Draft

ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

SC&A'S EVALUATION OF CS-137/SR-90 VALUES AND ACTINIDES USING INL WASTE REPORTS IN RELATIONSHIP TO ASSIGNING INTAKES

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ABBREVIATIONS AND ACRONYMS

ABRWH	Advisory Board on Radiation and Worker Health
Ac	actinium
Al	aluminum
Am	americium
ANP	Aircraft Nuclear Propulsion
ATR	Advance Test Reactor
BNL	Brookhaven National Laboratory
Ce	cerium
CFA	Central Facility Area
CFR	Code of Federal Regulations
Ci	curie
Cm	curium
Co	cobalt
CPP	Chemical Processing Plant
Cs	cesium
d	day
DR	dose reconstruction
D&D	decontamination and decommissioning
ER	evaluation report
ETR	Engineering Test Reactor
Eu	europium
FAP	fission and activation product
ICPP	Idaho Chemical Processing Plant
INEL	Idaho National Engineering Laboratory
INL	Idaho National Laboratory
liq	liquid
Meas	Measured
µCi	microcurie
µCi/ml, uCi/ml	microcurie per milliliter
MTR	Materials Testing Reactor
Nb	niobium

Np	neptunium
NIOSH	National Institute for Occupational Safety and Health
NRTS	National Reactor Testing Station
ORAUT	Oak Ridge Associated Universities Team
OTIB	Occupational Technical Information Bulletins
Pa	protactinium
PBF	Power Burst Facility
Pm	promethium
Pr	praseodymium
Pu	plutonium
Ru	ruthenium
SEC	Special Exposure Cohort
SPERT	Special Power Excursion Reactor Test
Sr	strontium
SRDB	Site Research Database
SS	stainless steel
TAN	Test Area North
Th	thorium
TKBS	Site Technical Basis Document
TRA	Test Reactor Area
U	uranium
WER	Waste Experimental Reduction
WMC	Waste Management Complex
y	year
Zr	zirconium

EXECUTIVE SUMMARY

In the National Institute for Occupational Safety and Health's (NIOSH's) evaluation report (ER) for the Idaho National Laboratory (INL) Special Exposure Cohort (SEC) petition SEC-00219 of March 12, 2015 (NIOSH 2015), one of the major assumptions was that a bioassayed indictor radionuclide [strontium-90 (Sr-90) and/or cesium-137 (Cs-137)] can be used to assign dosimetric-significant fission and activation product (FAP) and actinide (alpha emitter) intakes using the ratio method. This method requires that radionuclide ratios remain fairly constant for the many processes and locations, and over most of the operating history of INL.

In view of INL's numerous types of reactors, experimental charter, and the various fuels and materials shipped in from other sites for processing, SC&A performed a preliminary analysis of some of the available INL bioassay, Brookhaven National Laboratory (BNL) fuel, and swipe data in 2015 to obtain an indication of the validity of this assumption (SC&A 2015). As outlined in that report, SC&A found there were indications that the Cs-137/Sr-90 values were not always centered on unity. SC&A then searched for documentation of quantitative analyses of the fuel elements processed in the dissolver at the Idaho Chemical Processing Plant (ICPP) in order to determine the radionuclide components that workers may have been exposed to; however, such documentation has not been located to date. Therefore, SC&A searched the Site Research Database (SRBD) for other documents that could provide quantitative radionuclide data. During this search, SC&A located numerous INL waste reports that contained quantitative Cs-137 and Sr-90 measurements performed on the same samples (some also contained actinide analyses in the later years); these reports spanned a relatively long time period (1957–1993) for the major operational areas within INL. Quantitative radionuclide data for waste materials (air, liquid, and solid) at the INL facilities provide a good representation of the potential intake exposures to workers. Therefore, these data were analyzed in detail to evaluate if there is a reasonably consistent relationship between the Cs-137/Sr-90 concentrations, and if these indicating radionuclides could be used to assign other radionuclide intakes such as FAPs for dose reconstruction (DR) purposes. In addition, quantitative actinide data in relationship to Sr-90 and Cs-137 were analyzed when available. Data for the ICPP were not analyzed for the period 1963–1974, because this was the period of the SEC.

Cs-137/Sr-90

A total of 251 matched pairs of measured Cs-137 and Sr-90 activities were located and analyzed, spanning the period 1957–1993 for a number of major facilities at the INL site. Of these 251 matched pairs of data, 33% contained Cs-137/Sr-90 values centered on unity, within a factor of 2 (i.e., Cs-137/Sr-90 = 0.5 to 2.0). The remaining Cs-137/Sr-90 values were outside this interval, with values ranging from 0.04 to 2,587. The Cs-137/Sr-90 values are separated according the major facilities in Appendix A of this report.

Actinides/Sr-90

A total of 59 matched pairs of measured Sr-90 and an actinide [americium-241 (Am-241), plutonium-238 (Pu-238), Pu-239, uranium-234 (U-234), or U-236] activity were located and analyzed, spanning the period 1970–1995 for various facilities at the INL site. The measured actinide/Sr values were compared to the actinide/Sr values recommended in Table 5-22 of ORAUT-TKBS-0007-5, *Idaho National Laboratory and Argonne National Laboratory – West – Occupational Internal Dose*, Revision 3. A comparison ratio value centered on 1.0 would

indicate agreement between the measured and recommended values; however, ratio values not centered on unity would indicate insufficient, or excessive, actinide intake assignments during DR. Of these 59 matched pairs, 7% contained actinide/Sr values centered on unity, within a factor of 2 (i.e., actinide/Sr = 0.5 to 2.0). The remaining actinide/Sr values were outside this interval, some ranging orders of magnitude away from unity. The actinide/Sr-90 values are illustrated in Appendix B of this report. The results were not separated according to the major facilities because of the low number of matched pairs for each individual facility.

Actinides/Cs-137

A total of 72 matched pairs of measured Cs-137 and an actinide (Am-241, Pu-238, Pu-239, U-234, or U-236) activity were located and analyzed, spanning the period 1970–1995 for various facilities at the INL site. The measured actinide/Cs values were compared to the actinide/Cs values recommended in Table 5-23 of ORAUT-TKBS-0007-5. A comparison ratio value centered on 1.0 would indicate agreement between the measured and recommended values; however, ratio values not centered on unity would indicate insufficient, or excessive, actinide intake assignments during DR. Of these 72 matched pairs, 11% contained actinide/Cs values centered on unity, within a factor of 2 (i.e., actinide/Cs = 0.5 to 2.0). The remaining actinide/Cs values were outside this interval; some ranging orders of magnitude away from unity. The actinide/Cs-137 values are illustrated in the Appendix C of this report. The results were not separated according to the major facilities because of the low number of matched pairs for each individual facility.

These results indicate that at INL the Cs-137/Sr-90 values may not be sufficiently centered on unity as required by ORAUT-OTIB-0054, *Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses*, Revision 03, for assigning FAP intakes. Also, actinide/Sr, or actinide/Cs, values may not be sufficiently constant (or known) as required by ORAUT-TKBS-0007-5 (Tables 5-22 and 5-23) for assigning actinide intakes, even in situations where it can be assumed that the actinides are tied to an indicating radionuclide, such as Sr-90 or Cs-137.

1.0 INTRODUCTION AND BACKGROUND

NIOSH responded to INL SEC-00219 in an ER of March 12, 2015 (NIOSH 2015). In that ER, and also in the technical basis document for INL (ORAUT-TKBS-0007-5), NIOSH's basis for assigning internal intakes/doses for most years and locations at the INL (except those covered by NIOSH's proposed SEC class and the reserved areas/dates) relies on the important assumption that the Cs-137/Sr-90 values are approximately unity, that FAPs are directly tied by a known ratio to Sr-90 or Cs-137 (as per ORAUT-OTIB-0054), and that actinides are directly tied by a known ratio to Sr-90 or Cs-137 (as per Tables 5-22 and 5-23 of ORAUT-TKBS-0007-5).

In a previous evaluation using a relatively small sampling of bioassay and swipe data (SC&A 2015), SC&A found indications that the measured Cs-137/Sr-90 values were not centered on unity, and that the measured actinide/Sr or actinide/Cs values were not constant or representative of those recommended in ORAUT-TKBS-0007-5. Therefore, SC&A searched for further documentation of measured quantitative radionuclide analyses of Sr-90, Cs-137, and actinide activity. Searches for documentation of quantitative analyses of the fuel elements processed in the dissolver at the ICPP have not produced significant data to date. The INL electronic bioassay database, which may provide additional quantitative radionuclide matched-pair data in the near future, is currently in the process of being completed and verified.

In the process of searching the SRDB, SC&A located INL waste management reports that contained quantitative Sr-90 and Cs-137 measurements performed on the same samples (some also contained actinide analyses in the later years); these reports span a relatively long time period (1957–1993) and cover a number of the major operational areas within INL. These data provide a good representation of the materials workers were exposed to, and the potential intake mixtures. These data were obtained by performing an SRDB search using the keywords "Waste Report," "Radioactive Waste," and "Radioactive Waste Report." A list of the documents that contained useful radionuclide measures, and some of the recorded data that were used in this evaluation, is provided in Attachment 1 of this report. Analyses of these data are provided in the following sections.

2.0 CS-137/SR-90 VALUES

NIOSH's ER and ORAUT-TKBS-0007-5 rely heavily on the use of ORAUT-OTIB-0054 to assign FAP intakes using Sr-90 or Cs-137 as the indicating radionuclide for numerous other FAP radionuclides at INL for most locations and time periods. An example of Table 7-3a from ORAUT-OTIB-0054 is provided here as Figure 1. As can be seen from this table, assignment of FAP intakes is dependent on the Cs-137/Sr-90 value being approximately 1.0.

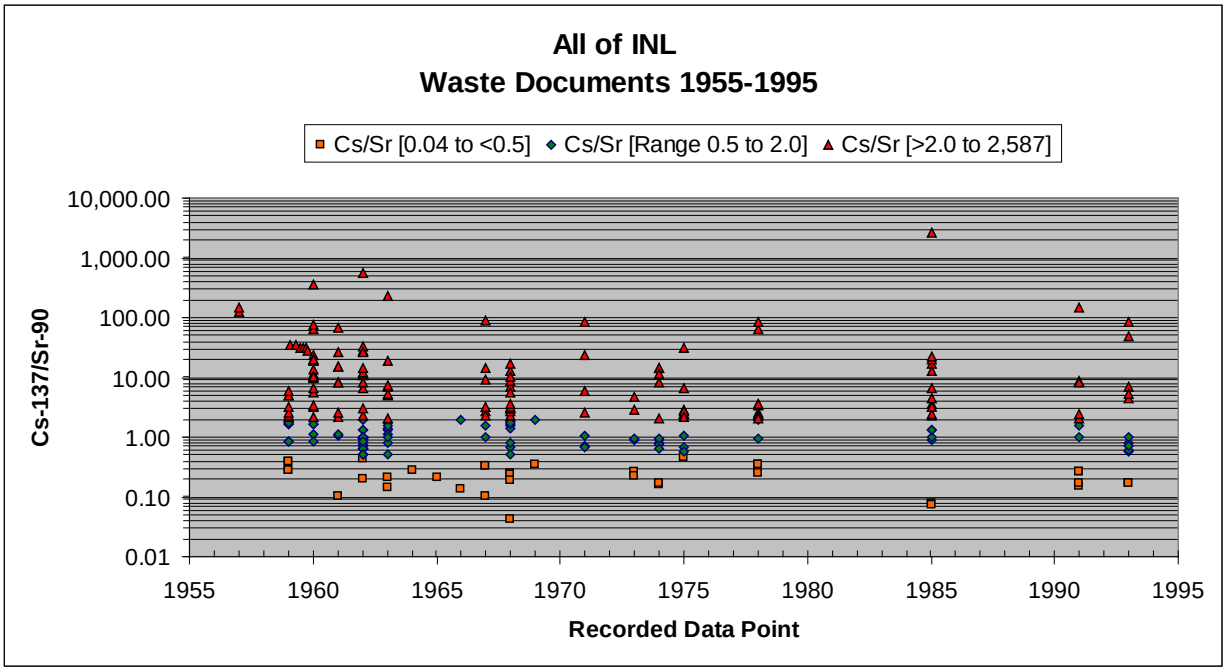
Figure 1. Table 7-3a, FAP-to-Sr-90 or -Cs-137 Ratios for ATR-1 (ORAUT-OTIB-0054)

Table 7-3a. Associated radionuclide activity fractions for assigning intakes: ATR 1.

