCTW listed), it does not warrant bundling with the period 1990–1998 (see finding 10).

7.3 Coworker datasets

For the third vantage point concerning establishing that unmonitored subcontractors worked side by side with monitored subcontractors, SC&A concludes that the current sampling effort in RPRT-0092 was not successful in identifying suitable coworkers for americium for 1981–1987, as just 13 percent of the overall population (16 percent of the unmonitored population) was matched based on coworker urinalysis. For fission products 1980–1989, just 1.4 percent of the overall population (37 percent of the unmonitored population) were effectively matched by in vivo. No suitable coworker matches were identified for fission products in the 1972–1974 period, and only a single unmonitored worker was identified for americium exposure during this same period. No coworker evaluations for any radionuclides were possible for 1975–1979. For plutonium, the sampling effort identified coworker matches for about 15 percent of the worker

population (29 percent of the unmonitored population), which raised the effective monitored population from 50 percent to 65 percent for 1972–1974.

For 1990–1998, a focused review of plutonium coworker matches during the WSRC period notes that while nearly 96 percent of the identified coworker matches involve the same job plan, inclusion of additional criteria (e.g., the same date, time, and craft) decreases this percentage significantly. When considering all four criteria for a coworker match (job plan, date, time, and craft), appropriate coworker matches for plutonium were identified in RPRT-0092 just 45 percent of the time.

7.4 Overall conclusions

Overall, SC&A concludes that the RPRT-0092 assessment of subcontractor completeness for 1972–1998 does not reflect the policies, procedures, and practice during the DuPont operating era of 1972–1990 and, therefore, makes unfounded assumptions and evaluations of bioassay performance that lead to invalid results and conclusions. Those sitewide conditions only change with the advent of new and updated RWP and bioassay procedures implemented by WSRC in the early 1990s, at which point the RPRT-0092 assessment can be substantiated. Further, questions of overall data completeness persist based on destruction of subcontractor records and reported gaps in worker exposure records, compounded by issues of records retention and irretrievability.

In summary, without the validation of subcontractor data completeness that the RPRT-0092 evaluation was to provide, there has been no substantiation that there are sufficient job-specific bioassay measurements available to ensure that the coworker data in OTIB-0081 are either bounding or representative of the exposure potential of subcontractors performing permit-driven work across the SRS site.

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Appendix 1: SC&A's Analysis of OTIB-0081 NOCTS Bioassay Data per SRS Area (1972–1990)

SC&A performed an analysis of the NOCTS coworker data used in ORAUT-OTIB-0081, revision 04 (NIOSH, 2019c), to determine if those data suffered from the same lack of SRS facility coverage as the job plan and SWPs data do in RPRT-0092 for the period 1972–1989 (i.e., limited to Area A). SC&A sorted approximately 47,000 in vitro bioassay records (obtained from the file, “SRS combined in-vitro data 051717.xlsx,” in the folder, “Bioassay Data-May Contain PII,” provided by NIOSH) and approximately 22,000 in vivo bioassay records (obtained from the file, “SRS combined in-vivo data 0083117.xlsx,” in the folder, “Bioassay Data-May Contain PII,” provided by NIOSH) according to the area in which the work task was located to determine the fraction of the total bioassays that were from the major areas at SRS. The results are summarized in figures A1 and A2 below.

Figure A1. Fraction of NOCTS in vitro bioassays from areas at SRS (1972–1990)

