Response to SC&A's Evaluation of Savannah River Site Subcontractor Bioassay Data Completeness, SCA-TR-2017-SEC009-SCA

Response Paper

National Institute for Occupational Safety and Health

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EXECUTIVE SUMMARY

Sanford Cohen & Associates (SC&A) was tasked by the Advisory Board on Radiation and Worker Health to conduct a review of bioassay data completeness for Construction Trade Workers (CTW) at the Savannah River Site (SRS), resulting in the report *Evaluation of Savannah River Site Subcontractor Bioassay Data Completeness* (Fitzgerald, 2017). In their report, SC&A judged the SRS bioassay program as "dysfunctional" and stated that the bioassay results available for subcontractor CTWs for the period 1989 through 1998 did not satisfy NIOSH criteria for coworker datasets.

This response to the report includes an analysis by National Institute for Occupational Safety and Health (NIOSH) of bioassay data completeness using workers identified by SC&A and a critique of the methods used by SC&A with three specific issues.

Using workers from select Radiation Work Permits (RWPs), SC&A ascertained whether their bioassay results were within 30-day and 90-day windows after the date the worker signed onto the RWP. NIOSH examined tritium workers and non-tritium workers separately and calculated the number of days between work and the next bioassay sample. While agreeing with the 30- and 90-day evaluation points for tritium workers, NIOSH considers any plutonium, uranium or fission products result obtained within one year of work to represent a valid internal monitoring interval. NIOSH also examined RWPs identified by SC&A as having workers lacking bioassay results for other workers doing the same tasks and found 100% of tritium and non-tritium subcontractor CTW workers were covered either by their own bioassay results or by coworker results.

NIOSH Issue 1: *Bioassay data should have been separated into tritium and non-tritium and appropriate time intervals used for evaluation.*

Some of the workers identified by SC&A to have missing bioassay results were identified from Standing RWPs (SRWPs) which were in place for up to a year at a time; included tens to hundreds of workers, most with routine bioassay results; and were typically created for entry into controlled areas that did not include airborne or contamination areas.

NIOSH Issue 2: *Some SRWPs should have been excluded from analysis.*

The SRS bioassay program included pre-scheduled routine sampling, special sampling for cause, and job-specific sampling for those workers whose routine bioassay types did not satisfy requirements listed on RWPs. In a 1997 Notice of Violation (NOV) the Department of Energy (DOE) cited SRS for failures in the job-specific bioassay program, specifically that workers did not always provide requested samples and that the issue had been identified previously without satisfactory corrections. SC&A presented this NOV as evidence of "a chronic history of wide non-compliance with job-specific bioassay requirements."

Data from the first four months of 1997 that were reported to DOE, resulting in the NOV, indicated a participation rate for all bioassay samples of greater than 96%. All workers who did not provide samples in 1997 were sampled in 1998 with no identified uptakes.

Bioassay sampling was required by DOE under 10 C.F.R. 835 for workers likely to receive an internal exposure exceeding 100 millirem CEDE annually. SRS determined that no worker was likely to exceed this level in a year but used bioassays to monitor workers who had the potential to exceed it. This was to verify the effectiveness of other controls such as procedures, engineered controls, surveys, protective clothing, respirators, job surveillance, and air monitoring. SRS data for 1996 through mid-1998 indicated fewer than 0.1% of the samples indicated a measurable uptake. DOE did not find failures of worker protection under 10 C.F.R. 835 but instead cited SRS under 10 C.F.R. 820 for procedural issues.

NIOSH Issue 3: *The Notice of Violation applied only to RWP job-specific bioassay samples which were not required by regulation and were only one part of an overall worker protection program.*

NIOSH agrees with SC&A that some workers did not provide job-specific bioassay samples but does not agree with their conclusion that the existing bioassay data do not meet the NIOSH requirements for coworker analysis.

INTRODUCTION

SC&A's *Evaluation of Savannah River Site Subcontractor Bioassay Data Completeness* (Fitzgerald, 2017) provides the results of SC&A's review of the Savannah River Site (SRS) bioassay data for subcontractor construction trade workers (subCTW) from 1989 through 1998. In its evaluation, SC&A non-randomly selected some RWPs and then selected certain workers from those RWPs; thus, neither the RWPs nor the workers were selected randomly. SC&A then attempted to identify bioassay results within 30 and 90 days of the RWP sign-in date regardless of the radionuclides tested for. SC&A also cited a 1997 Notice of Violation (NOV) relating to participation in the SRS bioassay program. SC&A came to a number of conclusions leading to the following statement in the Executive Summary:

> *While there has been some discussion of what would constitute reasonable "success" criteria for sampled completeness of subcontractor CTW bioassay records, these results and compliance history indicate a dysfunctional job-specific bioassay program at SRS whose results are manifestly incomplete for at least the period 1989–1998 and should not be relied upon for coworker model development.* (Fitzgerald, 2017)

In this response paper, NIOSH presents its concerns of an analysis of the data used by SC&A in its review. NIOSH also discusses the factors associated with issuance of the 1997 NOV and SRS follow-up actions taken in response. NIOSH also provides the results of its own evaluation of bioassay data completeness for a different time period and discusses them *vis a vis* SC&A results/conclusions.

SUMMARY OF BIOASSAY SAMPLE TYPES

SRS implemented bioassay programs to cover 35 facilities that processed actinides, fission products, and tritium (Thomas, 1993). During the time period covered in SC&A's evaluation (1989-1998), SRS performed urine sampling for radioactive material using both routine and special sampling. Workers with "reasonable potential" for internal exposure were included in the routine bioassay program. The special bioassay program was designed for assessing "inadvertent intakes" of radioactive material that could exceed the 100 mrem threshold (LaBone, 2001a).

Routine Sampling Program

SRS designed the routine sampling program to assess the adequacy of facility controls and personnel protective measures. DOE orders in place during this period (5480.11 and later 10 C.F.R. 835) indicated that facilities should, where feasible, be designed and operated with engineered controls that would prevent worker intakes of radioactive materials.

The routine bioassay program had two parts, prescheduled sampling and job-specific sampling. The program was used in facilities where workers had a reasonable potential for exposure to radioactive materials (Westinghouse SRC, 1990).

During the period under SC&A evaluation (1989-1998), a worker's enrollment in the routine bioassay program was based not only on the radioactive hazards associated with the facility where the individual worked, but also the type of work the worker normally performed. SRS considered a worker who routinely performed tasks requiring respiratory protection to be at greater risk of involvement in an incident resulting in an intake than, for instance, a manager who occasionally performed a cursory walk-through of a facility. Therefore, for the purposes of the bioassay program, SRS defined three categories of workers that were in effect until the implementation of 10 C.F.R. 835:

- Category I: Hands-on workers with the highest intake potential. They routinely work in Contamination or High Contamination Areas and are required to wear respiratory protection. For these employee, the routine program typically requires quarterly urine samples and an annual chest count.

- Category II: Supervisors, engineers, or operators who do not perform hands-on work, but who routinely enter Radiologically Controlled Areas (RCAs) to observe work or record data. They are typically required to submit an annual urine sample but do not receive annual chest counts.

- Category III: Other people working on site who occasionally enter RCAs but only do so to observe work. These employees are at little to no risk of receiving an intake. They are not required to submit routine urine samples, nor do they receive annual chest counts (Actinide Basis, 1993).

With the implementation of 10 C.F.R. 835, SRS defined the three categories of workers for actinide bioassay as:

- Those "likely" to exceed 100 mrem CEDE[1]
- Those with "reasonable potential" to exceed 100 mrem CEDE
- Those with "no potential" to exceed 100 mrem CEDE

While useful to confirm the adequacy of workplace monitoring and worker protection programs, routine sampling was not required at SRS during the 1990s, either by order or by the regulations in place during the period of SC&A's review. No worker at SRS was considered likely to exceed 100 millirem CEDE (Findley, 1998, PDF p. 6).

For the tritium bioassay program, workers were placed on the routine program when they routinely entered RCAs with the potential for tritium contamination or airborne tritium activity (Tritium Basis, 1993).

[1] NOTE: To formalize the definition of who may fit this criterion, SRS performed a statistical study of bioassay data for the years 1999 and 2000 to test the process of judging a worker's likelihood of exceeding 100 mrem from intakes of radioactive materials (LaBone, 2001a).

For both actinide and tritium bioassay, prescheduled sampling was used to sample workers who routinely worked in locations with Airborne Radioactivity Area postings. Samples were generally scheduled annually or semi-annually based on a worker's date of birth or other recurring event. A large majority of routine bioassay samples were collected with prescheduled sampling. Data reported in the NOV showed that the greatest majority of routine bioassay (e.g., 95% during the first four months of 1997) was requested through prescheduled sampling.

Job-specific sampling was used to sample workers not on prescheduled sampling but who needed to enter locations requiring respiratory protection. Like prescheduled sampling, job-specific sampling was used to assess the adequacy of facility controls and personnel protective measures. A definition of the job-specific sampling from September 1997 described it as follows:

> *Job-specific urine sampling is also known as "RWP (Radiation Work Permit) sampling" and is administered exclusively by radiological control personnel. RWPs are written to describe a specific scope of work to be performed. Additional information such as the expected radiological hazards to be encountered, respiratory protection if needed, and dosimetry requirements are listed on the RWP. Based on the degree and nature of the radiological hazards it may be necessary to request each worker performing "hands on" work to leave a urine bioassay sample, hence the term "job-specific sampling." If a worker is wearing respiratory protection and is not on an appropriate routine sampling program then a job-specific sample should be requested*. (Findley, 1997)

Job-specific sampling was not performed to measure a suspected intake. At SRS, dose was not assigned from job-specific bioassay sampling results. However, results of prescheduled and job-specific bioassays could flag a worker for special bioassay sampling.

Samples collected from routine sampling for uranium, actinides, and fission products were generally collected over 24 hours, although some were collected as 8-hour samples. Tritium samples were generally spot samples even when prescheduled.