Table 7-3 values: ATR 1									
	Intake relative to Sr-90					Intake relative to Cs-137			
Nuclide	10 d	40 d	180 d	1 y	Nuclide	10 d	40 d	180 d	1 y
Co-60	2.05E-04	2.03E-04	1.95E-04	1.85E-04	Co-60	2.03E-04	2.01E-04	1.93E-04	1.83E-04
Sr-89	6.72E+01	4.46E+01	6.61E+00	5.29E-01	Sr-89	6.66E+01	4.42E+01	6.54E+00	5.24E-01
Sr-90	**1.00E+00**	**1.00E+00**	**1.00E+00**	**1.00E+00**	Sr-90	9.90E-01	9.90E-01	9.89E-01	9.89E-01
Y-90	1.00E+00	1.00E+00	1.00E+00	1.00E+00	Y-90	9.93E-01	9.90E-01	9.90E-01	9.89E-01
Y-91	8.04E+01	5.64E+01	1.09E+01	1.23E+00	Y-91	7.96E+01	5.59E+01	1.07E+01	1.21E+00
Zr-95	8.67E+01	6.28E+01	1.39E+01	1.90E+00	Zr-95	8.59E+01	6.22E+01	1.38E+01	1.88E+00
Nb-95	7.49E+01	7.41E+01	2.66E+01	4.08E+00	Nb-95	7.42E+01	7.34E+01	2.63E+01	4.04E+00
Ru-103	4.50E+01	2.65E+01	2.26E+00	8.73E-02	Ru-103	4.45E+01	2.63E+01	2.24E+00	8.64E-02
Ru-106	1.74E+00	1.65E+00	1.28E+00	9.17E-01	Ru-106	1.72E+00	1.63E+00	1.27E+00	9.07E-01
I-131	1.21E+03	9.13E+01	5.29E-04	6.33E-11	I-131	1.20E+03	9.05E+01	5.23E-04	6.26E-11
Cs-134	7.48E-01	7.29E-01	6.47E-01	5.52E-01	Cs-134	7.41E-01	7.22E-01	6.40E-01	5.46E-01
Cs-137	1.01E+00	1.01E+00	1.01E+00	1.01E+00	**Cs-137**	**1.00E+00**	**1.00E+00**	**1.00E+00**	**1.00E+00**
Ce-141	8.62E+01	4.55E+01	2.32E+00	4.54E-02	Ce-141	8.54E+01	4.51E+01	2.30E+00	4.49E-02
Ce-144	2.89E+01	2.69E+01	1.93E+01	1.25E+01	Ce-144	2.86E+01	2.66E+01	1.91E+01	1.23E+01
Pr-143	7.60E+01	1.65E+01	1.30E-02	1.04E-06	Pr-143	7.52E+01	1.63E+01	1.29E-02	1.03E-06
Pm-147	2.81E+00	2.96E+00	2.74E+00	2.42E+00	Pm-147	2.78E+00	2.94E+00	2.71E+00	2.40E+00
Eu-154	2.36E-02	2.35E-02	2.30E-02	2.23E-02	Eu-154	2.34E-02	2.32E-02	2.27E-02	2.21E-02

SC&A located a total of 251 matched pairs of measured Cs-137 and Sr-90 activity in the INL waste reports, spanning the period 1957–1993 for the INL site. SC&A analyzed these data to determine the Cs-137/Sr-90 values for each matched pair for the INL site, and then separated them according to the major individual facilities. Only recorded and paired data points specifically listing Cs-137 and Sr-90 in units of activity (µCi, Ci, etc.) on the same material were used in these analyses; this included air, liquid, and solid waste. Figure 2 contains the results for the 251 INL data pairs analyzed.

Figure 2. Cs-137/Sr-90 Values for 251 Data Pairs from INL Waste Reports



Of the 251 pairs, 33% contained Cs-137/Sr-90 values centered on unity, within a factor of 2 (i.e., Cs-137/Sr-90 = 0.5 to 2.0); these are represented by the diamonds in the plot. The remaining Cs-137/Sr-90 values (squares for <0.5 and triangles for >2.0) were outside this interval, with values ranging from 0.04 to 2587.

The Cs-137/Sr-90 values were separated according to the major INL facilities; those plots are provided in Appendix A. Table 1 is a summary of the results for all of INL and also broken down by individual facilities.

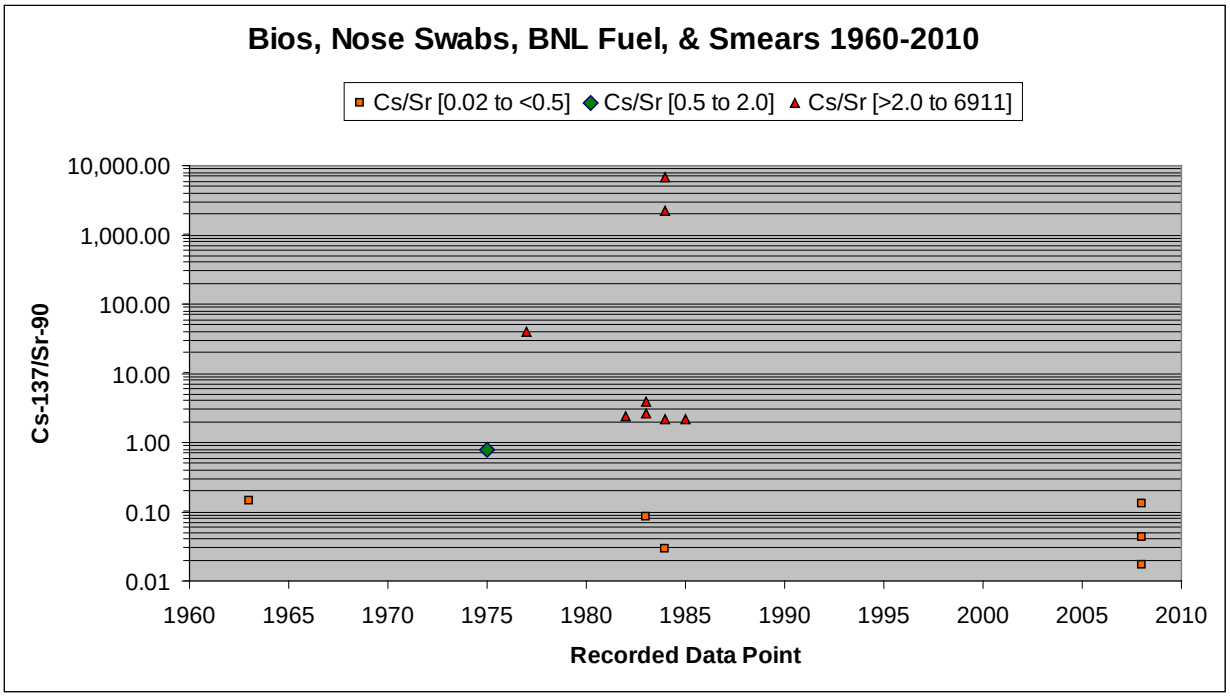
Table 1. Summary of Cs-137/Sr-90 Values for INL and Various Facilities

Facility	No. of Pairs	No. of Pairs with Cs/Sr Value of 0.5 to 2.0	% of Pairs with Cs/Sr Value of 0.5 to 2.0
CFA, etc.	32	12	38%
ICPP	71	38	54%
TAN & ANP	73	22	30%
TRA	75	12	16%
INL (total)	251	84	33%

As can be seen from Table 1, the majority of the Cs-137/Sr-90 values were not centered on unity.

SC&A had previously analyzed a relatively small sample of bioassays, BNL Fuels, and smears (SC&A 2015). These data are summarized in Figure 3.

Figure 3. Summary of Cs-137/Sr-90 Values from Bioassays, BNL Fuel, and Smears



Comparison of the Cs-137/Sr-90 values in Figure 2 and Figure 3 indicates that the data from the INL waste reports are compatible with the previous bioassay, BNL fuel, and smear data.

3.0 ACTINIDE/SR-90 AND ACTINIDE/CS-137 VALUES

According to NIOSH's ER, the basis for assigning actinide intakes, except for special situations, is directly tied (in a constant ratio) to an indicating radionuclide (Sr-90 or Cs-137) using Table 5-22 (Sr-90 ratios) and/or Table 5-23 (Cs-137 ratios) of ORAUT-TKBS-0007-5. These tables are reproduced here as Figures 4 and 5.

Figure 4. Table 5-22, Actinide-to-Sr90 Ratios (ORAUT-TKBS-0007-5)

Table 5-22. Actinide-to-Sr-90 ratios.[a]

Actinide	Reactor fuel types[b]			
	Al	Zr	SS	Max
Ac	8.0E-12 Ac-227	1.3E-11 Ac-227	2.3E-10 Ac-227	2.3E-10 Ac-227
Th	2.4E-08 Th-228	6.4E-08 Th-228	2.3E-07 Th-228	2.3E-07 Th-228
Pa	1.2E-10 Pa-231	1.1E-10 Pa-231	3.8E-09 Pa-231	3.8E-09 Pa-231
U	5.6E-05 U-234	6.2E-06 U-236	1.4E-03 U-234	1.4E-03 U-234
Np	3.4E-06 Np-237	3.7E-06 Np-237	6.8E-07 Np-237	3.7E-06 Np-237
Pu	8.7E-03 Pu-238	1.5E-02 Pu-238	3.7E-03 Pu-239	1.5E-02 Pu-238
Am	1.4E-04 Am-241	3.9E-06 Am-241	9.0E-08 Am-241	1.4E-04 Am-241
Cm	4.9E-05 Cm-244	1.8E-06 Cm-244	1.1E-10 Cm-242	4.9E-05 Cm-244

a. The values in this table were obtained from the MS Excel workbook titled *INEL – Actinide Ratios* (ORAUT 2009a).
b. Al = aluminum; Zr = zirconium; SS = stainless-steel; Max = maximum; The actinide isotopes to use for the dose calculations are provided below each actinide ratio; The actinide isotopes listed are the predominant alpha-emitting actinides in the source term for a given fuel type.

Figure 5. Table 5-23, Actinide-to-Cs-137 Ratios (ORAUT-TKBS-0007-5)

Table 5-23. Actinide-to-Cs-137 ratios.[a]

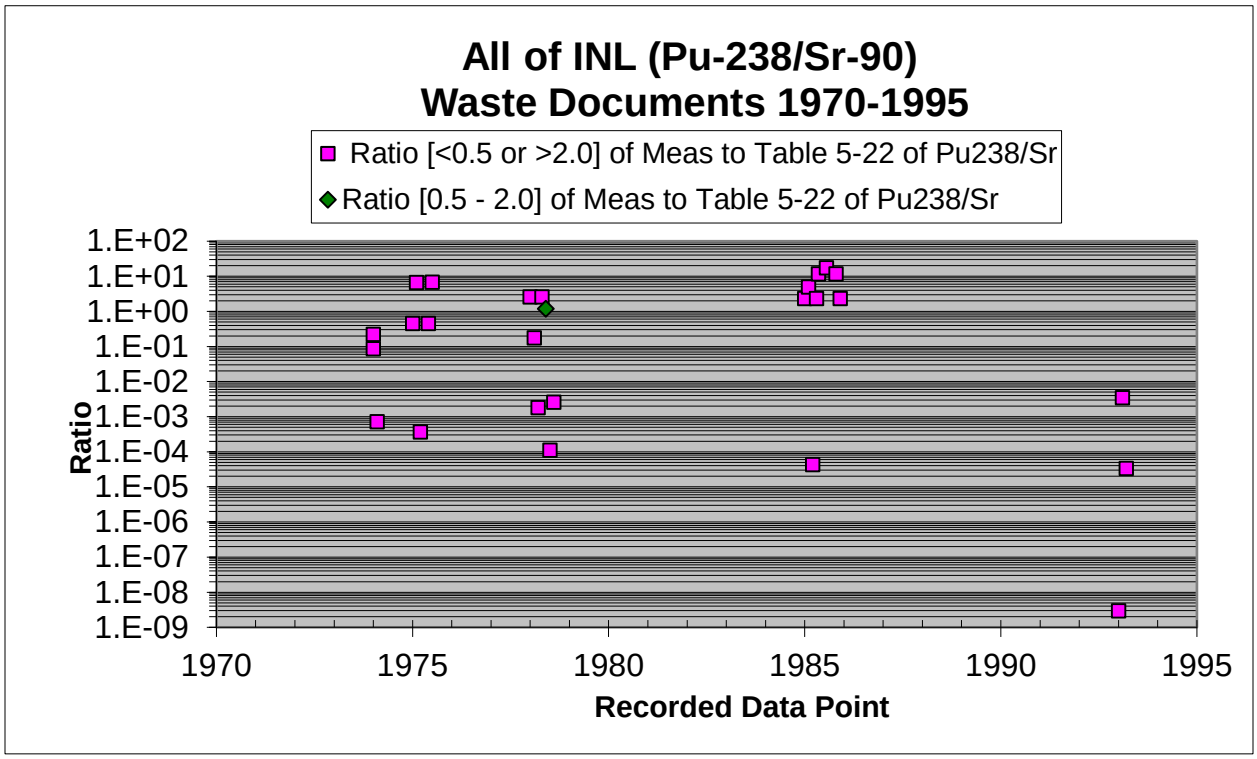
Actinide	Reactor fuel types[b]			
	Al	Zr	SS	Max
Ac	7.6E-12 Ac-227	1.3E-11 Ac-227	2.1E-10 Ac-227	2.1E-10 Ac-227
Th	2.3E-08 Th-228	6.2E-08 Th-228	2.1E-07 Th-228	2.1E-07 Th-228
Pa	1.2E-10 Pa-231	1.1E-10 Pa-231	3.5E-09 Pa-231	3.5E-09 Pa-231
U	5.3E-05 U-234	6.0E-06 U-236	1.3E-03 U-234	1.3E-03 U-234
Np	3.2E-06 Np-237	3.5E-06 Np-237	6.2E-07 Np-237	3.5E-06 Np-237
Pu	8.3E-03 Pu-238	1.4E-02 Pu-238	3.4E-03 Pu-239	1.4E-02 Pu-238
Am	1.3E-04 Am-241	3.7E-06 Am-241	8.3E-08 Am-241	1.3E-04 Am-241
Cm	4.7E-05 Cm-244	1.7E-06 Cm-244	1.0E-10 Cm-242	4.7E-05 Cm-244

a. The values in this table were obtained from the MS Excel workbook titled *INEL – Actinide Ratios* (ORAUT 2009a).
b. Al = aluminum; Zr = zirconium; SS = stainless-steel; Max = maximum; The actinide isotopes to use for the dose calculations are provided below each actinide ratio; The actinide isotopes listed are the predominant alpha-emitting actinides in the source term for a given fuel type.

Because this method involves assigning actinide intakes and doses over a long time span and numerous areas/operations, it results in the majority of the internal alpha dose assignments for INL workers who did not have specific actinide radionuclide bioassays. Therefore, SC&A used measured actinide/Sr-90 and actinide/Cs-137 values to determine if the ratio values recommended in Tables 5-22 and 5-23, respectively, are applicable to DR for INL workers. The major dose contributors in these tables are from Am-241, Pu-238, Pu-239, U-234, and U-236; therefore, these were the radionuclides evaluated in this analysis. SC&A determined the value of the measured actinide/Sr-90 (or actinide/Cs-137) and compared that value to the recommended value in Table 5-22 (or Table 5-23) to obtain a relative ratio. A relative ratio centered on unity indicates that the measured value is in agreement with the recommended value. A ratio >1.0 indicates that the measured value would assign an intake greater than that recommended in the tables, and a ratio <1.0 indicates that the measured value would assign an intake less than that recommended in the tables.