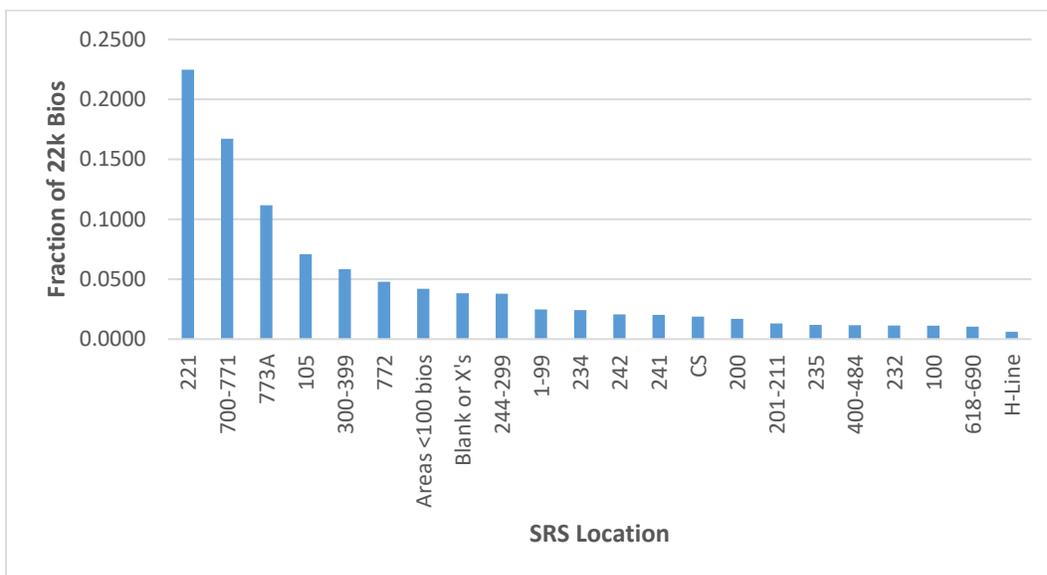
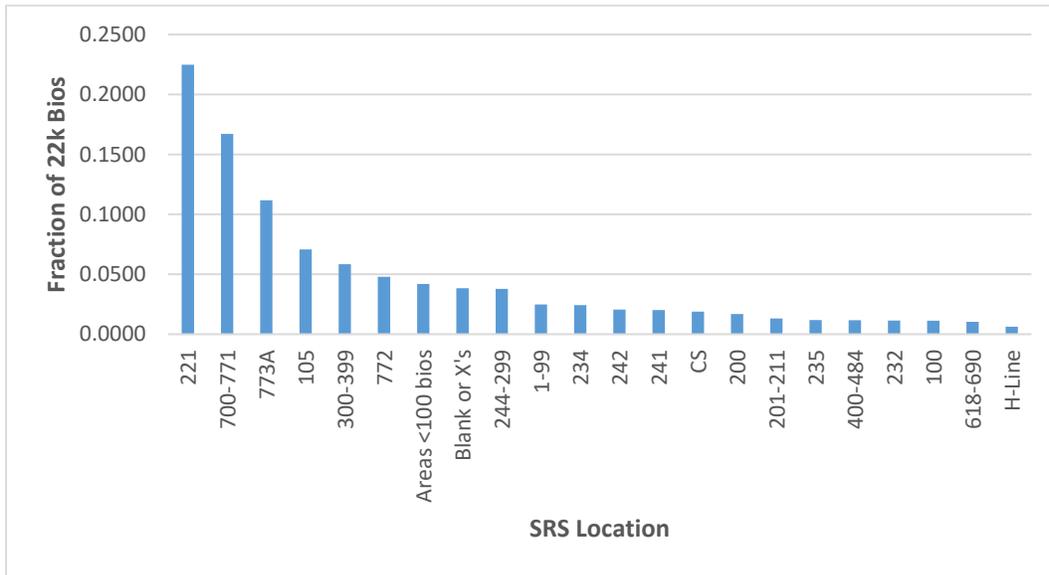


Figure A2. Fraction of NOCTS in vivo bioassays from areas at SRS (1972–1990)



This analysis indicates that the 1972–1990 NOCTS coworker bioassay data used in OTIB-0081 were not concentrated in only Area A, as the RPRT-0092 1972–1989 job plan and SWP data were.

Appendix 2: SC&A's Analysis Used to Spot Check RPRT-0092 Data Process

SC&A sorted the information listed in NIOSH's file, "CTW Bioassay Requirements Table C-2.xlsx" (obtained from NIOSH's folder G, "Report Tables") to obtain examples of RWPs that covered the 9-year period of interest (1990–1998), a variety of SRS areas (Areas F, H, M, and Z), and various crafts. From the results of this sorting, potential SID numbers and corresponding CTW numbers were obtained. SC&A then used the selected SID documents from NIOSH's folder E to obtain the details of the RWP, sign-in sheet, CTW name, and CTW bioassay data. SC&A used the NIOSH file, "Master list of Employees to CTW number for Report Final.xlsx" (obtained from NIOSH's folder G, "Report Tables"), to cross-reference the CTW name on the sign-in sheet to the CTW number used in the tables in attachment C of RPRT-0092.