Special Bioassay Program

SRS designed the Special Bioassay program to assess "inadvertent intakes" of radioactive material that could exceed the 100 mrem threshold (LaBone, 2001a). Under this program, samples were required in response to unusual or unanticipated circumstances. For example, a sample was required whenever a worker was suspected of receiving an intake that would result in a CEDE of 100 mrem or greater (LaBone, 2001b, PDF p. 2). Intakes of radionuclides were assigned when positive results of special bioassay sampling were confirmed.

REVIEW OF RADIATION WORK PERMIT WORKER BIOASSAY

To respond to SC&A comments, NIOSH used workers identified in radiation RWP data, RWP sign-in sheet data, and bioassay results captured by SC&A in December 2016 and February 2017. NIOSH only considered data for the period January 1, 1989 through December 31, 1995. While SC&A only reported data for subCTW in their report, NIOSH considered all workers identified by SC&A in the RWP and sign-in sheets.

In their analysis, SC&A did not specifically break out work by area or type. NIOSH separated workers by tritium work and non-tritium work. Work with exposure to tritium was performed at SRS reactors and tritium processing areas. Non-tritium work was performed in the F and H canyons, M Area, Building 773-A, and at SRS reactors. For non-tritium work, NIOSH considers plutonium to be the radionuclide of interest for the F and H canyons and Building 773, and enriched uranium the radionuclide of interest for M Area.

NIOSH reviewed bioassay data available for each worker and determined the first bioassay sampling event after the work date. Rather than segregating results within 30- and 90-day periods, NIOSH calculated the number of days between work and sampling for each. SC&A used 30 days and 90 days as evaluation points for all bioassay radionuclides. However, by procedure, some SRS workers would have been sampled for plutonium either twice per year or once each year depending on work location, while workers routinely sampled for fission products would have been sampled once each year. NIOSH considers any plutonium, uranium or fission products result obtained within one year of work to represent a valid internal monitoring interval. NIOSH agrees with the use of 30- and 90-day evaluation points for tritium.

Results of SC&A's analysis of subCTW bioassay are summarized in Table 1.

Table 1. Summary of SC&A Analyzed Bioassay Result.

Criteria	% Workers with Bioassay Results
All RWP, bioassay within 30 days	66
All RWP, bioassay within 90 days	80
RWP specifically indicated bioassay, bioassay within 30 days	71
RWP specifically indicated bioassay, bioassay within 90 days	84

SC&A stated in the conclusion of their report:

> *SC&A concludes that the bioassay dataset for CTW subcontractors, specifically, and CTWs, generally, is demonstrably incomplete for 1989–1998 (and likely before that time period) and does not satisfy the criteria set forth in NIOSH's Draft Criteria for the Evaluation and Use of Coworker Datasets.* (NIOSH, 2015).

Figure 1 shows the actual job-specific bioassay process (Morgan, 1998), as determined in a root-cause analysis in response to the 1997 Notice of Violation (discussed in detail below). The SC&A report jumps from the point where a worker signs in on an RWP at the beginning of the process (Box 1) to the end of the process (Box 2) to determine if the worker has a sample 30 or 90 days after the RWP. If the contractor was not scheduled to leave a sample for 100 days, there would not have been a sample.

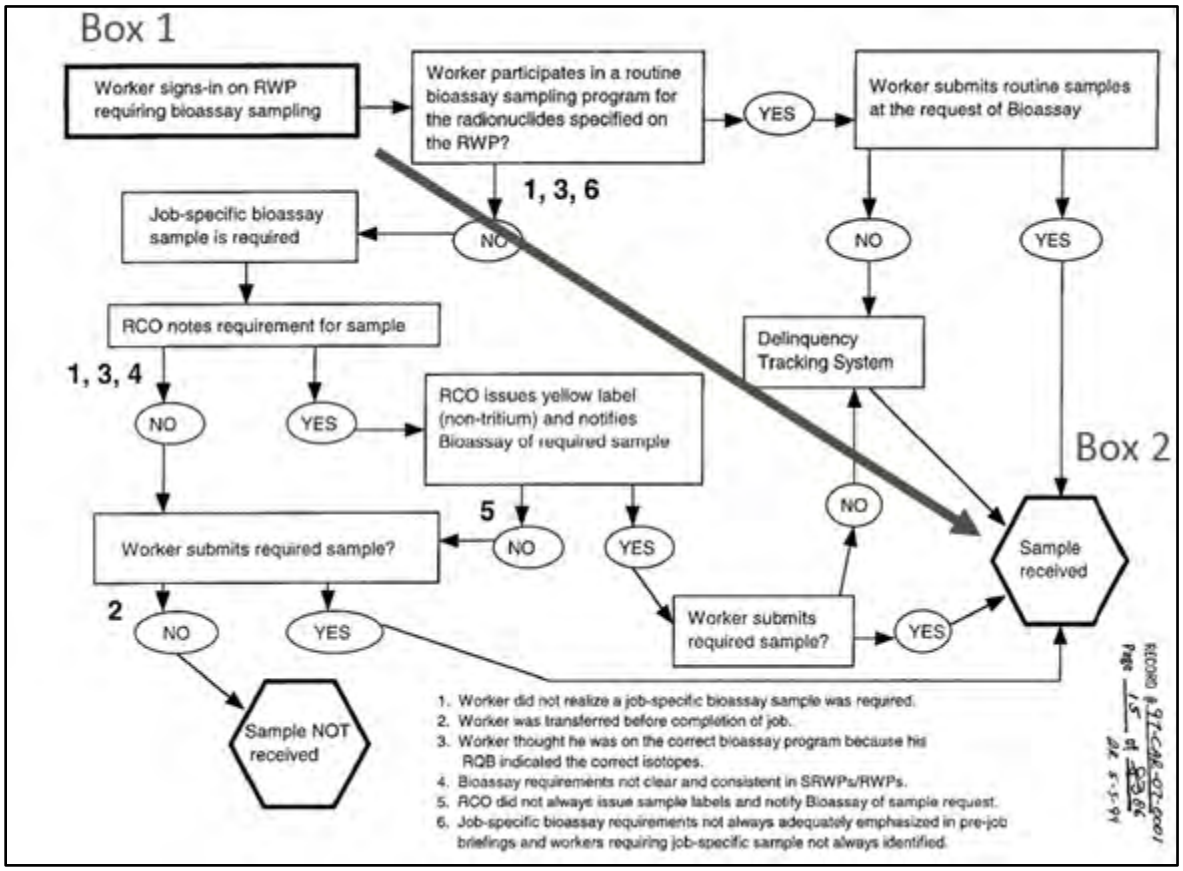


Figure 1. SC&A Path Through the Actual Job-specific Bioassay Process

Tritium Workers

Using the SC&A set of data, tritium workers were selected from RWPs covering the period from 1989 to 1991, and 1994 to 1995. NIOSH identified 130 subCTW workers; bioassay was not required from two of them. Bioassay results were identified for 124 of the 128 subCTW for which bioassay was required. Table 2 provides summary statistics for these workers; Attachment A provides details for individual workers. The mean number of days from the end of the daily job to the receipt of a tritium bioassay sample was 7.0 days for subCTW. No sample was submitted later than 70 days following the RWP job. An intake of 1500 pCi of tritium, in the form of HTO, yields a dose of 100 mrem. Such an intake can be detected in urine to about day 75 with a detection limit of $5x10^5$ pCi (0.5 µCi)/day.

Table 2. Summary of Tritium Workers with Tritium Bioassay.

Criteria	Result
Number of subCTW	130
Number of subCTW on RWP requiring bioassay	128
Number of subCTW with H3 bioassay	124
Percentage of subCTW with data	96.9
Mean days subCTW	7.0[a]
Number of subCTW on routine H3 bioassay	111
Percentage of subCTW on routine H3 bioassay	89.5
Percentage of subCTW covered by personal or worker	100.0

a. Routine frequency for tritium determined by checking for tritium bioassay every 30 days.

Many SRS RWPs during the period of evaluation were standing permits and remained open for several weeks to a full year. Generally, tens to hundreds of workers signed in to such standing RWPs. For example, at least 25 workers, 17 of them subCTW, signed into RWP K89S-001 from September 18, 1989 to December 1, 1989. Two of the four subCTW without bioassay worked under SRWP 89S-001 (Figure 3) which did not permit entry into posted areas of Radiation Control Areas (RCA) nor require bioassay. More information on this SRWP are given in Attachment C.

Bioassay results are available to NIOSH from coworkers working on the same job for the four subCTW without personal bioassay results; this translates to 100% coverage by personal or direct coworker bioassay. Three other subCTWs were identified without personal tritium bioassay. While NIOSH has not reviewed the work conditions of the RWPs those subCTW worked in, ORAUT identified coworkers with tritium bioassay using data captured by SC&A (undated).

Table 3. Coworkers with Tritium Bioassay.

Worker No.	Job Date	RWP	Worker No. of Coworker
85	1/29/1990	90K-146	84
270	5/4/1995	95L-001[a]	240
261	9/7/1995	95C-005[b]	260
262	9/7/1995	95C-005[b]	260

a. SRS 1995a.
b. SRS 1995b.

NIOSH assumes that other workers with no results did not leave samples. Workers not leaving a sample occurred randomly; there is no pattern or order in missed results.

Routine urine bioassay and workplace monitoring were two parts of the complementary program for monitoring tritium exposure (Tritium Basis, 1993). Workplace monitoring was the primary method of control for all other radionuclides. Tritium bioassay was based on routine retrospective sampling with a frequency of one sample per month for a worker or workgroup in

which at least ten percent of members were sampled to represent exposures to all group members (Tritium Basis, 1993; Westinghouse SRC, 1990). While SC&A and NIOSH evaluated whether identified workers were sampled as the result of a particular job, workers were generally sampled frequently over the course of a year. While a few workers were not sampled, and others may have missed some samples, there is no impact on the use of tritium bioassay data for coworker analysis given the large number of samples taken and the randomness of missed samples.

In 1989, SRS reported over 125,000 tritium results; in 1990, almost 176,000. Through July 1993, there were 62,788 samples. About 36% of those gave positive results. The average tritium dose was 0.05 mrem; the largest individual worker tritium dose through July 1993 was 32 mrem (Tritium Basis, 1993). In the 1993 tritium technical basis document, SRS reported that the last assimilation exceeding 100 mrem occurred in 1988. Since 1972, the 95th percentile subCTW tritium dose has been less than 100 mrem with a downward trend, as shown in Figure 2. Since 1980, the DuPont CTWs 95th percentile dose has been less than 100 mrem, again with a downward trend. Tritium monitoring of subcontractors is not a dose reconstruction problem at SRS.