SC&A analyzed the waste report data for all of INL; the results were not separated according to the major facilities because of the low number of matched pairs for each individual facility. Only recorded and paired data points specifically listing an actinide and Sr-90 (and/or Cs-137) in units of activity (µCi, Ci, etc.) on the same material were used in this analyses; this included air, liquid, and solid waste. Figure 6 contains the results for the 26 Pu-238/Sr-90 data pairs analyzed.

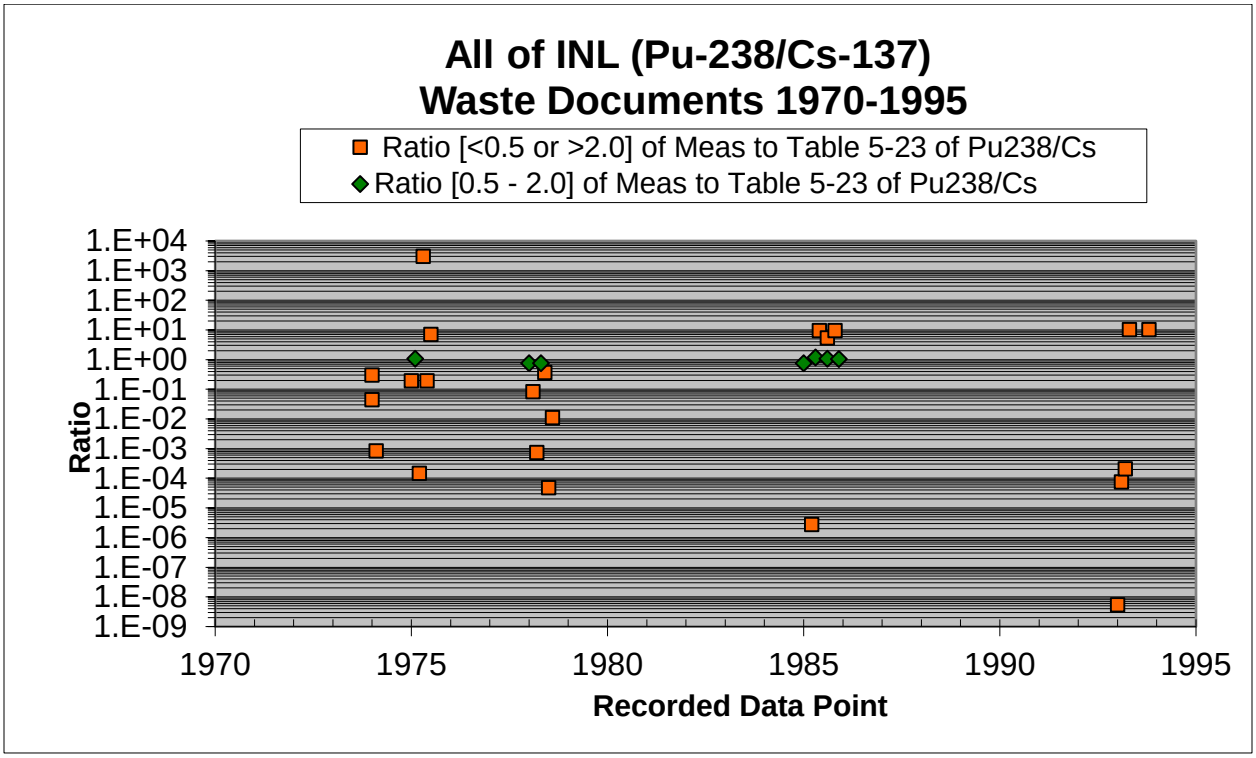
Figure 6. Measured Pu-238/Sr-90 Values Compared to Table 5-22 from ORAUT-TKBS-0007-5



In this case, only 1 (shown as a diamond in Figure 6) of the 26 Pu-238/Sr-90 data pairs fell within the 0.5 to 2.0 range; the other ratios (squares in Figure 6) had a wide range of values.

Figure 7 contains the results for the 29 Pu-238/Cs-137 data pairs analyzed.

Figure 7. Measured Pu-238/Cs-137 Values Compared to Table 5-23 from ORAUT-TKBS-0007-5



In this case, 7 (diamonds in Figure 7) of the 29 Pu-238/Cs-137 data pairs fell within the 0.5 to 2.0 range; the other ratios (squares) had a wide range of values.

The actinide/Sr-90 values for 59 data pairs were also analyzed for Am-241, Pu-239, U-234, and U-236. These results are contained in figures shown in Appendix B. Table 2 summarizes the results for INL for the five actinide radionuclides evaluated.

Table 2. Summary of Measured Actinide/Sr-90 Values Compared to Ratio Values Recommended in Table 5-22 of ORAUT-TKBS-0007-5

Radionuclide	No. of Pairs	No. of Pairs With Ratio Value of 0.5 to 2.0	% of Pairs With Ratio Value of 0.5 to 2.0
Am-241	7	2	29%
Pu-238	26	1	4%
Pu-239	9	1	11%
U-234	13	0	0%
U-236	4	0	0%
Total:	59	4	7%

The actinide/Cs-137 values for 72 data pairs were also analyzed for Am-241, Pu-239, U-234, and U-236. These results are contained in figures as shown in Appendix C. Table 3 summarizes the results for INL for the five actinide radionuclides evaluated.

Table 3. Summary of Measured Actinide/Cs-137 Values Compared to Ratio Values Recommended in Table 5-23 of ORAUT-TKBS-0007-5

Radionuclide	No. of Pairs	No. of Pairs With Ratio Value of 0.5 to 2.0	% of Pairs With Ratio Value of 0.5 to 2.0
Am-241	11	1	9%
Pu-238	29	7	24%
Pu-239	11	0	0%
U-234	17	0	0%
U-236	4	0	0%
Total:	72	8	11%

As can be seen from Tables 2 and 3, the majority of the measured-to-recommended values were not centered on unity.

4.0 SUMMARY AND CONCLUSIONS

This investigation indicates the following, based on the measured data points analyzed to date:

- **Cs-137/Sr-90 –** The majority of the Cs-137/Sr-90 values were not centered on unity. Only 33% of 251 data points analyzed for Cs-137/Sr-90 from the 1957–1993 INL waste reports fell within a range of 0.5–2.0. Some ratio values were orders of magnitude above and below unity.

- **Use of ORAUT-OTIB-0054** – This document is based on the Cs-137/Sr-90 value being centered on unity. Therefore, using it to assign FAP intakes based on Sr-90 bioassays compared to Cs-137 bioassays would produce significantly different intakes/doses in many cases, because at INL the materials the workers were exposed to did not always contain equal activities of Cs-137 and Sr-90. For example, potentially, two workers with the same intakes, but one bioassayed for Sr-90 and the other bioassayed for Cs-137, would be assigned very different intakes/doses using ORAUT-OTIB-0054 due to the difference in the actual Sr-90 and Cs-137 contents of the materials detected in the bioassays.

- **Actinide/Sr-90 –** The majority of the measured actinide-to-Sr-90 values were different from those recommended in ORAUT-TKBS-0007-5, Table 5-22. Only 7% of the 59 data pairs matched the actinide-to-Sr-90 ratios recommended in Table 5-22 within a factor of 2. Some ratios were orders of magnitude above and below those recommended.

- **Actinide/Cs-137 –** The majority of the measured actinide to Cs-137 values were different from those recommended in ORAUT-TKBS-0007-5, Table 5-23. Only 11% of the 72

data pairs matched the actinide-to-Cs-137 ratios recommended in Table 5-23 within a factor of 2. Some ratios were orders of magnitude above and below those recommended.

- **Use of only Sr-90 or Cs-137 –** Evaluating the numerous plots in Appendices B and C indicates that the sole use of Sr-90 or Cs-137 does not offer an advantage in consistency when assigning actinide intakes.

Comparing the results obtained from the waste reports to those obtained previously using bioassays, BNL fuels, and smears (SC&A 2015) indicates similar issues with using the ratio method at INL.

Considering these findings, using an indicating radionuclide (such as Sr-90 and/or Cs-137) to assign FAP and actinide intakes at INL does not appear to provide a method that results in assigning intakes that are indicative of the materials the workers were actually exposed to.

Additional information concerning measured radionuclide ratios can be analyzed when the complete INL bioassay database becomes available, and if quantitative analyses of ICPP dissolver feed material are located.

5.0 REFERENCES

NIOSH. 2015. *SEC Petition Evaluation Report – INL Petition SEC-00219 of September 16, 2014*, National Institute for Occupational Safety and Health, Division of Compensation Analysis and Support, Cincinnati, Ohio, March 12, 2015.

ORAUT 2009. MS Excel workbook, *INEL-Actinide Ratios*, Revision 0, Oak Ridge Associated Universities Team, Oak Ridge Tennessee. December 18, 2009. [SRDB Ref. ID 77440]

ORAUT-TKBS-0007-5. 2010. *Idaho National Laboratory and Argonne National Laboratory – West - – Occupational Internal Dose*, Revision 03, Oak Ridge Associated Universities Team, Cincinnati, Ohio. March 2, 2010.

ORAUT-OTIB-0054. 2015. *Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses*, Revision 03, Oak Ridge Associated Universities, Cincinnati, Ohio. February 6, 2015.

SC&A 2015. *SC&A's Evaluation of the NIOSH ER Proposed Use of FAP Bioassay Indicator Radionuclides (in Conjunction with OTIB-54 and ORAUT-TKBS-0007-5) for Assessment of FAP and Actinide intakes at INL*. November 10, 2015. SC&A, Inc., Vienna, Virginia, and Saliant, Inc., Jefferson, Maryland.

APPENDIX A: CS-137/SR-90 VALUES FOR MAJOR INL FACILITIES

Figure A-1. CFA Cs-137/Sr-90

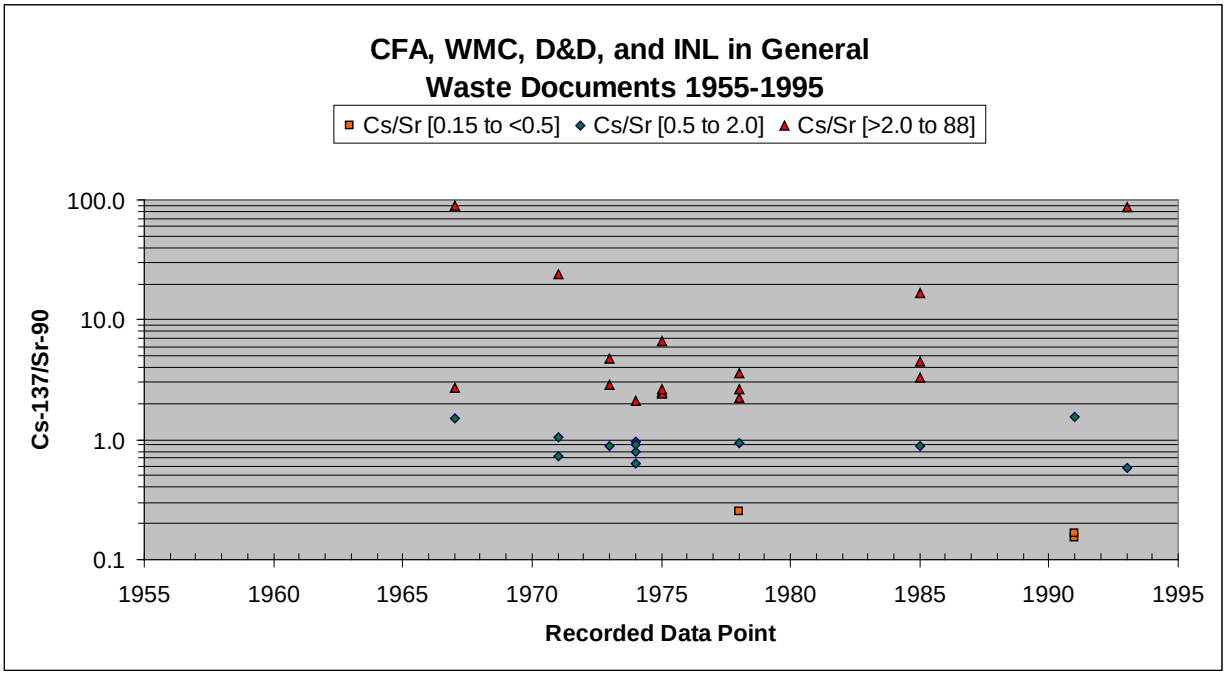


Figure A-2. ICPP Cs-137/Sr-90

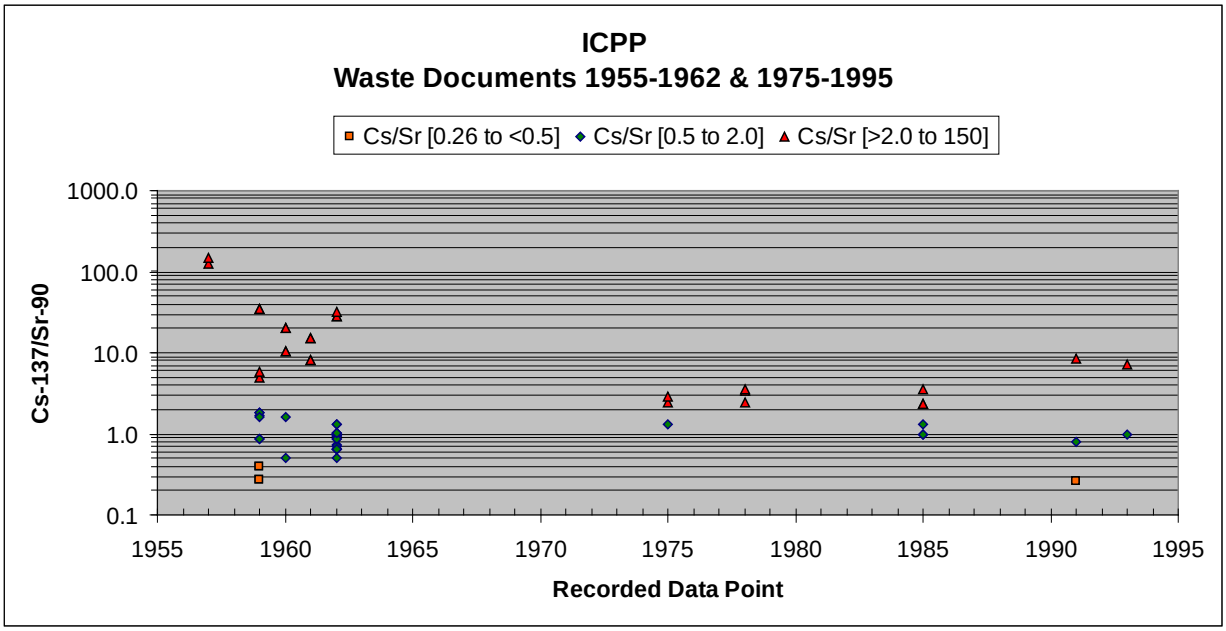


Figure A-3. TAN & ANP Cs-137/Sr-90

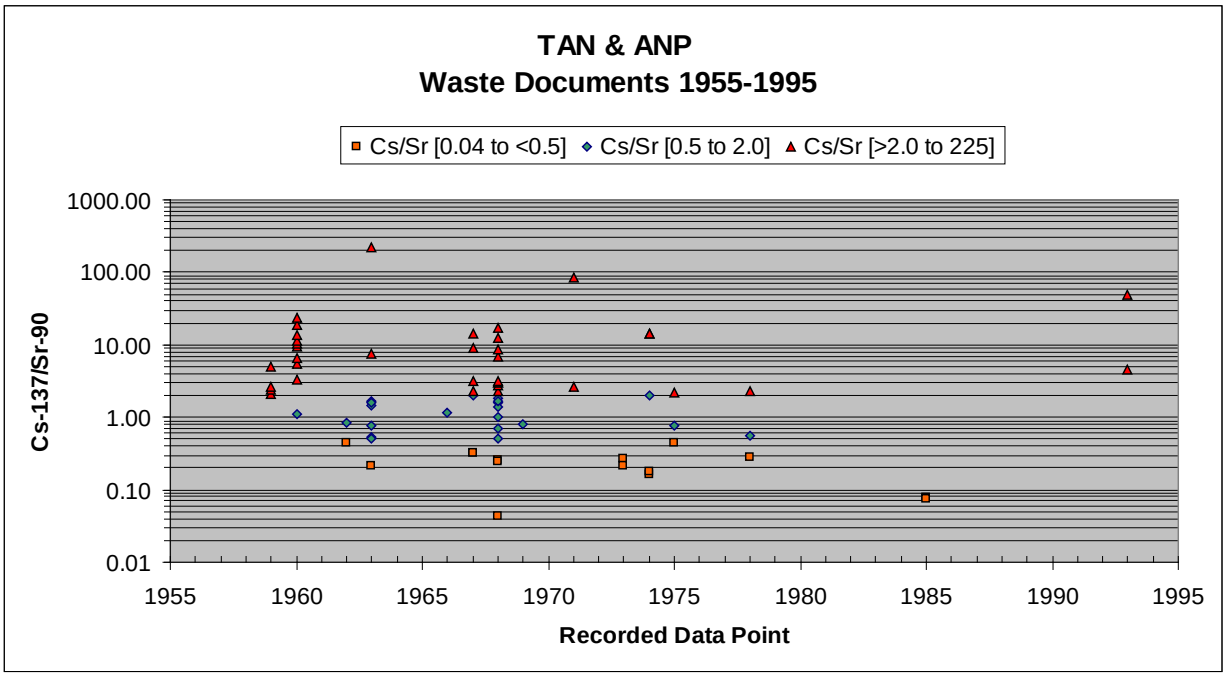


Figure A-4. TRA Cs-137/Sr-90

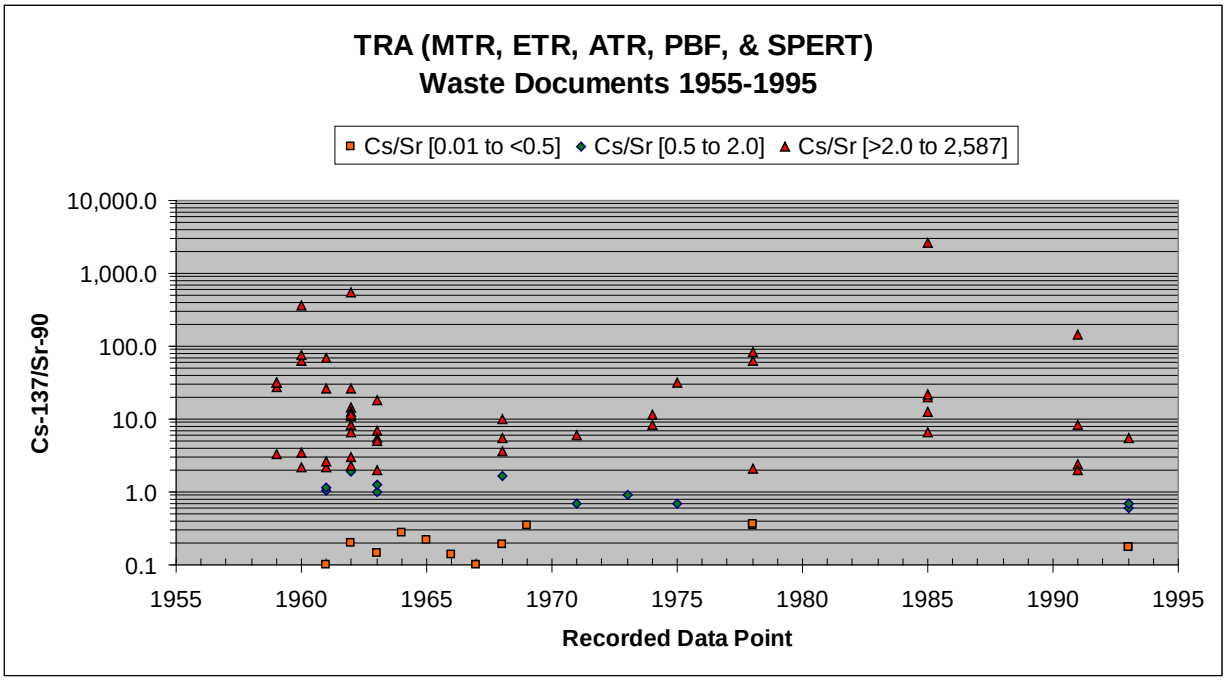
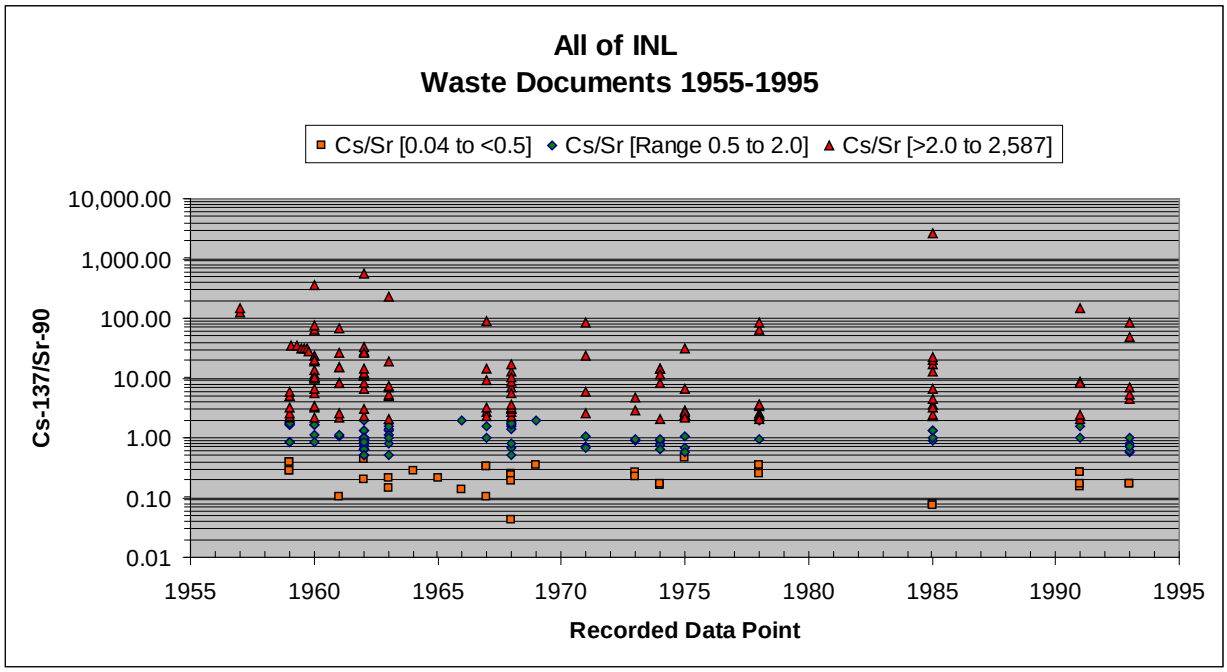