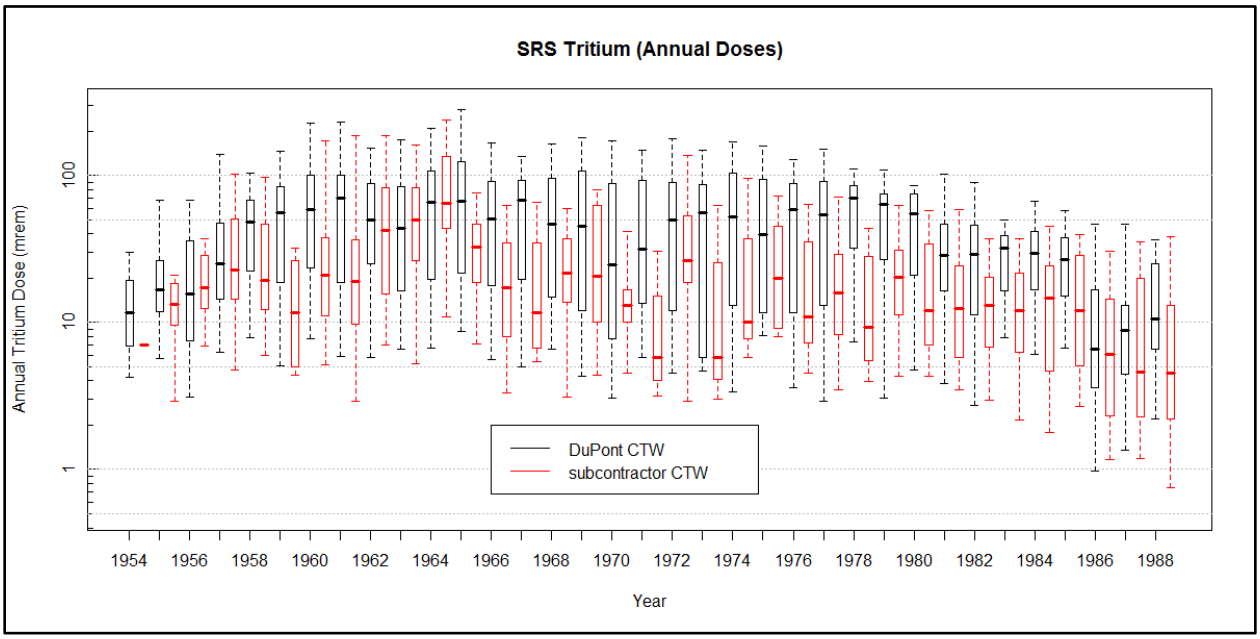


Figure 2. SRS Tritium Dose, 95th Percentiles

Table A-1 provides the results of NIOSH's evaluation of tritium bioassay for tritium workers. Using the available data and coworker intake models, NIOSH can reconstruct tritium intakes for subCTWs with sufficient accuracy as the 95th percentile dose is less than 100 mrem.

Non-tritium Workers

Using the SC&A set of data, non-tritium workers were selected from RWPs covering the period from 1992 to 1994. SC&A reported 62 non-tritium bioassay results. NIOSH identified more results due to looking beyond 90 days. NIOSH identified 107 subCTW workers; bioassay was not required from five of those 107 by the RWP. Bioassay results were identified for 99 of the 102 subCTW for which bioassay was required. SRS plutonium monitoring required each worker in the workgroup to have one urine bioassay and one chest count annually. In addition, SRS required each member of a workgroup to leave a sample if any member of the workgroup received a confirmed plutonium intake (Westinghouse SRC, 1990). Table 4 shows summary statistics for these workers; Attachment B provides the details. The mean number of days from the end of the daily job to receipt of a bioassay sample is 150.1 days for subCTW, which was beyond the 90-day limit used by SC&A, but well within the semiannual and annual sampling frequencies given by SRS (Westinghouse SRC, 1990, PDF p. 234).

Table 4. Summary of Non-Tritium Workers with Plutonium Bioassay.

Criteria	Result
Number of subCTW	107
Number of subCTW on RWP requiring bioassay	104
Number of subCTW with bioassay	99
Percentage of subCTW with data	95.1
Mean days subCTW	150.1
Number of subCTW on routine bioassay	93
Percentage of subCTW on routine bioassay	89.4
Percentage of subCTW covered by personal or worker	100.0

NIOSH found bioassay data obtained from coworkers for all five subCTW without bioassay results. Coworkers were identified from the same RWPs on the same day or performing the same task in the same location. Non-tritium bioassay results were found for two of the five subCTW but the samples were collected about three years after the 1994 working date. Specifics of the radiation work permits and the subcontractor construction trade workers and coworkers are presented in Attachment C, Table C-1 occurring in 1992, and Table C-2 occurring in 1994. Two of the coworkers identified on the RPW sheets are not in the SC&A data set. Bioassay results for those two workers were verified in the SRS Health Protection Radiation Exposure Database (HPRED).

While this report identifies some workers without bioassay, it also demonstrates the availability of bioassay data from coworkers performing similar tasks in the radiological environment on the same job. Using available data and coworker intake models, NIOSH can reconstruct plutonium intakes for subCTW with sufficient accuracy.

Table 5 provides total bioassays by year for all subCTW, which includes tritium and actinide monitoring. NIOSH found 95.6% of all subCTW were directly monitored for intakes of

radionuclides, and 88.7% of those workers were on routine urine bioassay as recorded by SRS bioassay data reported for the individuals. One hundred (100%) of all evaluated subcontractor workers were either directly monitored or worked with one or more coworkers who were directly monitored.

Table 5. Summary of Subcontractor Bioassay.

Year	No. of subCTW where Bioassay Required	No. with Bioassay Data	No. with Monitored Coworker	Total Monitored or with Coworker Monitor	No. on Routine Bioassay
1989	17	17	N/A[a]	17	15
1990	64	63	1	64	61
1991	11	11	N/A	11	10
1992	63	60	3	63	57
1993	12	12	0	12	10
1994	49	46	3	49	42
1995	16	13	3	16	11
Total (All Years)	232	222	10	232	206

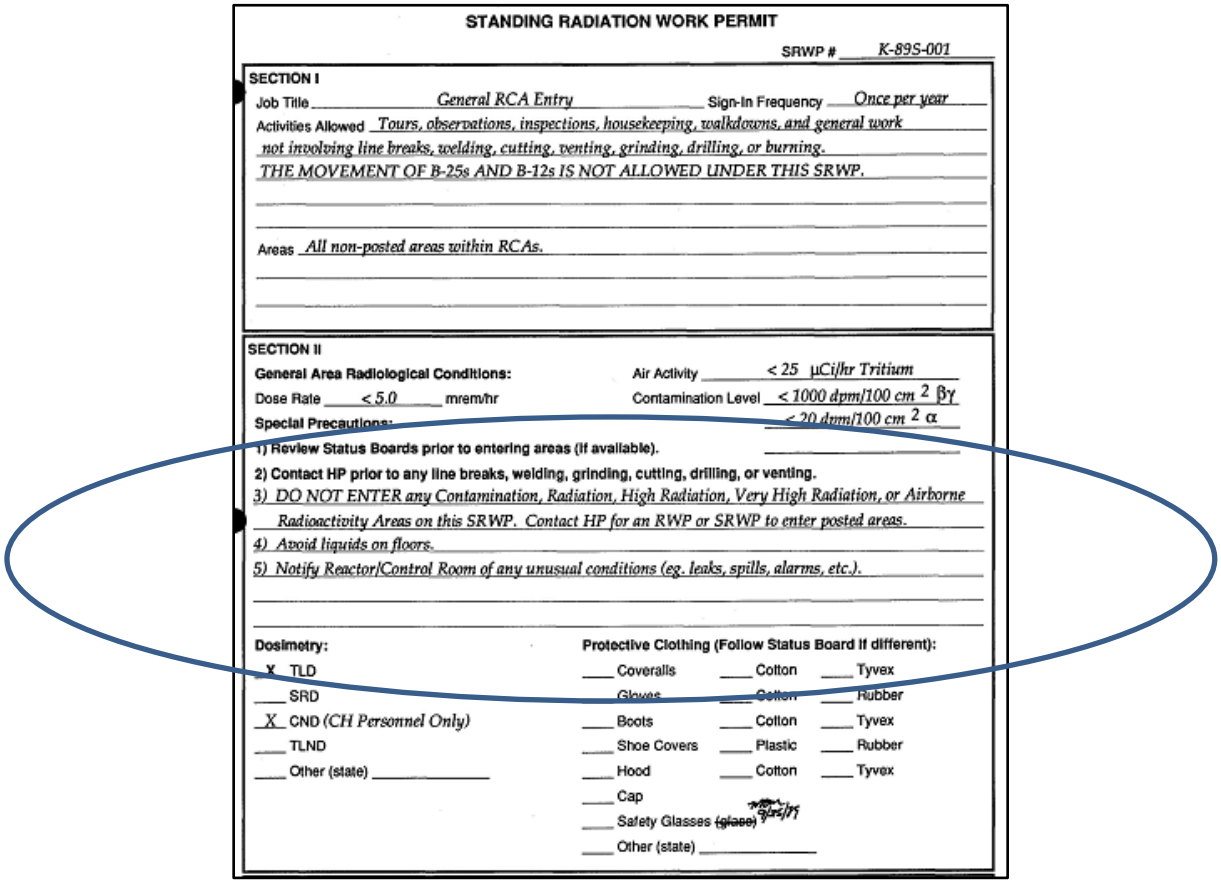
a. N/A = Not applicable.

While NIOSH agrees that the use of 30- and 90-day criteria are appropriate for tritium bioassay, annual monitoring was usually the requirement for non-tritium (actinide samples); thus, SC&A excluded a significant number of monitored subcontractors from their analysis and indicated they were not monitored when, in fact, they were monitored.