Figure A-5. INL Cs-137/Sr-90



APPENDIX B: ACTINIDE/SR-90 VALUES

Figure B-1. INL Am-241/Sr-90

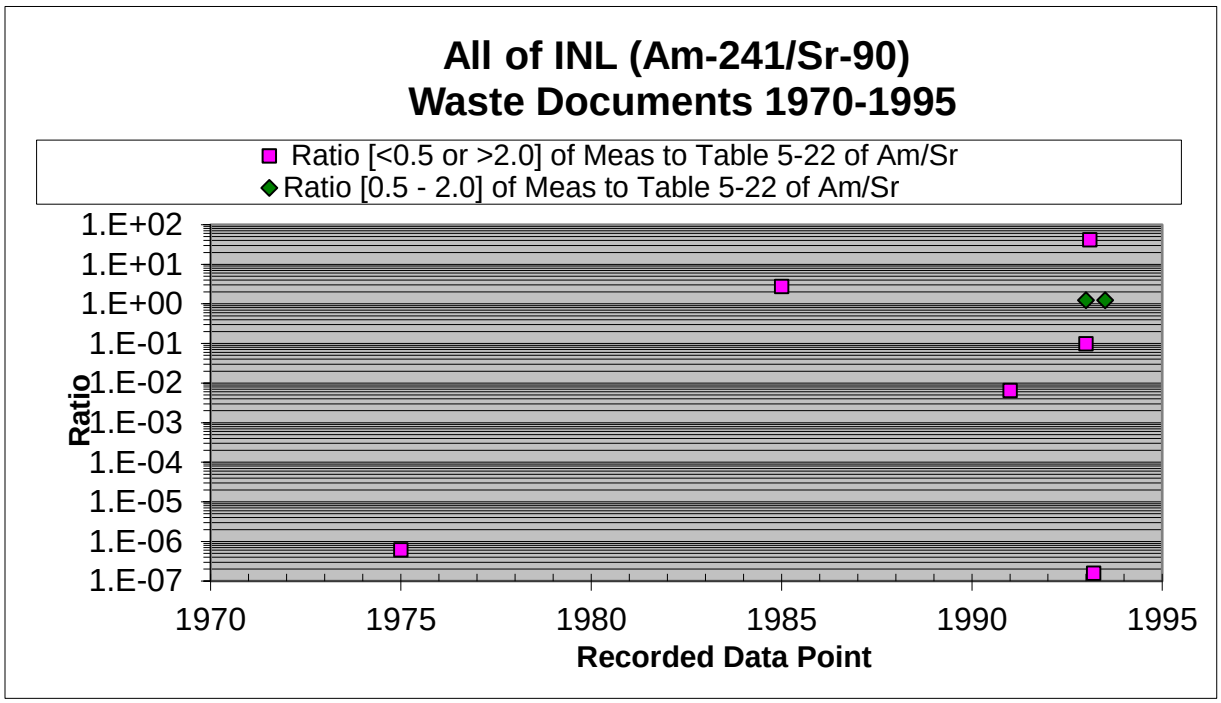


Figure B-2. INL Pu-238/Sr-90

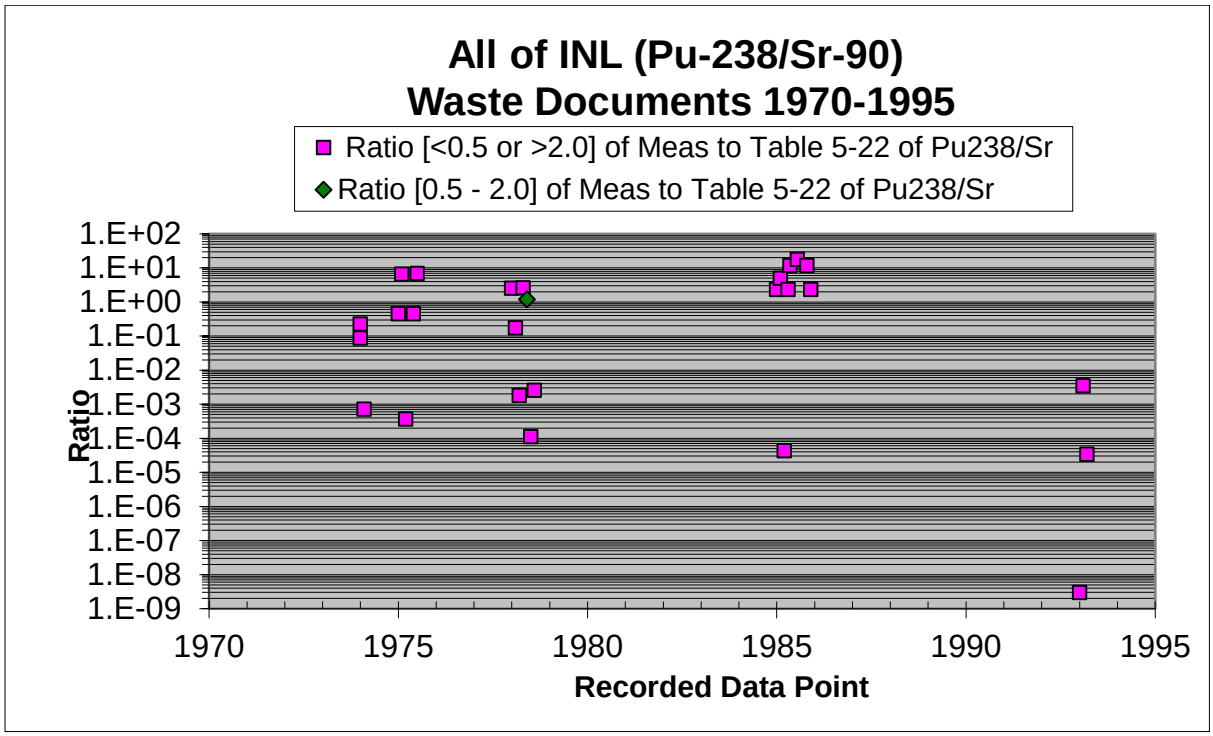


Figure B-3. INL Pu-239/Sr-90

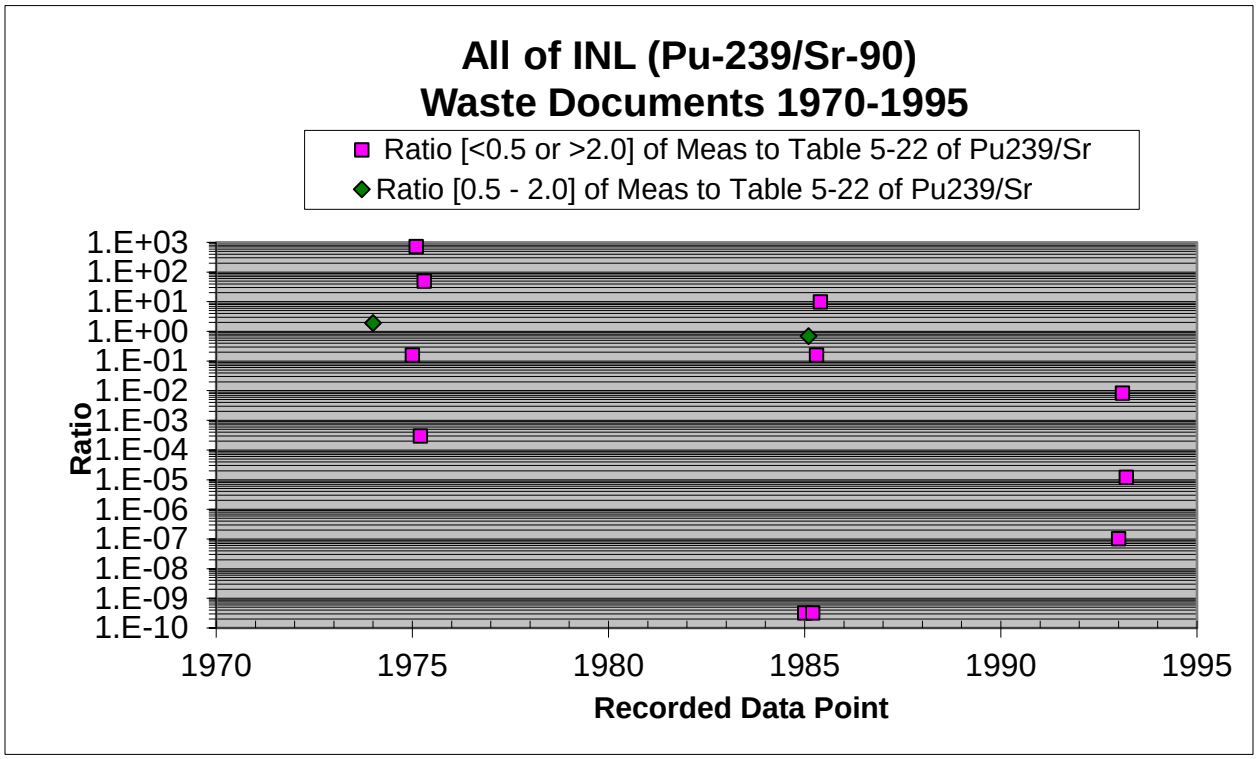


Figure B-4. INL U-234/Sr-90

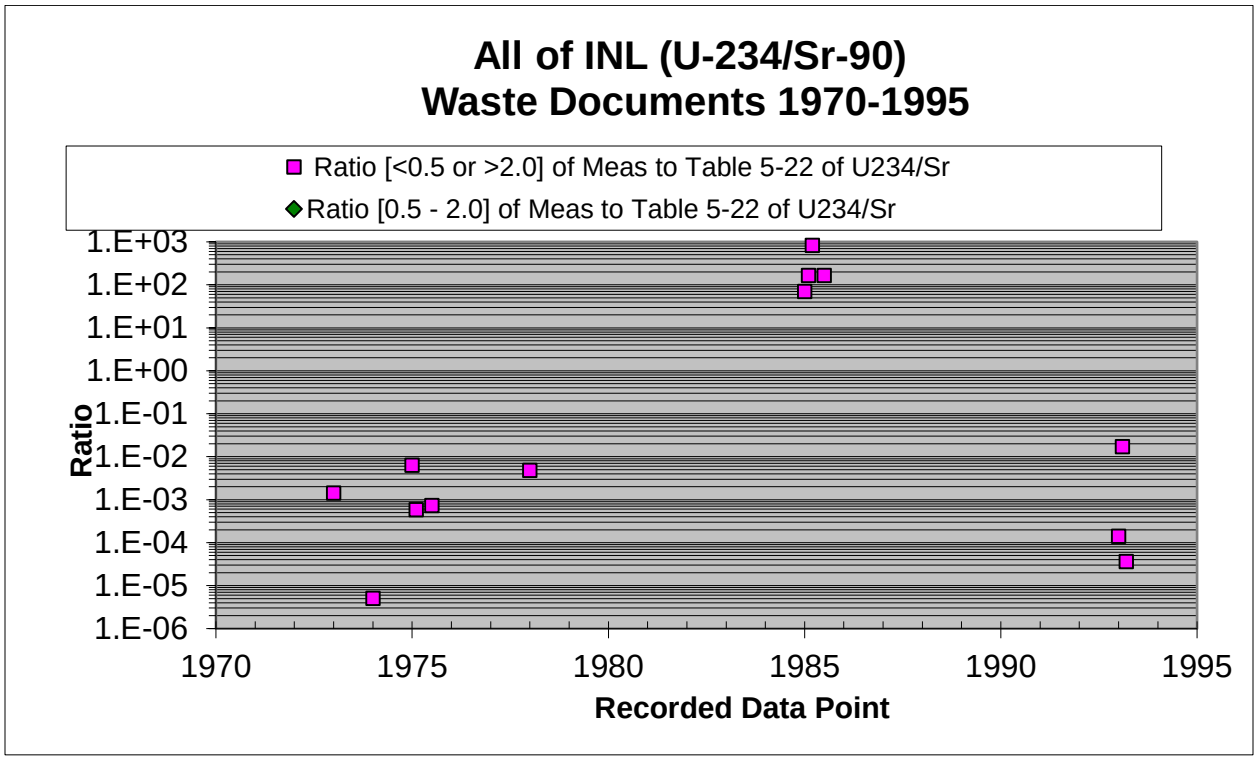
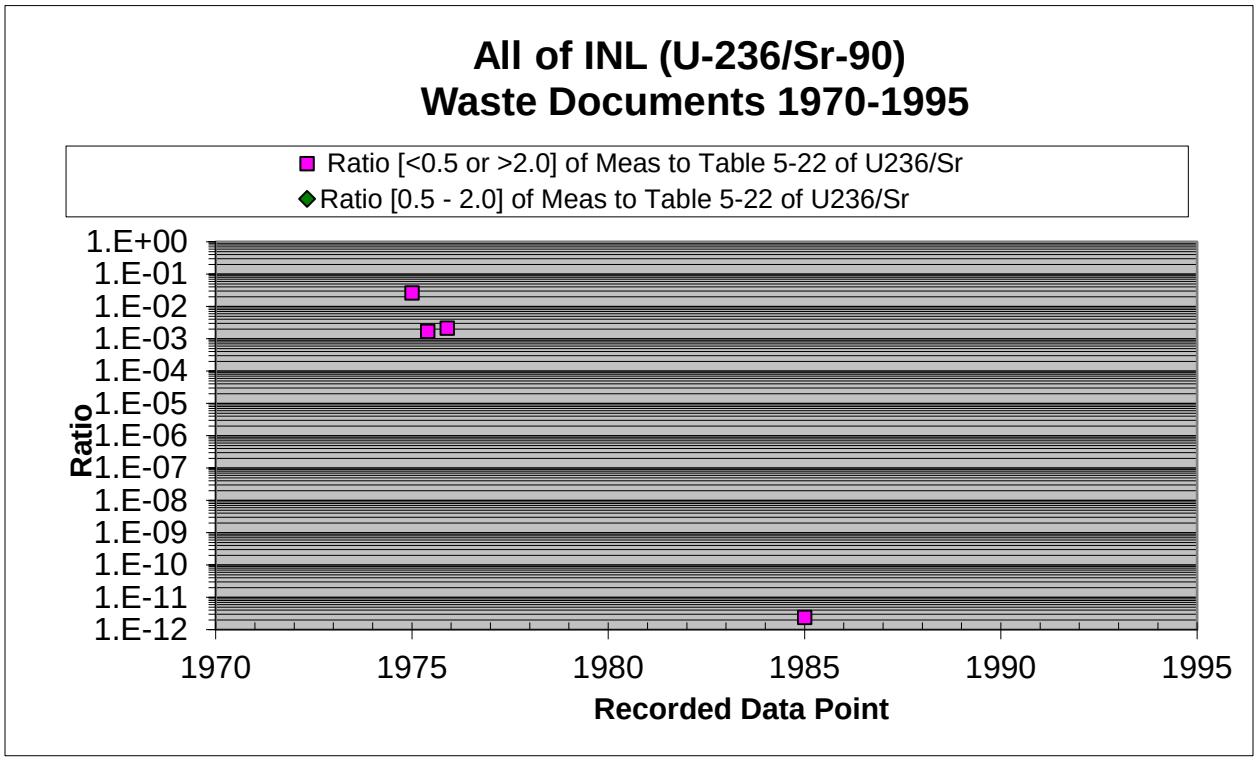


Figure B-5. INL U-236/Sr-90



APPENDIX C: ACTINIDE/CS-137 VALUES

Figure C-1. INL Am-241/Cs-137

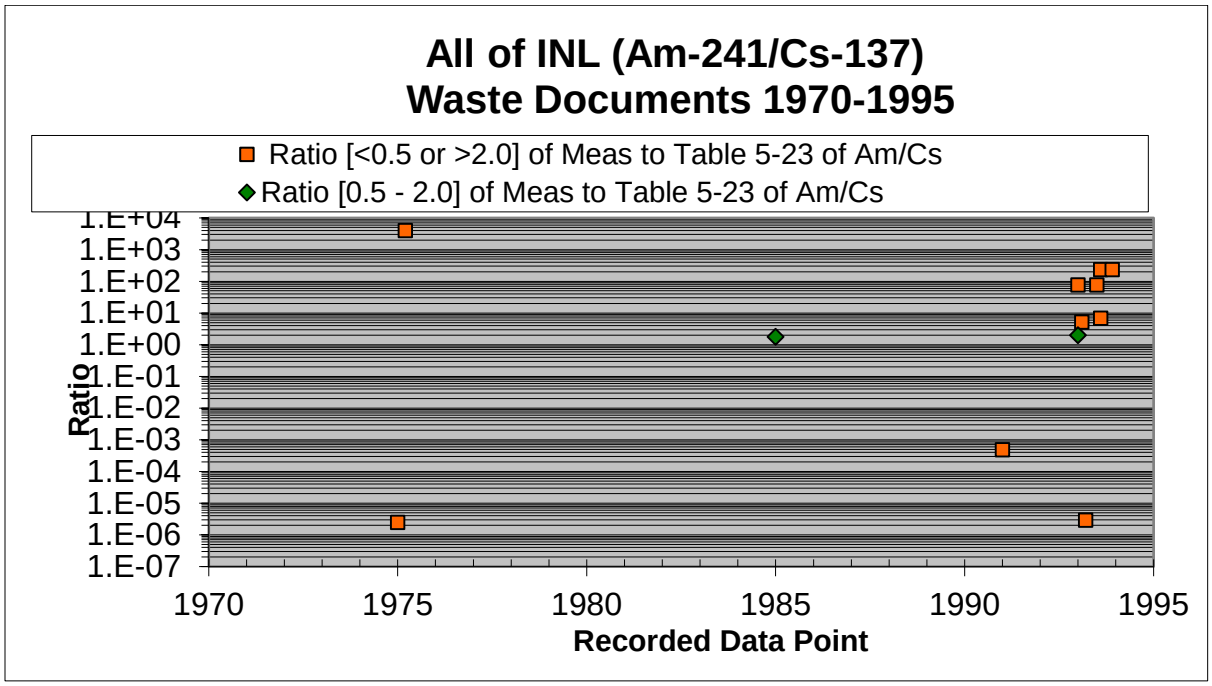


Figure C-2. INL Pu-238/Cs-137

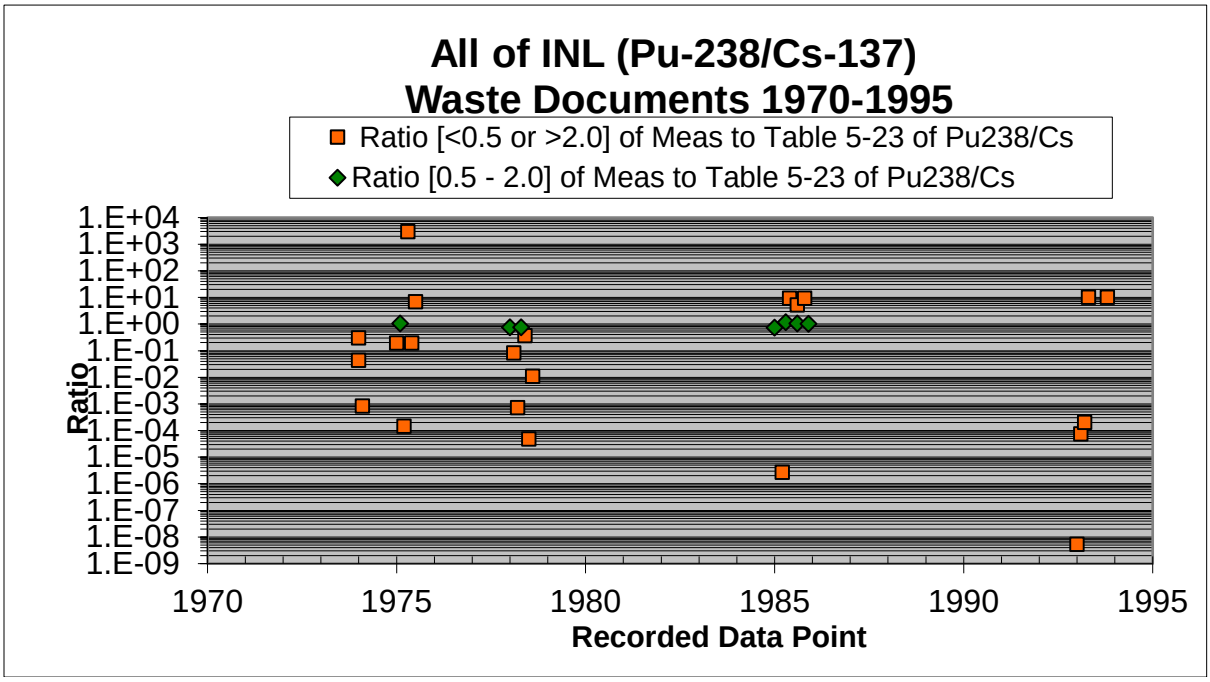


Figure C-3. INL Pu-239/Cs-137

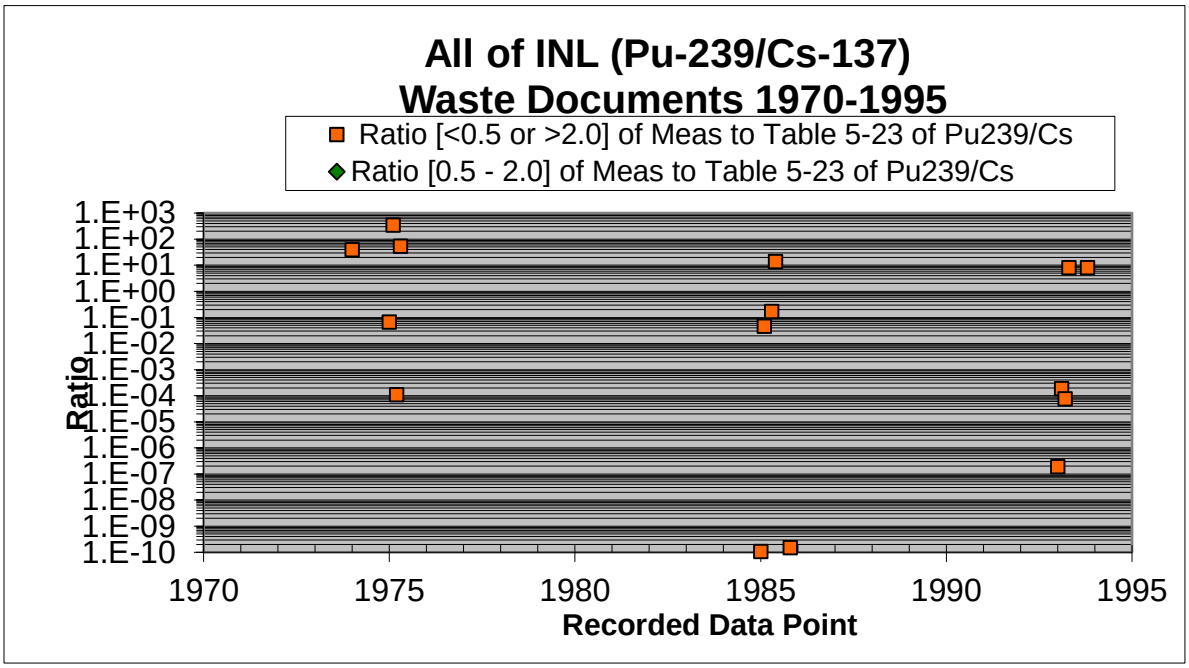


Figure C-4. INL U-234/Cs-137

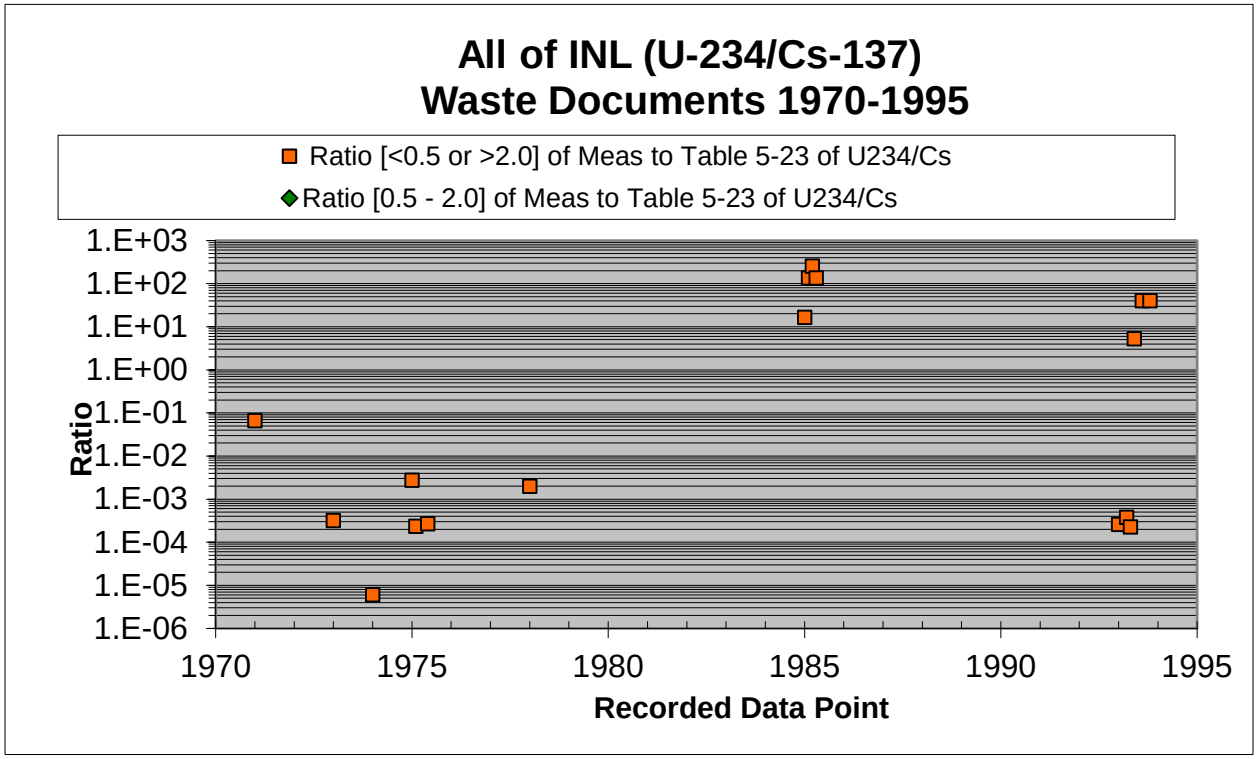
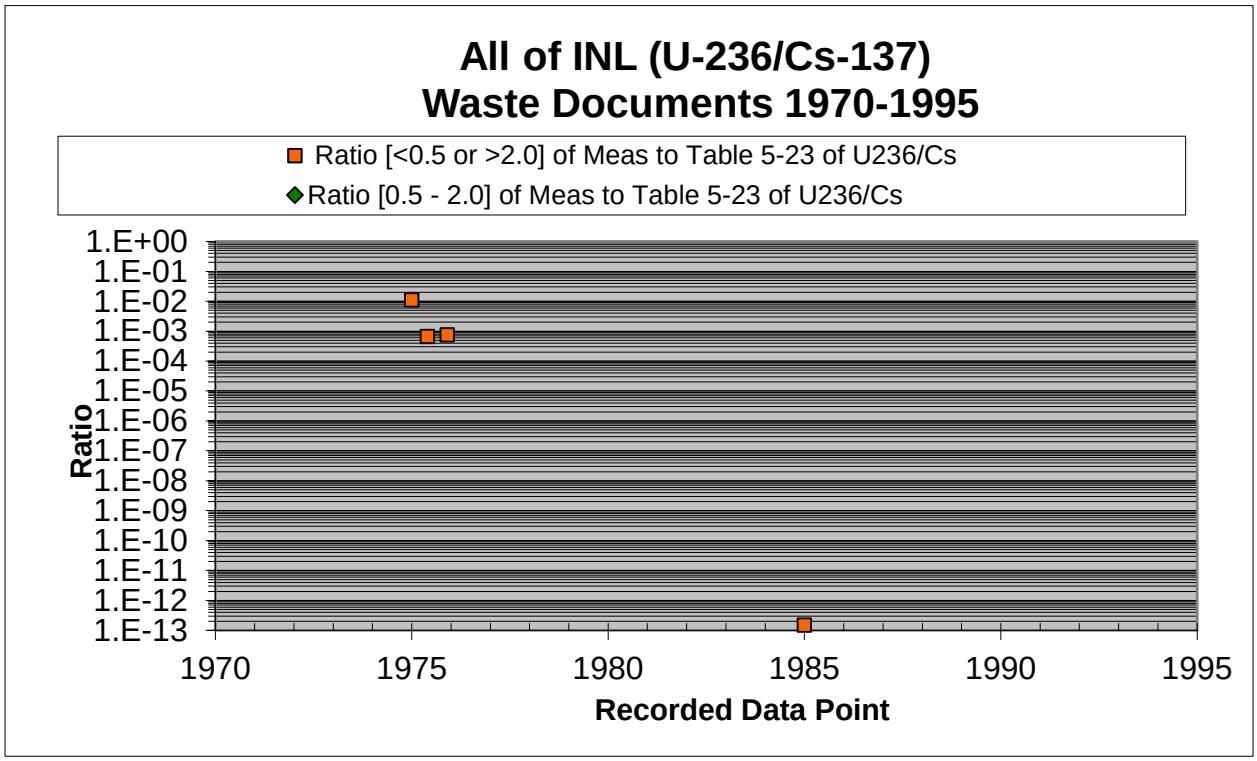


Figure C-5. INL U-236/Cs-137



ATTACHMENT 1. DOCUMENTS AND DATA USED IN EVALUATION OF Cs/Sr AND ACTINIDES

List of Documents Used from SRBD

Ref ID #	Document File Name
85575	085575_Radioactive Waste Reports 1967–1968.pdf
86962	086962_Radioactive Waste Reports 1959.pdf
86970	086970_ICPP Radioactive Waste Reports 1959.pdf
86971	086971_ANP Radioactive Waste Reports 1959.pdf
86973	086973_ETR Radioactive Waste Reports 1959.pdf
86991	086991_SPERT Radioactive Waste Reports 1959.pdf
87007	087007_NRTS Radioactive Waste Reports 1959.pdf
87014	087014_MTR (and ETR Liquids) Radioactive Waste Reports 1960.pdf
87029	087029_ICPP Radioactive Waste Reports 1960.pdf
87191	87191_Radioactive Waste Management for 1985
87203	087203_Radioactive Waste Reports ANP Facility 1960.pdf
87204	087204_Radioactive Waste Reports 1961.pdf
87211	087211_Radioactive Waste Reports ICPP Facility 1961.pdf
87231	087231_Radioactive Waste Reports ICPP Facility 1962.pdf
87258	087258_Radioactive Waste Reports MTR (and ETR Liquids) Facility 1962.pdf
87904	87904_Waste Data for the National Reactor Testing Station Idaho
88069	88069_Radioactive Waste Management Information for 1991 and Record-to-Date
118841	118841_Radioactive Waste Management Information for 1978
136493	136493_Radioactive Waste Management Information for 1993 and Record to Date
138091	138091_ICPP Monthly Radioactive Waste Reports 1959.pdf
138095	138095_ICPP Monthly Radioactive Waste Reports 1960.pdf
138096	138096_ICPP Monthly Radioactive Waste Reports 1961.pdf
138098	138098_ICPP Monthly Radioactive Waste Reports 1962.pdf
138732	138732_SPERT Radioactive Waste Reports January - November 1963.pdf
138736	138736_Solid Radioactive Waste Report MTR and ETR Liquid January - October.pdf
138739	138739_Solid Radioactive Waste Report TAN January - December 1963.pdf
138892	138892_Radioactive Waste Reports, MTR Liquid and Airborne and ETR Liquid.pdf
139139	139139_Radioactive Waste Reports MTR (liquid, airborne, solid) and ETR.pdf
139151	139151_Radioactive Waste Reports TAN-STEP June 1962 - December 1962.pdf
139175	139175_ICPP Monthly Radioactive Waste Reports 1957.pdf
139182	139182_SPERT I Radioactive Waste Reports 1960.pdf
139839	139839_NRTS Radioactive Waste Management Information for 1971
140037	140037_NRTS Radioactive Waste Management Information for 1973
140039	140039_Idaho National Engineering Laboratory Radioactive Waste Management Information for 1974
140040	140040_Idaho National Engineering Laboratory Radioactive Waste Management Information for 1975