NIOSH Issue 1: *Bioassay data should have been separated into tritium and non-tritium and appropriate time intervals used for evaluation.*

Standing Radiation Work Permit

Some of the workers selected by SC&A for analysis performed tasks under a Standing (long-term) Radiation Work Permit (Fitzgerald, 2017). SRWPs were issued to cover routine work, tours, observations, inspections, housekeeping, walkthroughs, supervisory duties, and general work not involving line breaks, welding or cutting, venting, grinding, drilling, or burning. These permits prescribed general work requirements and worker protection. Figure 3 shows a redacted example of such a permit, SRWP# K-89S-001, for work performed at K Reactor area. Although some workers listed on an SRWP may have been on the routine bioassay program, work instances on an SWRP should have not have been included in the evaluation. The SWRP clearly states that workers were not to enter Airborne Radioactivity Areas or Contamination Areas. Thus, there was no potential for internal exposure.



STANDING RADIATION WORK PERMIT

SRWP # K-89S-001

SECTION I

Job Title: General RCA Entry — Sign-In Frequency: Once per year

Activities Allowed: Tours, observations, inspections, housekeeping, walkdowns, and general work not involving line breaks, welding, cutting, venting, grinding, drilling, or burning.

THE MOVEMENT OF B-25s AND B-12s IS NOT ALLOWED UNDER THIS SRWP.

Areas: All non-posted areas within RCAs.

SECTION II

General Area Radiological Conditions:

Dose Rate: < 5.0 mrem/hr

Air Activity: < 25 µCi/hr Tritium

Contamination Level: < 1000 dpm/100 cm 2 βγ

< 20 dpm/100 cm 2 α

Special Precautions:

1) Review Status Boards prior to entering areas (if available).

2) Contact HP prior to any line breaks, welding, grinding, cutting, drilling, or venting.

3) DO NOT ENTER any Contamination, Radiation, High Radiation, Very High Radiation, or Airborne Radioactivity Areas on this SRWP. Contact HP for an RWP or SRWP to enter posted areas.

4) Avoid liquids on floors.

5) Notify Reactor/Control Room of any unusual conditions (eg. leaks, spills, alarms, etc.).

Dosimetry:

X TLD
___ SRD
X CND (CH Personnel Only)
___ TLND
___ Other (state) _____

Protective Clothing (Follow Status Board if different):

___ Coveralls	___ Cotton	___ Tyvex
___ Gloves	___ Cotton	___ Rubber
___ Boots	___ Cotton	___ Tyvex
___ Shoe Covers	___ Plastic	___ Rubber
___ Hood	___ Cotton	___ Tyvex

___ Cap
___ Safety Glasses (glass)
___ Other (state) _____

Figure 3. Example of an SRS Standing Radiation Work Permit

NIOSH Issue 2: *Some Standing RWPs (SRWPs) should have been excluded from analysis.*

NOTICE OF VIOLATION OF MISSED JOB-SPECIFIC BIOASSAY SAMPLES

In their review, SC&A stated that a "*chronic history of wide noncompliance with job-specific bioassay requirements existed at SRS, resulting in a Departmental Notice of Violation being levied in 1998.*" They indicate that this primarily effects subcontractors.

The NOV was applied as a result of worker non-participation in the job-specific bioassay program. As shown above, the job-specific bioassay program consisted of SRS and subcontracted CTWs as well as SRS operations workers. The non-participation appears random from a review of names identified on the RWPs and bioassay results held by NIOSH. A majority of CTWs were on the routine bioassay program, which was not part of the NOV and, as shown below, had full compliance and participation. The job-specific bioassay program formed a portion of the overall bioassay program and was part of a "Defense in Depth" strategy.

In a May 1997 self-assessment, SRS found that while all workers were complying with the routine bioassay program, many were not following through by providing job-specific bioassay samples. SRS determined that the issue of worker non-participation in the job-specific bioassay program was a potential noncompliance with the Price-Anderson Amendments Act. This was reported into the Noncompliance Tracking System (NTS) on December 10, 1997, with a Corrective Action Report issued on December 8th, followed by a formal root cause determination completed in January 1998. An off-normal occurrence was entered into DOE's Occurrence Reporting and Processing System (ORPS) on December 18, 1997 (DOE ORPS, 1998).

On September 21, 1998, the Department of Energy (DOE) issued a preliminary NOV (NTS-SR-SRS-ESH-1997-0001) to Westinghouse Savannah River Company. The NOV was for a violation of 10 C.F.R. 830 and was titled "Inadequate Bioassay Program Participation" (Brush, 1998). The NOV text described several issues related to workers following through with required job-specific bioassays, specifically that work was not performed in accordance with Procedure 5Q1.1-504, RWP, in that:

> *…from January 1, 1996, to September 30, 1997, procedural requirements were not adhered to in that: (1) workers signed-in on RWPs without adhering to RWP requirements for bioassay (i.e., workers failed to submit bioassay samples as required); (2) site management did not hold workers and the work group supervisors accountable for worker submission of RWP required bioassay samples; (3) the names and social security numbers of workers required to submit RWP, job-specific bioassay samples were not documented and the Bioassay Customer representative was not notified for purposes of sample tracking; and (4) bioassay requirements were not always identified on RWPs as required.*

The NOV stated that work was not being performed in accordance with Procedure 5Q1.1-506, *In Vivo* and *In Vitro* Bioassay Scheduling and Administration, in that:

> *…between January 1, 1996, and September 20, 1997, SRS Facility Evaluation Board reports identified that (1) workers were on incorrect bioassay programs, as identified by their RQB and consequently did not submit job-specific bioassay samples as required; (2) line management did not always ensure that new employees were placed on the correct bioassay schedule, the Bioassay Schedule Report was not always provided to line management for accuracy review, and job-specific bioassay sampling requirements were not always identified on RWPs; and (3) bioassay assignments were not always reviewed when personnel received an annual whole body count.*

This violation was cited as a Severity Level II problem. DOE fined SRS a civil penalty of $37,500 for failing to meet 10 C.F.R. 830.120(c)(2)(i), Work Processes (Findley 1998).

Item 1 above described a disconnect between the information in the database used by the analytical laboratory to perform routine bioassay samples, HPRED, and the information on their radiation qualification badges (RQB), which were used to trigger job-specific bioassays. The site had found that, for a few workers, the information on their RQB did not match the information in HPRED. Figure 4 shows an RQB from 1994 with the bioassay code "PU-02 EU-02 SR-01" indicating a routine bioassay for plutonium on a two-year schedule, enriched uranium on a two-year schedule, and strontium on a yearly schedule.

On February 19, 1998, SRS sent 4000 form letters to every site employee and subcontractor currently on a routine bioassay program asking them to compare the bioassay codes on their RQB and those listed in the letter. Less than 100 discrepancies were identified (< 2.5%) (Morgan, 1998, PDF p. 49).

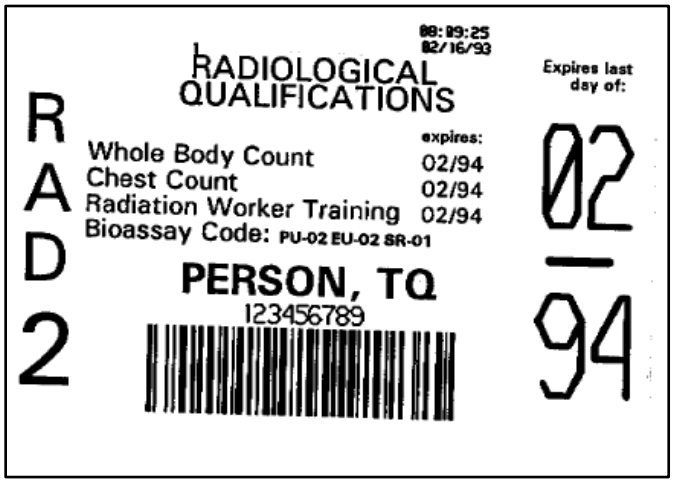


Figure 4. Generic Example of a 1994 Radiation Qualification Badge

During one assessment in 1995, SRS determined that 23% of the workers evaluated had not provided samples as requested under the job-specific bioassay program (Brush, 1998). The NOV also stated:

> *Contrary to the above, processes to detect and prevent quality problems were not adequately established and implemented and corrective actions did not prevent recurrence in that in November 1995, DOE identified to SRS that radiation work permit-prescribed bioassay sampling requirements were not effectively implemented in that 23 percent of workers did not submit bioassay samples as required. Corrective actions were implemented by SRS. However, the corrective actions were not effective to prevent recurrence in that non-participation by radiation workers in the job-specific portion of the bioassay program continued through 1996 and increased to a level of non-participation of 79 percent by the second quarter of 1997.*

This was also a Severity Level II problem and DOE fined SRS an additional $37,000 for failing to meet 10 C.F.R. 830.120(c)(1)(iii), Quality Improvement (Findley, 1998).

A May 1997 self-assessment found that, out of a total 3,200 samples requested during first four months of 1997, 107 bioassay samples were not provided by workers (DOE ORPS, 1998, PDF p. 3). Of the 3,200 samples requested, 5% were for job-specific requirements, as required on the job's RWP; the remainder were routine bioassay samples. Participation for routine samples was found to be 100%. The 107 missing samples were all requested for job-specific requirements and indicated a 66% non-participation rate for job-specific bioassay samples or approximately 3% of all bioassay samples. The overall participation rate for the first four months of 1997 was approximately 97%.

A follow-up assessment in September 1997 found non-participation for job-specific samples to be at about 79% for the second quarter of 1997. After a series of actions, including management briefings, a review of the bioassay samples requested in October found only 14% to be outstanding as of December 8, 1997, and those were "being actively tracked." The site identified 256 workers who did not supply samples as requested in 1997, all under the job-specific program. All of these workers provided samples in 1998 and none were identified to have any uptakes.