Summary of Data Used from SRBD Documents

SRDB Ref #	Pdf #	Time period	Area	Type of waste	Meas. Sr-90	Meas. Cs-137	Units	Sr90/ Cs-137	Cs-137/ Sr-90
139175	16	1957	ICPP	liq	0.01	1.5	%	0.01	150.00
139175	24	1957	ICPP	liq	0.04	5	%	0.01	125.00
86962	16	1959	MTR&ETR	liq	5.00E-08	1.60E-06	uCi/ml	0.03	32.00
86970	5	1959	ICPP	liq	8.50E-09	1.43E-08	uCi/ml	0.59	1.68
86970	7	1959	ICPP	liq	2.30E-06	9.10E-07	uCi/ml	2.53	0.40
86970	8	1959	ICPP	liq	7.10E-08	4.20E-07	uCi/ml	0.17	5.92
86970	9	1959	ICPP	liq	3.90E-07	3.35E-07	uCi/ml	1.16	0.86
86970	11	1959	ICPP	liq	1.70E-07	6.00E-06	uCi/ml	0.03	35.29
86970	12	1959	ICPP	liq	2.70E-06	7.40E-07	uCi/ml	3.65	0.27
86970	13	1959	ICPP	liq	3.80E-06	6.80E-06	uCi/ml	0.56	1.79
86971	2	1959	ANP	liq	1.28E-07	6.38E-07	none	0.20	4.98
86971	3	1959	ANP	liq	3.09E-07	8.12E-07	none	0.38	2.63
86971	4	1959	ANP	liq	3.15E-07	6.70E-07	none	0.47	2.13
86971	5	1959	ANP	liq	1.01E-06	2.38E-06	none	0.42	2.36
86973	14	1959	ETR	liq	0.27	0.89	mCi	0.30	3.30
86991	5	1959	SPERT	liq	2.00E-07	5.60E-06	uCi/ml	0.04	28.00
87007	7	1959	MTR&ETR	liq	5.00E-08	1.60E-06	uCi/ml	0.03	32.00
138091	5	1959	ICPP	liq	8.50E-09	1.43E-08	uCi/ml	0.59	1.68
138091	7	1959	ICPP	liq	2.30E-06	9.10E-07	uCi/ml	2.53	0.40
138091	9	1959	ICPP	liq	3.90E-07	3.35E-07	uCi/ml	1.16	0.86
138091	10	1959	ICPP	liq	3.90E-07	1.90E-06	uCi/ml	0.21	4.87
138091	11	1959	ICPP	liq	1.70E-07	6.00E-06	uCi/ml	0.03	35.29
138091	12	1959	ICPP	liq	2.70E-06	7.40E-07	uCi/ml	3.65	0.27
138091	13	1959	ICPP	liq	3.80E-06	6.80E-06	uCi/ml	0.56	1.79
139139	13	1959	MTR&ETR	liq	5.00E-08	1.60E-06	uCi/ml	0.03	32.00
87014	8	1960	MTR&ETR	liq	1.20E-07	4.30E-05	uCi/ml	0.00	358.33
87014	16	1960	MTR&ETR	liq	1.50E-06	9.50E-05	uCi/ml	0.02	63.33
87014	18	1960	MTR&ETR	liq	1.20E-07	9.20E-06	uCi/ml	0.01	76.67
87029	13	1960	ICPP	liq	4.66E-08	9.30E-07	uCi/ml	0.05	19.96
87029	14	1960	ICPP	liq	3.92E-07	4.10E-06	uCi/ml	0.10	10.46
87029	15	1960	ICPP	liq	4.25E-07	6.90E-07	uCi/ml	0.62	1.62
87203	2	1960	ANP	liq	5.25E-07	1.70E-06	none	0.31	3.24
87203	3	1960	ANP	liq	1.06E-06	1.18E-06	none	0.90	1.11
87203	4	1960	ANP	liq	1.40E-07	3.35E-06	none	0.04	23.93
87203	5	1960	ANP	liq	4.46E-08	5.00E-07	none	0.09	11.21
87203	6	1960	ANP	liq	6.40E-07	3.50E-06	none	0.18	5.47
87203	8	1960	ANP	liq	9.89E-07	6.53E-06	none	0.15	6.60
87203	9	1960	ANP	liq	8.24E-07	1.58E-05	none	0.05	19.17
87203	10	1960	ANP	liq	1.30E-07	1.25E-06	none	0.10	9.62
87203	11	1960	ANP	liq	1.29E-06	1.10E-06	none	1.17	0.85
87203	12	1960	ANP	liq	2.93E-07	3.06E-06	none	0.10	10.44
87203	13	1960	ANP	liq	3.08E-07	4.16E-06	none	0.07	13.51
138095	11	1960	ICPP	liq	4.66E-08	9.30E-07	uCi/ml	0.05	19.96
138095	12	1960	ICPP	liq	3.92E-07	4.10E-06	uCi/ml	0.10	10.46
138095	13	1960	ICPP	liq	4.25E-07	6.90E-07	uCi/ml	0.62	1.62
139182	2	1960	SPERT	liq	2.70E-06	5.90E-06	uCi/ml	0.46	2.19
139182	15	1960	SPERT	liq	2.80E-06	9.70E-06	uCi/ml	0.29	3.46
87204	6	1961	MTR&ETR	liq	1.98E-06	4.32E-06	uCi/ml	0.46	2.18
87204	12	1961	MTR&ETR	liq	8.50E-06	8.90E-06	uCi/ml	0.96	1.05
87204	18	1961	MTR&ETR	liq	2.70E-06	3.10E-06	uCi/ml	0.87	1.15
87204	26	1961	MTR&ETR	liq	4.50E-07	1.17E-05	uCi/ml	0.04	26.00
87204	30	1961	MTR&ETR	liq	2.05E-07	1.40E-05	uCi/ml	0.01	68.29
87204	44	1961	MTR&ETR	liq	4.00E-07	1.03E-06	uCi/ml	0.39	2.58
87211	2	1961	ICPP	liq	2.04E-07	3.06E-06	uCi/ml	0.07	15.00
87211	4	1961	ICPP	liq	9.22E-07	7.43E-06	uCi/ml	0.12	8.06
138096	2	1961	ICPP	liq	2.04E-07	3.06E-06	uCi/ml	0.07	15.00
138096	3	1961	ICPP	liq	9.22E-07	7.43E-06	uCi/ml	0.12	8.06
87904	14	1961	TRA	liq	58.4	5.9	Ci	9.90	0.10
87231	2	1962	ICPP	liq	7.80E-08	3.90E-08	none	2.00	0.50
87231	3	1962	ICPP	liq	7.95E-04	6.77E-04	uCi/ml	1.17	0.85
87231	6	1962	ICPP	liq	9.45E-04	6.14E-04	uCi/ml	1.54	0.65
87231	8	1962	ICPP	liq	8.95E-04	8.82E-04	uCi/ml	1.01	0.99

SRDB Ref #	Pdf #	Time period	Area	Type of waste	Meas. Sr-90	Meas. Cs-137	Units	Sr90/ Cs-137	Cs-137/ Sr-90
87231	9	1962	ICPP	liq	1.82E-07	5.09E-06	none	0.04	27.97
87231	10	1962	ICPP	liq	1.59E-03	1.54E-03	uCi/ml	1.03	0.97
87231	12	1962	ICPP	liq	1.86E-03	1.73E-03	uCi/ml	1.08	0.93
87231	14	1962	ICPP	liq	1.60E-03	1.59E-03	uCi/ml	1.01	0.99
87231	16	1962	ICPP	liq	2.20E-03	1.41E-03	uCi/ml	1.56	0.64
87231	18	1962	ICPP	liq	1.63E-03	1.15E-03	uCi/ml	1.42	0.71
87231	20	1962	ICPP	liq	9.34E-04	9.41E-04	uCi/ml	0.99	1.01
87231	22	1962	ICPP	liq	6.87E-04	9.00E-04	uCi/ml	0.76	1.31
87231	24	1962	ICPP	liq	1.14E-03	8.45E-04	uCi/ml	1.34	0.74
87258	2	1962	MTR&ETR	liq	8.90E-07	1.30E-05	uCi/ml	0.07	14.61
87258	5	1962	MTR&ETR	liq	6.60E-07	8.20E-06	uCi/ml	0.08	12.42
87258	8	1962	MTR&ETR	liq	6.00E-07	6.70E-06	uCi/ml	0.09	11.17
87258	10	1962	MTR&ETR	liq	6.00E-07	5.00E-06	uCi/ml	0.12	8.33
87258	12	1962	MTR&ETR	liq	5.80E-07	1.10E-06	uCi/ml	0.53	1.90
87258	14	1962	MTR&ETR	liq	3.50E-07	4.00E-06	uCi/ml	0.09	11.43
87258	16	1962	MTR&ETR	liq	7.00E-07	8.00E-06	uCi/ml	0.09	11.43
87258	18	1962	MTR&ETR	liq	5.70E-07	1.50E-05	uCi/ml	0.04	26.32
87258	20	1962	MTR&ETR	liq	2.00E-08	1.10E-05	uCi/ml	0.00	550.00
87258	22	1962	MTR&ETR	liq	9.00E-07	2.70E-06	uCi/ml	0.33	3.00
87258	24	1962	MTR&ETR	liq	2.00E-06	1.30E-05	uCi/ml	0.15	6.50
87258	26	1962	MTR&ETR	liq	1.50E-06	3.42E-06	uCi/ml	0.44	2.28
138098	4	1962	ICPP	liq	6.87E-04	9.00E-04	uCi/ml	0.76	1.31
138098	6	1962	ICPP	liq	9.34E-04	9.41E-04	uCi/ml	0.99	1.01
138098	8	1962	ICPP	liq	1.63E-03	1.15E-03	uCi/ml	1.42	0.71
138098	10	1962	ICPP	liq	2.20E-03	1.41E-03	uCi/ml	1.56	0.64
138098	12	1962	ICPP	liq	1.60E-03	1.59E-03	uCi/ml	1.01	0.99
138098	14	1962	ICPP	liq	1.86E-03	1.73E-03	uCi/ml	1.08	0.93
138098	15	1962	ICPP	liq	1.59E-03	1.54E-03	uCi/ml	1.03	0.97
138098	16	1962	ICPP	liq	1.82E-07	5.09E-06	uCi/ml	0.04	27.97
138098	18	1962	ICPP	liq	8.95E-04	8.82E-04	uCi/ml	1.01	0.99
138098	20	1962	ICPP	liq	9.45E-04	6.14E-04	uCi/ml	1.54	0.65
138098	22	1962	ICPP	liq	5.79E-05	1.88E-03	uCi/ml	0.03	32.47
138098	23	1962	ICPP	liq	7.80E-08	3.90E-08	uCi/ml	2.00	0.50
138098	24	1962	ICPP	liq	7.95E-04	6.77E-04	uCi/ml	1.17	0.85
139151	2	1962	TAN	liq	2.16E-06	1.13E-06	uCi/ml	1.91	0.52
139151	3	1962	TAN	liq	5.20E-06	2.30E-06	uCi/ml	2.26	0.44
139151	14	1962	TRA	liq	40.9	8.1	Ci	5.05	0.20
138732	3	1963	SPERT	liq	2.97E-06	6.04E-06	none	0.49	2.03
138736	5	1963	MTR&ETR	liq	8.40E-07	5.90E-06	uCi/ml	0.14	7.02
138736	17	1963	MTR&ETR	liq	7.20E-07	3.90E-06	uCi/ml	0.18	5.42
138736	19	1963	MTR&ETR	liq	5.00E-06	2.50E-05	uCi/ml	0.20	5.00
138736	21	1963	MTR&ETR	liq	5.20E-07	9.60E-06	uCi/ml	0.05	18.46
138736	23	1963	MTR&ETR	liq	7.00E-07	9.00E-07	uCi/ml	0.78	1.29
138739	3	1963	TAN	liq	1.01E-09	2.27E-07	none	0.00	224.75
138739	7	1963	TAN	air	2.86E-11	6.10E-12	none	4.69	0.21
138739	9	1963	TAN	air	3.58E-12	1.85E-12	uCi/ml	1.94	0.52
138739	12	1963	TAN	air	5.73E-11	8.18E-11	none	0.70	1.43
138739	15	1963	TAN	air	8.30E-12	1.41E-11	uCi/ml	0.59	1.70
138739	18	1963	TAN	air	3.39E-12	2.65E-12	uCi/ml	1.28	0.78
138739	29	1963	TAN	liq	1.44E-06	2.27E-06	uCi/ml	0.63	1.58
138739	32	1963	TAN	liq	1.36E-06	1.55E-06	uCi/ml	0.88	1.14
138739	35	1963	TAN	liq	2.27E-07	1.70E-06	uCi/ml	0.13	7.49
138892	2	1963	MTR&ETR	liq	1.60E-06	1.60E-06	uCi/ml	1.00	1.00
138892	14	1963	TRA	liq	47.3	6.7	Ci	7.06	0.14
138892	14	1964	TRA	liq	17.3	4.7	Ci	3.68	0.27
138892	14	1965	TRA	liq	27.8	6.0	Ci	4.63	0.22
138892	14	1966	TRA	liq	29.2	4.0	Ci	7.30	0.14
138892	18	1966	TAN	liq	0.01	0.02	Ci	0.50	2.00
85575	10	1967	CFA	liq	4.00E-06	6.10E-06	uCi/ml	0.66	1.53
85575	19	1967	TAN	air	1.27E-11	4.10E-12	uCi/ml	3.10	0.32
85575	25	1967	CFA	liq	1.14E-06	3.10E-06	uCi/ml	0.37	2.72
85575	40	1967	TAN	liq	1.60E-07	1.58E-07	uCi/ml	1.01	0.99
85575	54	1967	TAN	liq	4.68E-07	1.48E-06	uCi/ml	0.32	3.16
85575	55	1967	TAN	air	1.89E-12	6.15E-13	uCi/ml	3.07	0.33

SRDB Ref #	Pdf #	Time period	Area	Type of waste	Meas. Sr-90	Meas. Cs-137	Units	Sr90/ Cs-137	Cs-137/ Sr-90
85575	70	1967	TAN	liq	1.05E-06	2.37E-06	uCi/ml	0.44	2.26
85575	79	1967	TAN	liq	2.38E-06	3.43E-05	none	0.07	14.41
85575	86	1967	CFA	liq	3.40E-08	3.00E-06	uCi/ml	0.01	88.24
85575	14	1967	TRA	liq	51.6	5.2	Ci	9.92	0.10
85575	18	1967	TAN	liq	0.04	0.36	Ci	0.11	9.00
85575	98	1968	TAN	liq	2.81E-07	8.46E-07	uCi/ml	0.33	3.01
85575	102	1968	TRA	liq	9.10E-07	9.14E-06	none	0.10	10.04
85575	116	1968	TAN	liq	4.20E-07	1.25E-06	uCi/ml	0.34	2.96
85575	130	1968	TAN	liq	1.88E-07	2.94E-07	uCi/ml	0.64	1.56
85575	131	1968	TAN	air	7.12E-14	4.94E-14	uCi/ml	1.44	0.69
85575	136	1968	TRA	liq	9.10E-07	3.28E-06	uCi/ml	0.28	3.60
85575	150	1968	TAN	air	4.07E-13	1.02E-13	uCi/ml	3.99	0.25
85575	163	1968	TAN	liq	4.52E-07	6.26E-07	uCi/ml	0.72	1.38
85575	165	1968	TAN	liq	2.70E-06	4.59E-05	uCi/ml	0.06	17.00
85575	180	1968	TAN	air	2.37E-13	1.02E-14	uCi/ml	23.24	0.04
85575	189	1968	TAN	liq	3.29E-06	6.13E-06	uCi/ml	0.54	1.86
85575	214	1968	TAN	air	6.16E-13	3.08E-13	uCi/ml	2.00	0.50
85575	217	1968	TAN	liq	8.10E-08	5.64E-07	uCi/ml	0.14	6.96
85575	218	1968	TAN	air	4.53E-12	7.55E-12	uCi/ml	0.60	1.67
85575	230	1968	TAN	air	1.52E-13	1.22E-13	uCi/ml	1.25	0.80
85575	231	1968	TAN	liq	2.70E-08	3.42E-07	uCi/ml	0.08	12.67
85575	243	1968	TAN	liq	1.77E-08	1.55E-07	uCi/ml	0.11	8.76
85575	244	1968	TAN	air	2.10E-13	5.10E-14	uCi/ml	4.12	0.24
85575	256	1968	TRA	liq	1.32E-07	7.17E-07	uCi/ml	0.18	5.43
85575	257	1968	TAN	air	5.54E-14	1.54E-13	uCi/ml	0.36	2.77
85575	262	1968	TAN	liq	2.17E-07	6.90E-07	uCi/ml	0.31	3.18
85575	269	1968	TRA	liq	2.34E-05	3.97E-05	uCi/ml	0.59	1.70
85575	14	1968	TRA	liq	22.0	4.2	Ci	5.24	0.19
85575	18	1968	TAN	liq	0.02	0.046	Ci	0.43	2.30
85575	14	1969	TRA	liq	32.8	11.4	Ci	2.88	0.35
85575	18	1969	TAN	liq	0.03	0.06	Ci	0.50	2.00
139839	10	1971	INEL	air	1.44E+01	1.52E+01	Ci	0.95	1.05
139839	10	1971	INEL	liq	1.47E+01	1.06E+01	Ci	1.38	0.72
139839	10	1971	INEL	solid	1.68E+01	4.01E+02	Ci	0.04	23.87
139839	43	1971	TRA	liq	2.01E-05	1.40E-05	uCi/ml	1.44	0.69
139839	46	1971	TRA	solid	-	4.298	Ci	0.23	-
139839	55	1971	TRA	air	5.97E-04	3.54E-03	Ci	0.17	5.93
139839	57	1971	TAN	liq	7.50E-08	1.97E-07	uCi/ml	0.38	2.62
139839	58	1971	TAN	solid	6.20E-01	5.34E+01	Ci	0.01	86.19
140037	9	1973	INEL	air	1.848	5.357	Ci	0.34	2.90
140037	9	1973	INEL	liq	4.475	3.931	Ci	1.14	0.88
140037	9	1973	INEL	solid	1.87E+02	8.95E+02	Ci	0.21	4.78
140037	45	1973	TRA	liq	4.16E-06	3.86E-06	uCi/ml	1.08	0.93
140037	57	1973	TAN	air	2.11E-13	5.63E-14	uCi/ml	3.75	0.27
140037	59	1973	TAN	solid	1.302	2.84E-01	Ci	4.58	0.22
140039	11	1974	INEL	air	3.195	6.731	Ci	0.47	2.11
140039	11	1974	INEL	liq	5.242	4.117	Ci	1.27	0.79
140039	11	1974	INEL	solid	1.58E+03	1.42E+03	Ci	1.11	0.90
140039	65	1974	TRA	liq	3.19E-07	3.70E-06	uCi/ml	0.09	11.58
140039	83	1974	TAN	air	1.78E-13	1.36E-13	uCi/ml	1.30	0.77
140039	84	1974	TAN	liq	7.06E-08	1.14E-08	uCi/ml	6.22	0.16
140039	85	1974	TAN	solid	1.54E+01	2.24E+02	Ci	0.07	14.58
140039	87	1974	CFA	liq	2.09E-07	2.00E-07	uCi/ml	1.05	0.96
140039	146	1974	TRA	liq	6.16E-07	5.08E-06	uCi/ml	0.12	8.25
140039	163	1974	TAN	liq	9.64E-08	1.68E-08	uCi/ml	5.75	0.17
140039	164	1974	TAN	solid	1.03E+01	1.44E+02	Ci	0.07	13.99
140039	166	1974	CFA	liq	3.18E-07	2.03E-07	uCi/ml	1.57	0.64
140040	9	1975	INEL	air	2.43E-01	5.97E-01	Ci	0.41	2.46
140040	9	1975	INEL	liq	4.74E-01	3.16	Ci	0.15	6.67
140040	9	1975	INEL	solid	2.16E+02	5.70E+02	Ci	0.38	2.64
140040	90	1975	TRA	liq	3.8	2.649	Ci	1.43	0.70
140040	95	1975	TRA	solid	-	6.16E-01	Ci	-	-
140040	109	1975	PBF	liq	4.82E-09	1.53E-07	uCi/ml	0.03	31.76
140040	114	1975	TAN	air	4.00E-14	2.24E-14	uCi/ml	1.79	0.56

SRDB Ref #	Pdf #	Time period	Area	Type of waste	Meas. Sr-90	Meas. Cs-137	Units	Sr90/ Cs-137	Cs-137/ Sr-90
140040	116	1975	TAN	liq	2.11E-08	9.55E-09	uCi/ml	2.21	0.45
140040	117	1975	TAN	solid	4.371	9.763	Ci	0.45	2.23
140040	119	1975	CFA	liq	7.31E-08	1.80E-07	uCi/ml	0.41	2.47
140040	122	1975	CPP	air	1.75E-10	4.30E-10	uCi/ml	0.41	2.46
140040	125	1975	CPP	liq	4.42E-07	4.59E-07	uCi/ml	0.96	1.04
140040	128	1975	CPP	solid	1.71E+02	5.03E+02	Ci	0.34	2.93
118841	11 to 14	1978	INEL	air	2.39E-02	8.58E-02	Ci	0.28	3.59
118841	11 to 14	1978	INEL	liq	3.972	8.966	Ci	0.44	2.26
118841	11 to 14	1978	INEL	solid	1.13E+03	2.96E+03	Ci	0.38	2.61
118841	80-81	1978	TRA	air	2.97E-05	1.01E-05	Ci	2.95	0.34
118841	82-83	1978	TRA	liq	7.15E-06	1.47E-05	uCi/ml	0.49	2.06
118841	97-98	1978	PBF	air	1.81E-14	1.16E-12	uCi/ml	0.02	63.94
118841	100-103	1978	PBF	liq	2.65E-07	2.22E-05	uCi/ml	0.01	83.89
118841	106	1978	TAN	air	2.46E-05	4.80E-05	Ci	0.51	1.95
118841	108	1978	TAN	liq	6.28E-08	1.80E-08	uCi/ml	3.48	0.29
118841	110	1978	TAN	air	3.36E-14	7.67E-14	uCi/ml	0.44	2.28
118841	112	1978	Decon	air	6.78E-15	6.26E-15	uCi/ml	1.08	0.92
118841	117	1978	TRA	air	3.43E-13	1.23E-13	uCi/ml	2.80	0.36
118841	121	1978	ICPP	air	1.56E-11	5.62E-11	uCi/ml	0.28	3.59
118841	125	1978	ICPP	liq	3.64E-07	1.24E-06	uCi/ml	0.29	3.42
118841	127	1978	ICPP	solid	1.04E+03	2.56E+03	Ci	0.41	2.46
118841	189	1978	WMC	solid	4.80E+00	1.20E+00	Ci	4.00	0.25
87191	22	1985	INEL	air	1.90E-03	6.22E-03	Ci	0.31	3.27
87191	22	1985	INEL	liq	5.08E-02	2.29E-01	Ci	0.22	4.50
87191	22	1985	INEL	solid	2.81E+01	4.68E+02	Ci	0.06	16.63
87191	93	1985	TRA	air	6.46E-16	1.67E-12	uCi/ml	0.00	2587.49
87191	97	1985	TRA	liq	3.70E-07	2.44E-06	uCi/ml	0.15	6.60
87191	109	1985	MTR	air	1.72E-15	3.41E-14	uCi/ml	0.05	19.85
87191	118	1985	TRA	air	1.77E-13	3.92E-12	uCi/ml	0.05	22.09
87191	120	1985	PBF	air	9.82E-14	1.26E-12	uCi/ml	0.08	12.87
87191	127	1985	TAN	air	1.63E-14	1.28E-15	uCi/ml	12.76	0.08
87191	130	1985	TAN	air	1.96E-13	1.44E-14	uCi/ml	13.58	0.07
87191	133	1985	CFA	air	5.76E-14	5.17E-14	uCi/ml	1.11	0.90
87191	154	1985	CPP	air	5.68E-13	1.32E-12	uCi/ml	0.43	2.33
87191	157	1985	CPP	liq	1.07E-08	1.40E-08	uCi/ml	0.77	1.31
87191	160	1985	CPP	solid	9.713	9.713	Ci	1.00	1.00
87191	162	1985	CPP	liq	4.56E-10	1.59E-09	uCi/ml	0.29	3.49
87191	164	1985	CPP	liq	1.07E-08	1.40E-08	uCi/ml	0.77	1.31
87191	167	1985	CPP	air	1.32E-11	3.13E-11	uCi/ml	0.42	2.37
88069	185	1991	CFA	air	4.55E-15	6.99E-16	uCi/ml	6.51	0.15
88069	192	1991	CFA	air	4.55E-15	7.55E-16	uCi/ml	6.03	0.17
88069	206	1991	CPP	air	8.44E-13	7.16E-12	uCi/ml	0.12	8.48
88069	209	1991	CPP	liq	4.08E-09	1.06E-09	uCi/ml	3.86	0.26
88069	211	1991	CPP	solid	2.36E+00	2.36E+00	Ci	1.00	1.00
88069	236	1991	CPP	liq	4.08E-09	1.06E-09	uCi/ml	3.86	0.26
88069	305	1991	PBF	air	1.16E-15	9.51E-15	uCi/ml	0.12	8.18
88069	383	1991	TRA	air	5.07E-15	1.20E-14	uCi/ml	0.42	2.37
88069	388	1991	TRA	liq	1.09E-08	2.19E-08	uCi/ml	0.50	2.01
88069	391	1991	TRA	solid	3.58E-01	5.19E+01	Ci	0.01	144.81
88069	454	1991	WER	air	9.29E-15	1.42E-14	uCi/ml	0.65	1.53
136493	214	1993	CFA	solid	8.55E-05	7.40E-03	Ci	0.01	86.50
136493	245	1993	CPP	air	2.49E-13	1.77E-12	uCi/ml	0.14	7.09
136493	247	1993	CPP	liq	1.09E-09	8.66E-10	uCi/ml	1.26	0.79
136493	248	1993	CPP	solid	7.20E-03	7.20E-03	Ci	1.00	1.00
136493	288	1993	D&D	solid	8.27E-01	4.78E-01	Ci	1.73	0.58
136493	451	1993	TAN	air	1.55E-15	7.08E-15	uCi/ml	0.22	4.58
136493	453	1993	TAN	solid	5.41E-02	2.633	Ci	0.02	48.68
136493	480	1993	TRA	air	9.81E-16	5.29E-15	uCi/ml	0.19	5.39
136493	484	1993	TRA	liq	1.58E-06	1.11E-06	uCi/ml	1.42	0.71
136493	487	1993	TRA	solid	8.526	1.475	Ci	5.78	0.17
136493	512	1993	ATR	solid	8.526	1.475	Ci	5.78	0.17
136493	519	1993	MTR	air	7.78E-16	4.73E-16	uCi/ml	1.65	0.61
136493	522	1993	TRA	solid	-	6.30E-05	Ci	15873.02	-
136493	524	1993	TRA	liq	1.58E-06	1.11E-06	uCi/ml	1.42	0.71

SRDB Ref #	Pdf #	Time period	Area	Type of waste	Meas. Sr-90	Meas. Cs-137	Units	Sr90/ Cs-137	Cs-137/ Sr-90
136493	557	1993	WER	solid	-	3.40E-03	Ci	294.55	-
136493	578	1993	WER	solid	-	3.40E-03	Ci	294.55	-

Note: Entries with hyphens represents data points w/o Sr-90 values but contained Cs-137 & actinide values that were used in this report.