In ORAUT-RPRT-0083, NIOSH reported that 68% of the subCTW evaluated for that report were directly monitored by bioassay, and that 92% of the evaluated subCTW have either direct monitoring data or a coworker on the same RWP who was directly monitored by bioassay. Figure 5 shows percentages of bioassay participation reported by NIOSH for the 1980s, and SC&A and SRS in the 1990s. In the histogram, the data for the years between 1981 and 1986 are taken from ORAUT-RPRT-0083. The data for the years 1989 through 1995 are from SC&A's report. The data for 1996 and 1997 reflect the percentage of participation in the Job-Specific bioassay program, as reported by SRS in their response to the NOV.

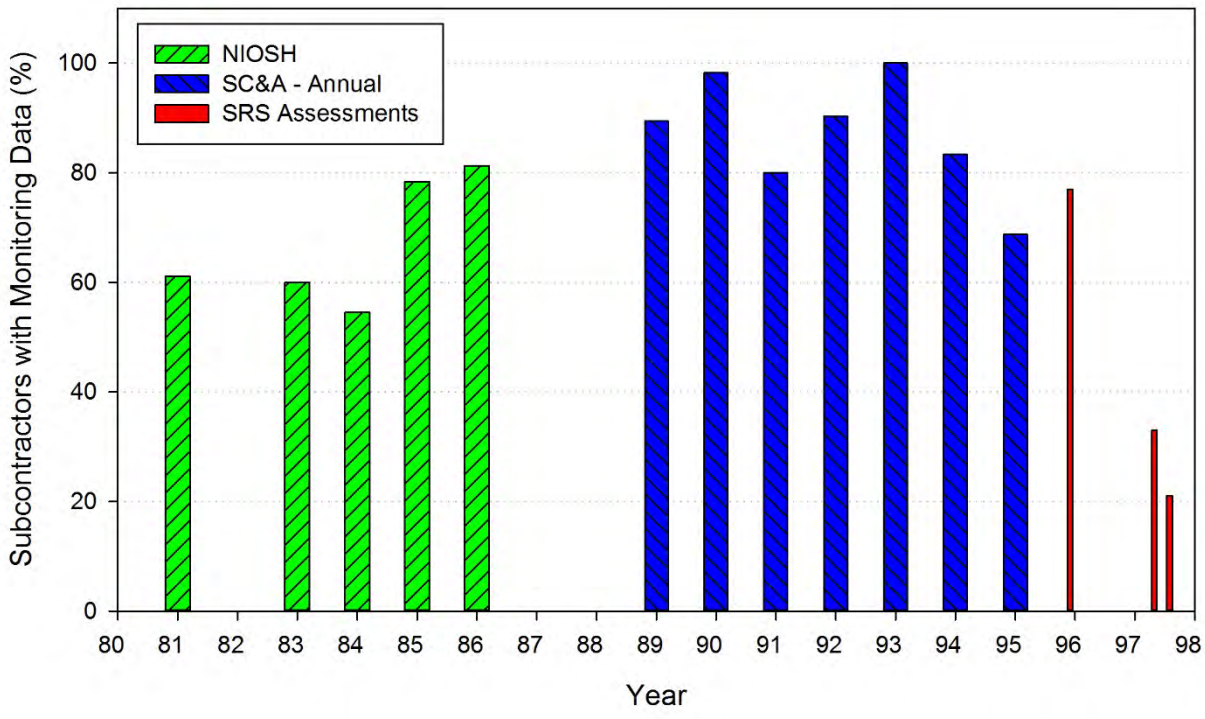


Figure 5. Percentage of Identified Subcontractors with Monitoring Data

On July 28, 1998, after communicating the issues to DOE (but prior to any enforcement actions), SRS management and staff conferred with DOE to discuss the identified issues. The NOV was not a violation of 10 C.F.R. 835. If workers had *not* been monitored properly for radiation exposure, the site would have been in violation of 10 C.F.R. 835.401(a)(1) Monitoring of the Workplace and/or 10 C.F.R.835.402(c)(1) Individual Monitoring.

Requirements for 10 C.F.R. 835.401(a)(1) Monitoring of the Workplace were stated as:

(a) Monitoring of individuals and areas shall be performed to:
(1) Demonstrate compliance with the regulations in this part;
(2) Document radiological conditions in the workplace;
(3) Detect changes in radiological conditions;
(4) Detect the gradual buildup of radioactive material in the workplace;
(5) Verify the effectiveness of engineering and process controls in containing radioactive material and reducing radiation exposure.
(b) Area monitoring in the workplace shall be routinely performed, as necessary, to identify and control potential sources of personnel exposure to radiation and/or radioactive material.

The requirements under 10 C.F.R. 835.402(c)(1) Individual Monitoring were:

> *(c) For the purpose of monitoring individual exposures to internal radiation, internal dose evaluation programs (including routine bioassay programs) shall be conducted for: (1) Radiological workers who, under typical conditions, are likely to receive 0.1 rem (0.001 Sievert) or more committed effective dose equivalent, and/or 5 rems (0.05 Sievert) or more committed dose equivalent to any organ or tissue, from all occupational radionuclide intakes in a year.*

The contemporary DOE Standard, *Guide of Good Practices for Occupational Radiological Protection in Plutonium Facilities, DOE-STD-1128-98* (DOE Standard, 1998, PDF pp. 149-150) states:

> *Workers who are considered likely to have intakes resulting in excess of 100-mrem CEDE are required to participate in a bioassay program. However, because of the extensive radiological control practices for plutonium facilities, including a high degree of engineered barrier containment, no typical plutonium worker is likely to have intakes of 100-mrem CEDE or more. However, this should not be used as an excuse to exclude workers from routine bioassay. Although no one should be considered likely to have intakes resulting in 100-mrem CEDE, some workers are at significantly higher risk for incurring an intake than others and should be on routine bioassay.*

This standard indicates that workers at a higher risk should be on a routine bioassay program. The standard was issued in 1998 (DOE Standard, 1998), reaffirmed in May 2003 (DOE Standard, 2003), and reaffirmed again with some small changes in February 2005 (DOE Standard, 2005). It remains the standard practice for plutonium sites today.

DOE did not assess any penalties or violation under 10 C.F.R. 835 against the site. No SRS workers were considered likely to exceed 0.1 rem. However, SRS included workers in "closest contact with radioactive materials in the routine bioassay program, including operators, maintenance, and health physics personnel" (DOE Standard, 1998, PDF p. 150).

In a July 28, 1998 meeting with DOE, SRS stated it had a formal no-intake policy for radionuclides, other than tritium. That policy, along with its formalized workplace indicators program (including air sampling and contamination surveys) were the primary means of determining whether a worker required bioassay sampling outside the routine bioassay program. For these cases, special bioassay sampling was performed. The bioassay program was part of an overall strategy described as "Defense in Depth" and included the zero-intake policy, engineered and procedural controls, personnel protective equipment, and surveillance. This surveillance included air monitoring, facility and personnel contamination surveys, and the routine bioassay program. The bioassay program was used to verify the effectiveness of the controls in place (Labone, 1997).

The routine bioassay program was a check of the effectiveness of the controls and was a trigger for special or "for-cause" bioassay samples. Routine actinide bioassay samples were requested from "workers who have a reasonable potential for intakes but who we are confident did not have intakes in excess of 2% of a stochastic annual limit on intake" (Labone, 1997). At the July 28, 1998 conference with DOE, SRS stated that "the workers themselves were the last line of defense in the workplace indicator program, which was the reason why a confirmatory program for workers was conducted" (Brush, 1998).

In their root cause analysis, SRS identified several causes for non-participation in the job-specific bioassay program. In their Root Cause Analysis Corrective Action Report (Morgan, 1998), they illustrated the expected existing process and actual process as two flow charts, shown below as Figures 6 and 7.

This figure is a flow chart with two main paths. One path shows the steps expected for workers providing a routine bioassay sample. The other path shows steps for a job-specific sample. Both have branches leading to a Delinquency Tracking system and all paths terminate at Sample Received.

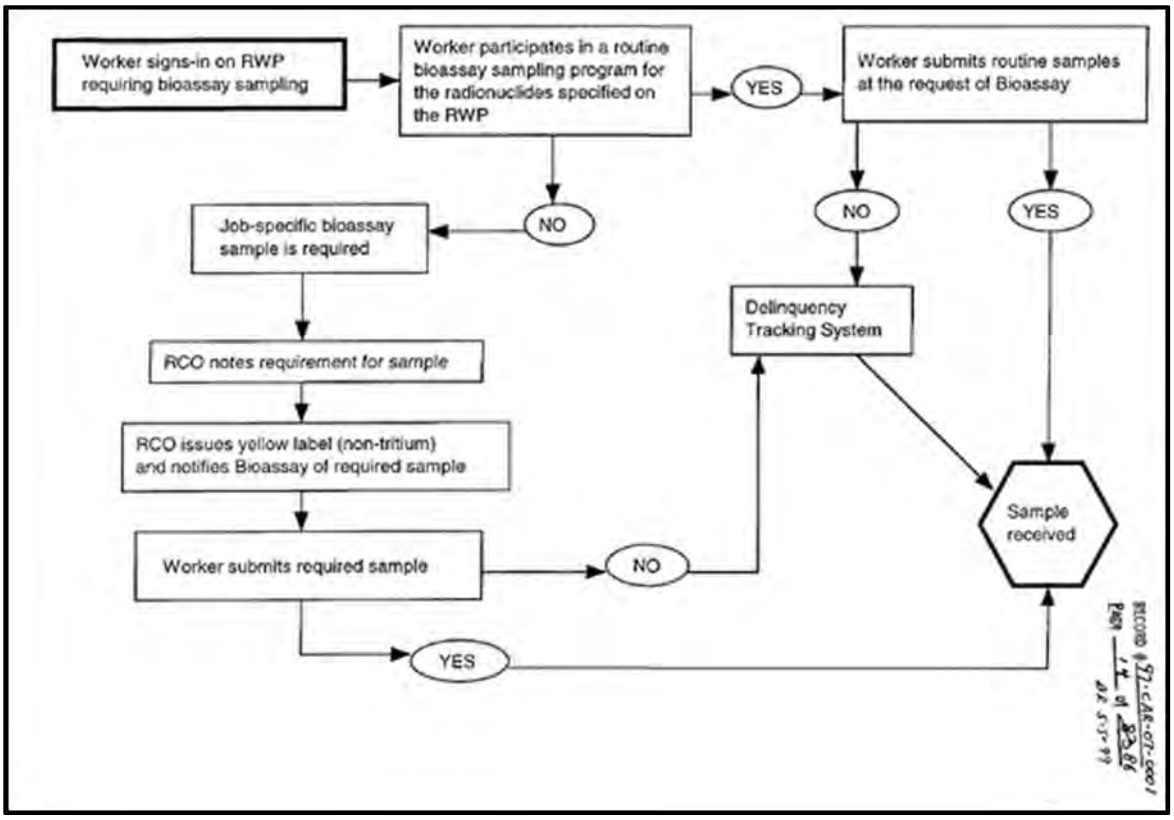


Figure 6. Existing Process, Expected, Attachment 1 to Root Cause Analysis Corrective Action Report

This process for job-specific bioassay samples was described as:

> *The purpose of the job-specific bioassay sampling program is to collect bioassay samples from workers whose routine bioassay program does not include some or all of the radionuclides present at the work site or who are not on a routine program. For example, a mechanic who may be routinely sampled for plutonium and enriched uranium may be assigned to work on a neptunium system. A job-specific bioassay sample for neptunium would be required to be submitted at the end of the task.*
>
> *The job-specific bioassay requirements are specified by Radiological Control Operations (RCO) in the preparation of the Radiological Work Permit/Standing Radiological Work Permit (RWP/SRWP). It is the responsibility of the worker to review the RWP/SRWP bioassay requirements against their routine bioassay program (shown on their Radiological Qualification Badge (RQB)). If a job-specific bioassay is required, RCO is to be notified. Except for tritium, RCO issues the employee a yellow (job-specific) bioassay label, tells the employee when to submit the sample, and notifies Bioassay to enter the employee on the delinquency tracking system. For tritium, the employee uses a white (routine) label instead of a yellow label.*
>
> *When the employee submits the sample, it is logged into the database to clear the record. If the employee fails to submit a sample, an escalating series of corrective actions are initiated which may result in suspending an employee's qualification to work in radiological areas.* (DOE ORPS, 1998)

The yellow and white labels were submitted to the laboratory to indicate analyses to be performed in addition to the routine analyses listed for the worker in HPRED.

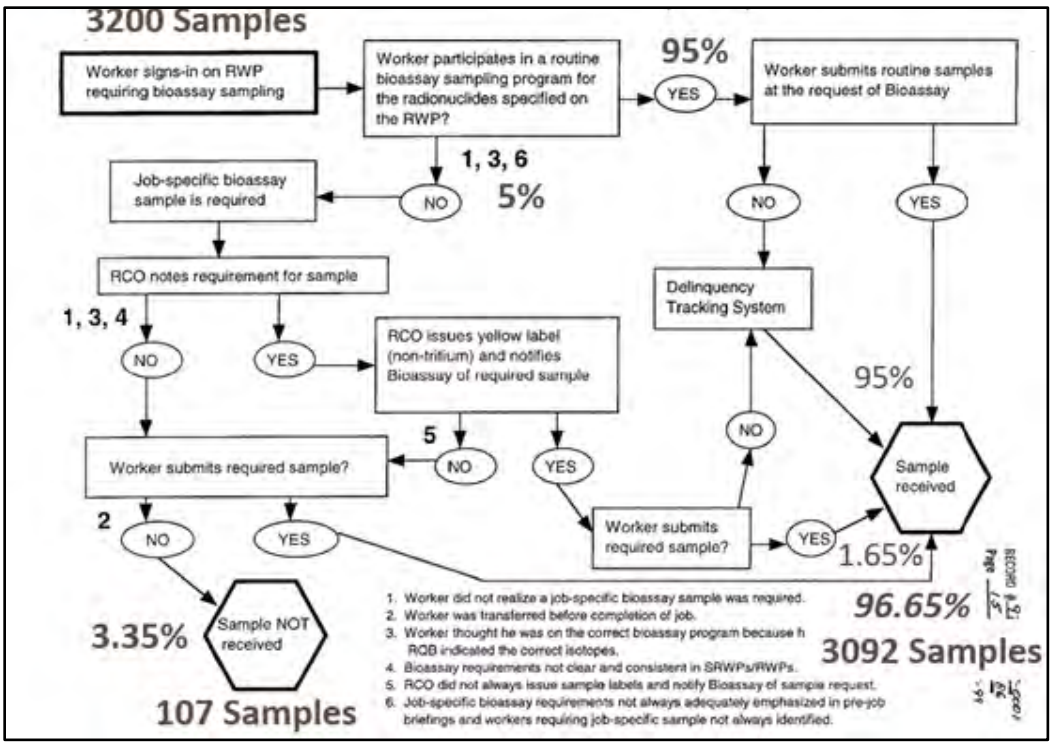


Figure 7. Attachment 2 to Root Cause Analysis Corrective Action Report, Expected Process, Actual with Added Text to Illustrate May 1997 Results

The results of the May 1997 self-assessment can be illustrated in this flowchart. It begins with the requested 3,200 samples; 95% of these were for routine samples and follow the path to the right and 5% follow the path on the left for job-specific samples. All of the requested routine samples were received by the analytical laboratory. For the job-specific bioassays, 3.35% or 107 of the requested samples terminated in the hexagonal node labeled "Sample NOT received." This resulted in 96.65% or 3092 samples received at the laboratory for the first four months of 1997.

This limited assessment of 3,200 requested bioassay samples found a 33% compliance rate for the job-specific samples. The follow-up assessment in September 1997 found a compliance rate of 21% for job-specific bioassay samples. The number of workers who did not provide samples in 1997 was 256.

SRS procedures held the individual worker responsible for submitting bioassay samples. For job-specific samples, they were to be told to provide them at the end of the assignment. SRS did not find any willful noncompliance with the program but identified several reasons, including:

1. Worker did not realize a job-specific sample was required.
2. Worker was transferred before completion of job.
3. Worker thought he was on the correct bioassay program because his RQB indicated the correct isotopes.
4. Bioassay requirements not clear and consistent in SWRPs/RWPs.
5. RCO (Radiological Control Operations) did not always issue sample labels and notify Bioassay of sample request.
6. Job-specific bioassay requirements not always adequately emphasized in pre-job briefings and workers requiring job-specific samples not always identified.

During the enforcement conference, SRS provided a summary of prescheduled routine actinide urine bioassay for 1996, 1997, and through mid-1998, as shown in Table 6 (Labone, 1997).

Table 6. Prescheduled Routine Actinide Urine Samples.

Criteria	1996 Results	1997 Results	1998 Results Through Mid-July
Number Requested	8,132	9,389	5,251
Number Received	8,062	9,053	4,864
Percent Received	99.1%	96.4%	92.6%
Number Initially Positive	79	105	82
Number Confirmed Intakes	2	2	0
Percent Confirmed Intakes	0.025%	0.022%	0%

Approximately 1,500 job-specific routine actinide samples were also collected in 1997, and 564 samples through the first half of 1998 with no positive results or intakes (see Table 7). The number of job-specific actinide samples for 1996 is not available and is not included in the sum of samples. For all of 1996, 1997, and through mid-July 1998, there were only four confirmed intakes out of approximately 24,800 routine and job-specific actinide urine samples.

Table 7. Job-Specific Actinide Urine Samples.

Criteria	1997 Results	1998 Results Through Mid-July
Number Requested	1,500 (approximately)	564
Number Positive	0	0
Number Confirmed Intakes	0	0

Special actinide samples were collected for cause, that is, only when there was a significant potential for an intake or when an intake was likely. Sampling was required under 10 C.F.R. 835.402(c)1 when an intake was expected to exceed 100 mrem under typical conditions. Special actinide samples were individually tracked by an SRS internal dosimetrist and used to assess dose. SRS provided a numerical summary of special actinide urine bioassay for 1996, 1997, and through mid-July 1998, as shown in Table 8. For all of 1996, 1997, and 1998 through mid-May, a total of 483 samples were requested and all were submitted and analyzed. Although all samples were collected for cases where exposures were expected to be possible only 12 samples or 2.4% of the Special Actinide urine samples resulted in confirmed intakes with only 8 of those or 1.6% resulting in intakes greater than 100 millirem CEDE. (LaBone, 1997).

Table 8. Special Actinide Urine Samples.

Criteria	1996 Results	1997 Results	1998 Results Through Mid-July
Number Requested	34	249	100
Number Received	34	249	100
Percent Received	100%	100%	100%
Number Confirmed Intakes	9	3	0
Percent Confirmed Intakes	6.7%	1.2%	0%
Number > 100 mrem	6	2	0

Implications for Dose Reconstruction

NIOSH respectfully disagrees with SC&A's conclusion that this NOV would prohibit dose reconstruction of subcontractor construction trades workers.

The NOV concerned the job-specific bioassay sampling solely and did not indicate any failure of the routine bioassay sampling or special bioassay sampling. The greatest bulk of bioassay samples at SRS during this time were for the prescheduled routine samples. Routine or prescheduled bioassay monitoring was the primary method of surveillance, as indicated by the large number of workers on routine bioassay compared to job-specific bioassay. The job-specific bioassay sampling was performed to verify the adequacy of workplace and worker protections and was a subset of the total surveillance program.

All workers who failed to provide bioassay samples under the job-specific program in 1997 were resampled and found to have no detectable intakes. In addition, the site evaluated the potential for those who may be missing samples in 1996 and concluded that they did not have a potential for intake exceeding 100 millirem CEDE (Brush, 1998).

The number of intakes at the site is very low (less than 0.1%) in this time period. In the ORPS report, SRS stated that:

> *To date, there is no evidence that workers have received an intake that has previously gone undetected due to the problems identified above. Dose is not assigned by job-specific bioassays. Radiological controls at SRS exist to monitor levels of radiation, contamination, and airborne radioactivity. If unanticipated elevated levels are measured, work is stopped until corrective action is taken. Any concern that a worker intake of radioactive material may have occurred is assessed as part of the special bioassay program* (DOE ORPS, 1998).

The DOE agreed that workers were adequately monitored; the NOV described failures of management oversight and of the application of established procedures under 10 C.F.R. 830 rather than under 10 C.F.R. 835, which would have indicated a failure of the site's ability to estimate worker exposures. The DOE acknowledged that the site operated a rigorous radiological control program. In a September 21, 1998 letter to SRS (Brush, 1998), the DOE stated:

> *DOE is aware that, for all radionuclides other than tritium, the SRS internal dosimetry program does not knowingly permit any worker to be exposed to airborne radioactive material. Further, it is noted that SRS has implemented a rigorous program for the comprehensive use of field indicators during work activities to signal that an unexpected radiological condition may have led to potential occupational intakes of radioactive material by a worker. Nonetheless, DOE also appreciates that the potential exists to overlook worker exposures to radioactive material due to unrecognized field conditions or other types of personnel error.*

With the follow-up sampling of the 256 workers conducted by the site, there are **no** missing bioassay in 1997 regardless of the initial 66% non-participation rate under the "limited assessment" and 79% nonparticipation rate under the "full assessment." There is **no** effect on the coworker model for 1997 because all of the worker data has been collected and evaluated. The site evaluated the potential for those who may be missing samples in 1996 and concluded that they did not have a potential for intake (Brush, 1998).

SC&A has not demonstrated that subcontractors were primarily or only monitored via job-specific bioassay that would bias a coworker model. The NOV affects both CTWs (SRS and Subcontractor) as well as operations workers (SRS) on the job-specific bioassay program. Significant workplace and individual monitoring information, including over 10,000 bioassay samples in 1997, supports the conclusion that there is no evidence of a workplace exposure nor an indication that there was a missed radionuclide intake at SRS.

NIOSH Issue 3: *The Notice of Violation applied only to RWP job-specific bioassay samples which were not required by regulation and were only one part of an overall worker protection program.*

The NOV was applied due to procedural failures under 10 C.F.R. 830. No workers were likely to exceed 100 millirem CEDE so bioassay monitoring was not required under DOE rules or by the Guide of Good Practices for Occupational Radiological Protection in Plutonium Facilities; DOE did not assess any violations under 10 C.F.R. 835. The job-specific bioassay sampling was

performed to verify the adequacy of workplace and worker protections. All workers who did not provide job-specific bioassay samples in 1997 were identified, samples were provided, and none resulted in identifiable intakes.

CONCLUSION

With respect to using routine prescheduled and job-specific bioassay to generate coworker distributions, the degree and direction of potential bias generated in a coworker model by missing samples is more important than the number of samples that were requested but not provided. Missing routine job-specific samples do not automatically invalidate the radiation protection program at SRS and do not automatically render the vast amounts of available monitoring data worthless in the context of generating a coworker model.

At SRS, routine urine bioassay was used to confirm adequacy of workplace monitoring and worker protection programs and consisted of prescheduled and job-specific sampling. A majority of workers, including subCTW, were on prescheduled urine bioassay. NIOSH evaluated bioassay for SRS workers identified by SC&A and found that almost 96% of the subCTW were monitored by personal bioassay on a timely basis, with over 88% of those being on routine prescheduled bioassay for actinides (see Table 4). Workers not leaving samples appear to be random (i.e., showing no apparent pattern). NIOSH identified coworkers on same RWP for another 8% of the workers identified by SC&A. Ninety-eight percent of the subcontractors evaluated in the SC&A report are covered by bioassay.

The NOV issued by the DOE was specific to the job-specific sampling portion of the routine bioassay program. The DOE concluded that SRS was not in violation of 10 C.F.R. 835 and found that calculation of doses to site workers was not impacted by the failure of some workers to leave bioassay samples. For the first four months of 1997, workers failed to leave some job-specific samples that accounted for about 3% of the total requested routine bioassay samples. All 256 of the workers who failed to leave job-specific samples in 1997 were subsequently sampled and found to have no identifiable uptakes. SRS collected 9,389 routine urine actinide bioassay samples in 1997 with two confirmed intakes, and approximately 1,500 job-specific samples, none of which had confirmed intakes. SRS collected over 25,000 urine tritium samples in 1996 and 24,000 urine tritium samples in 1997, with the highest cumulative worker dose of 52 mrem in 1996, and 41 mrem in 1997. It is highly implausible that the results of a small percentage of all routine urine samples would impact range and distribution of the bioassay results provided by SRS and held by NIOSH. For all results in 1996, 1997, and the first half of 1998, the fraction of actinide bioassay samples that resulted in a confirmed intake was less than 0.1%.

NIOSH therefore concludes that dose reconstruction is feasible and sufficiently accurate through the use of a coworker model. NIOSH identified the following issues.

NIOSH Issue 1: *Bioassay data should have been separated into tritium and non-tritium and appropriate time intervals used for evaluation.*

NIOSH Issue 2: *Some Standing RWPs (SRWPs) should have been excluded from analysis.*

NIOSH Issue 3: *The Notice of Violation applied only to RWP job-specific bioassay samples which were not required by regulation and were only one part of an overall worker protection program.*

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ATTACHMENT A

Table A-1. Detail of Tritium SubCTW with Tritium Bioassay.

Worker No.	Job Date	Bioassay Date	No. of Days Post Job
1	6/5/1990	6/7/1990	2
3	11/17/1990	11/19/1990	2
6	10/18/1990	10/18/1990	0
7	11/3/1990	11/3/1990	0
8	11/3/1990	11/3/1990	0
9	10/30/1990	10/30/1990	0
10	10/30/1990	10/30/1990	0
11	10/30/1990	10/30/1990	0
12	10/30/1990	10/30/1990	0
13	10/30/1990	10/30/1990	0
14	10/30/1990	10/30/1990	0
15	11/30/1990	11/30/1990	0
16	11/30/1990	11/30/1990	0
17	12/21/1990	12/26/1990	5
18	11/30/1990	11/30/1990	0
19	11/30/1990	12/7/1990	7
20	12/21/1990	12/21/1990	0
21	12/21/1990	12/21/1990	0
22	11/30/1990	12/1/1990	1
23	11/30/1990	11/30/1990	0
29	10/15/1989	10/16/1989	1
30	10/15/1989	11/21/1989	37
32	10/15/1989	11/1/1989	17
34	11/15/1989	11/22/1989	7
35	10/15/1989	10/27/1989	12
36	10/15/1989	10/18/1989	3
39	11/28/1990	11/30/1990	2
40	11/28/1990	11/29/1990	1
41	11/28/1990	12/10/1990	12
42	11/28/1990	1/2/1991	35
43	11/29/1990	12/3/1990	4
44	11/29/1990	12/4/1990	5
45	11/28/1990	11/29/1990	1
46	11/14/1990	12/7/1990	23

Worker No.	Job Date	Bioassay Date	No. of Days Post Job
48	11/28/1990	12/4/1990	6
50	11/28/1990	11/28/1990	0
51	12/21/1990	12/27/1990	6
52	11/20/1990	11/27/1990	7
53	11/20/1990	11/20/1990	0
54	11/20/1990	12/6/1990	16
55	11/20/1990	1/17/1991	58
56	12/4/1990	12/4/1990	0
57	12/21/1990	12/21/1990	0
61	9/2/1990	9/2/1990	0
62	9/2/1990	9/2/1990	0
63	8/31/1990	9/25/1990	25
64	8/31/1990	8/31/1990	0
65	8/31/1990	8/31/1990	0
68	8/31/1990	8/31/1990	0
69	8/31/1990	8/31/1990	0
70	8/31/1990	9/3/1990	3
71	8/31/1990	9/17/1990	17
72	8/31/1990	9/7/1990	7
74	6/15/1989	6/16/1989	1
75	6/15/1989	7/13/1989	28
76	1/27/1990	1/27/1990	0
77	1/22/1990	1/22/1990	0
78	1/3/1990	1/3/1990	0
79	1/3/1990	1/3/1990	0
80	2/11/1990	2/12/1990	1
82	1/31/1990	2/5/1990	5
83	1/29/1990	1/30/1990	1
84	1/29/1990	2/3/1990	5
85	1/29/1990	None[a]	N/A[b]
86	1/29/1990	1/30/1990	1
87	1/29/1990	2/1/1990	3
169	11/15/1989	11/30/1989	15
170	10/15/1989	11/10/1989	26
171	9/28/1989	9/28/1989	0
172	10/15/1989	10/20/1989	5

Worker No.	Job Date	Bioassay Date	No. of Days Post Job
173	10/15/1989	10/20/1989	5
175	10/15/1989	11/9/1989	25
176	11/15/1989	11/20/1989	5
177	10/15/1989	10/20/1989	5
178	11/15/1989	11/18/1989	3
213	7/23/1990	7/23/1990	0
214	3/21/1994	3/24/1994	3
215	5/30/1994	5/30/1994	0
216	6/29/1994	7/28/1994	29
217	6/15/1991	6/17/1991	2
218	6/15/1991	6/17/1991	2
219	6/15/1991	6/17/1991	2
220	6/15/1991	6/21/1991	6
221	6/15/1991	6/21/1991	6
222	4/20/1991	4/24/1991	4
223	6/15/1991	6/17/1991	2
224	6/30/1991	7/2/1991	2
225	6/30/1991	7/29/1991	29
226	6/15/1991	6/18/1991	3
227	6/15/1991	6/16/1991	1
228	11/8/1990	11/15/1990	7
229	11/8/1990	11/9/1990	1
230	11/8/1990	11/14/1990	6
231	10/5/1990	10/5/1990	0
232	10/4/1990	10/4/1990	0
238	6/22/1994	7/28/1994	36
239	6/22/1994	7/6/1994	14
240	6/3/1994	6/3/1994	0
241	6/3/1994	6/3/1994	0
242	9/1/1994	10/7/1994	36
243	6/28/1994	7/5/1994	7
244	8/22/1994	10/3/1994	42
245	8/22/1994	8/31/1994	9
248	8/11/1994	8/11/1994	0
249	8/11/1994	8/11/1994	0
250	8/11/1994	8/11/1994	0

Worker No.	Job Date	Bioassay Date	No. of Days Post Job
251	8/18/1994	8/18/1994	0
252	8/19/1994	8/19/1994	0
253	8/19/1994	8/22/1994	3
254	8/19/1994	8/24/1994	5
255	8/29/1994	None	N/A
256	10/11/1994	11/16/1994	36
257	1/5/1995	1/5/1995	0
258	1/5/1995	1/5/1995	0
259	1/5/1995	1/5/1995	0
260	9/7/1995	11/16/1995	70
261	9/7/1995	None	N/A
262	9/7/1995	None	N/A
264	2/1/1995	2/1/1995	0
265	10/9/1995	10/11/1995	2
266	11/28/1995	1/3/1996	37
267	11/27/1995	11/27/1995	0
268	2/14/1995	2/28/1995	14
269	2/1/1995	2/1/1995	0
270	5/4/1995	None	N/A
271	1/3/1995	1/3/1995	0
272	1/3/1995	1/5/1995	2
273	3/7/1995	3/7/1995	0

a. None indicates that no bioassay results were found for the period.
b. N/A = Not applicable.

ATTACHMENT B

Table B-1. Detail of Non-tritium SubCTW with Plutonium/Enriched Uranium Bioassay.

Worker No.	Job Date	Bioassay Date	No. of Days Post Job
89	3/1/1993	8/16/1993	168
90	3/3/1993	5/10/1995	798
93	3/3/1993	6/7/1993	96
95	3/16/1993	5/20/1993	65
96	3/16/1993	9/16/1993	184
97	3/16/1993	1/20/1994	310
98	3/25/1992	8/9/1994	867
99	3/25/1992	8/7/1992	135
100	3/27/1992	2/11/1993	321
101	3/27/1992	None[a]	N/A[b]
102	3/27/1992	4/24/1992	28
103	3/25/1992	4/28/1992	34
104	3/25/1992	4/24/1992	30
105	3/25/1992	7/21/1992	0
106	3/25/1992	5/19/1992	55
107	3/25/1992	6/8/1992	75
112	5/22/1992	6/5/1992	14
113	8/12/1992	9/8/1992	27
114	6/12/1992	12/3/1992	174
115	8/12/1992	5/3/1993	264
116	8/12/1992	11/7/1992	87
117	8/12/1992	9/9/1992	28
118	8/12/1992	None	N/A
119	8/10/1992	8/10/1992	0
120	8/10/1992	7/7/1993	331
121	8/11/1992	4/6/1993	238
122	8/14/1992	10/13/1992	60
123	8/13/1992	1/22/1993	162

Worker No.	Job Date	Bioassay Date	No. of Days Post Job
124	8/13/1992	11/11/1992	90
125	8/14/1992	11/10/1992	88
126	8/14/1992	12/2/1992	110
127	8/14/1992	8/22/1992	8
128	8/14/1992	3/9/1993	207
129	8/18/1992	12/10/1992	114
130	8/18/1992	11/6/1992	80
131	8/18/1992	8/20/1992	2
132	8/18/1992	2/8/1993	174
133	8/18/1992	None	N/A
134	8/18/1992	9/9/1992	22
135	8/11/1992	12/14/1992	125
136	6/2/1992	11/10/1992	161
137	5/22/1992	6/29/1992	38
138	5/22/1992	7/20/1992	59
139	5/22/1992	6/8/1992	17
140	5/22/1992	7/15/1992	54
141	5/22/1992	7/19/1992	58
143	5/22/1992	7/17/1992	56
144	5/22/1992	7/16/1992	55
145	5/22/1992	7/29/1992	68
146	5/22/1992	7/20/1992	59
147	5/18/1992	6/8/1992	21
148	5/18/1992	6/10/1992	23
149	5/18/1992	6/16/1992	29
151	5/19/1992	6/30/1992	42
152	5/19/1992	6/8/1992	20
153	5/19/1992	8/8/1992	81
154	5/19/1992	7/29/1992	71
155	5/19/1992	9/21/1992	125
156	5/19/1992	8/12/1992	85

Worker No.	Job Date	Bioassay Date	No. of Days Post Job
157	10/13/1992	2/5/1993	115
158	10/13/1992	4/7/1993	176
160	10/13/1992	11/14/1992	32
161	10/13/1992	7/7/1993	267
162	10/13/1992	1/20/1993	99
163	4/15/1993	7/19/1993	95
164	4/15/1993	11/19/1993	218
165	4/15/1993	7/13/1993	89
166	4/15/1993	10/20/1993	188
167	4/15/1993	8/16/1993	123
168	4/15/1993	5/6/1993	21
179	6/1/1994	8/7/1995	432
180	6/1/1994	10/19/1994	140
181	5/12/1994	8/24/1994	104
182	5/12/1994	6/17/1994	36
183	5/18/1994	8/10/1994	84
184	5/17/1994	6/13/1994	27
185	5/21/1994	11/14/1994	177
186	5/21/1994	None	N/A
187	6/1/1994	8/17/1994	77
189	9/21/1994	10/3/1994	12
192	5/18/1994	6/14/1994	27
193	12/12/1994	4/13/1995	122
194	12/12/1994	2/6/1996[d]	421
195	12/8/1994	4/7/1995	120
196	8/29/1994	4/17/1995	231
197	11/3/1994	10/17/1995	348
198	9/2/1994	11/3/1994	62
199	11/23/1994	12/4/1995[d]	376
200	11/23/1994	None	N/A
201	11/22/1994	4/1/1995	130

Worker No.	Job Date	Bioassay Date	No. of Days Post Job
202	11/22/1994	8/21/1997[e]	1003
203	11/22/1994	9/2/1997[e]	1015
204	3/16/1994	6/22/1994	98
206	11/22/1994	1/9/1995	48
207	6/6/1994	2/6/1995	245
208	3/24/1994	12/12/1994	263
209	5/29/1994	7/25/1994	57
210	3/29/1994	12/13/1994	259
211	4/12/1994	8/12/1994	122
233	4/7/1992	4/24/1992	17
234	4/7/1992	2/10/1993	309
235	4/7/1992	5/4/1992	27
236	4/7/1992	5/8/1992	31
237	4/8/1992	4/24/1992	16

a. None indicates that no bioassay results were found for the period.
b. N/A = Not applicable.
c. Unknown = exact date not known.
d. Bioassay is slightly beyond 1 year but a routine sample.
e. Bioassay is three years past work date though still usable for Pu dose reconstruction.

ATTACHMENT C

Detail for Coworkers with Tritium Bioassay

The expected isotopes are taken from Farrell and Findley (1999).

Year:	1989	SRWP#:	K89S-001 (Farrell and Findley, 1999)
Location:	K Area All non-posted areas within RCAs.	Isotopes:	None
Description:	General RCA Entry		
Respirator:	No		
Bioassay:	Not required		
HP Monitoring:	No		

Special Instructions:

1) Review Status Boards prior to entering areas (If available).
2) Contact HP prior to any line breaks, welding, grinding, cutting, drilling, or venting.
3) DO NOT ENTER any Contamination, Radiation, High Radiation, Very High Radiation, or Airborne Radioactivity Areas on this SRWP. Contact HP for an RWP or SRWP to enter posted areas.
4) Avoid liquids on floors.
5) Notify Reactor/Control Room of any unusual conditions (eg. leaks, spills, alarms, etc.).

Two workers (#33 and #174) were identified on this RWP without bioassay but tritium bioassay was not required.

Year: 1992
Location: 221H
Description: Upgrade Sec S for Installation of Frames
Respirator: Full-Face Respirator
Bioassay: None
HP Monitoring: Continuous
Special Instructions: None

RWP#: 92HC-229 (SRS, 1996)
Isotopes: Pu, Sr

Table C-1. RWP Worker Comparison, 1992.

Worker Number	Department	Respirator Qualified	Bioassay	WBC[a]	Date	Time In	Time Out	Time In	Time Out	Bioassay Isotope	Bioassay Date
100	Pipe	Yes	Yes	Yes	3/27/92	1700	1920	ND	ND	Pu, Sr	2/11/93
101	Pipe	Yes	Yes	Yes	3/27/92	2030	2245	ND	ND	b	ND
New-1[c]	Pipe	Yes	Yes	Yes	3/27/92	1700	1920	2030	2243	Pu, Sr	7/30/92

a. WBC = Whole Body Count.
b. Pu bioassay 10/12/95.
c. Relevant workers that were not identified in Fitzgerald (2017).

Year: 1994 SRWP#: 94-SRTC-410 (SRS, 1994)
Location: 773-A, C-001 Isotopes: Pu, Sr
Description: Construction to cut, weld on 125# streamline outside and inside C-001.
Respirator: Yes
Special Bioassay: Pu, Sr
HP Monitoring: Continuous
Special Instructions:

1) Follow all instructions from RCO personnel.
2) Modesty clothing is required.
3) Housekeeping is required prior to existing area.
4) Change-out gloves per RCO instructions.
5) Personnel must don a fresh air hood after removing plastic suit.

Table C-2. RWP Worker Comparison, 1994.

Worker Number	Bioassay	WBC[a]	Date	Time In	Time Out	Time In	Time Out	Bioassay Isotope	Bioassay Date
202	Yes	Yes	11/22/1994	2340	0245	ND	ND	Pu, Sr	8/21/1997[b]
203	Yes	Yes	11/22/1994	2340	0245	ND	ND	Pu, Sr	9/2/1997[b]
201	Yes	ND[c]	11/22/1994	2340	0245	ND	ND	Pu, Sr	8/23/1995
New-2[d]	Yes	ND	11/22/1994	2340	0245	ND	ND	Pu, Am, Sr	9/11/1995
199	Yes	Yes	11/23/1994	1200	1430	1530	1700	Pu, Sr	12/04/1995
200	No	Yes	11/23/1994	1200	1430	ND	ND	Pu, Sr	ND
187	Yes	ND	11/23/1994	1200	1430	1530	1700	Pu, Sr	8/23/1995
New-3[d]	Yes	ND	11/23/1994	1200	1500	1530	1710	Pu, Am, Sr	1/10/1995

a. WBC = Whole Body Count.
b. Bioassay is beyond 1-year interval as established in Westinghouse SRC (1990) and is treated in this report as not having bioassay for the 11/22/1994 work event.
c. ND = No Data.
d. Relevant workers that were not identified in Fitzgerald (2017).