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Summary of Analytical Services for the Hanford Site Radionuclide NESHAP Program

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract 89303320DEM000031



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Summary of Analytical Services for the Hanford Site Radionuclide NESHAP Program

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TERMS AND ACRONYMS

ANSI	American National Standards Institute
BNI	Bechtel National, Inc.
CAS	Chemical Abstracts Service
CERCLA	Comprehensive Environmental Response Compensation and Liability Act of 1980
CFR	<i>Code of Federal Regulations</i>
CPCCo	Central Plateau Cleanup Company
DOE	U.S. Department of Energy
DOE-HFO	U.S. Department of Energy – Hanford Field Office
EDP	Electronic Data Processing
EU	Emission Unit
H2C	Hanford Tank Waste Operations & Closure
HLMI	Hanford Laboratory Management and Integration
HMIS	Hanford Mission Integration Solutions
HPS	Health Physics Society
ID	Identification
LSB	Laboratory Supply Building
MDA	minimum detectable activity
MDC	minimum detectable concentration
MEI	Maximally Exposed Individual
mL	milliliter
NESHAP	National Emission Standards for Hazardous Air Pollutants
pCi	picocurie
PNNL	Pacific Northwest National Laboratory
RAEL-FF-01	Radioactive Air Emissions License FF-01
RDL	Required Detection Limit
SMART	Sample Management and Analytical Results Tracking
μCi	microcurie
WAC	<i>Washington Administrative Code</i>

1.0 INTRODUCTION

This document is a summary of the point source analytical requirements used to demonstrate compliance for the Department of Energy (DOE) Hanford Site operations with 40 Code of Federal Regulations (CFR) Part 61, “National Emission Standards for Hazardous Air Pollutants,” (NESHAP) Subpart H, “National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities,” and the Washington Administrative Code (WAC) 246-247, “Radiation Protection – Air Emissions.” This reference collects information from multiple source documents and is not intended to create, supersede, replace or over-ride any existing contractual, DOE, federal or state statutes, regulations, compliance agreements, orders, permits, licenses or other requirements. The requirement source document governs where any difference may exist.

The Hanford Mission Integration Solutions (HMIS) Environmental organization has been contracted by DOE to manage and report data collected from the sampling and monitoring of radioactive air emissions point sources, colloquially called stacks. The Environmental organization coordinates the analyses and reporting of samples collected at various facilities across the Hanford Site. These facilities operate approximately 52 stacks that require sampling, monitoring or estimating radioactive air emissions. The stacks are operated by Bechtel National, Inc. (BNI), Central Plateau Cleanup Company (CPCCo), Hanford Tank Waste Operations & Closure (H2C), Hanford Laboratory Management and Integration (HLMI), and Pacific Northwest National Laboratory (PNNL). Stack samples from CPCCo, HLMI and H2C facilities are collected by the operating contractor staff, delivered to HMIS, and then shipped to an offsite contracted laboratory for analyses.

The field and laboratory sample data uploaded into the Sample Management and Analytical Results Tracking (SMART) database are used to calculate sample volumes and concentrations. Sample concentrations are evaluated for compliance with federal and state regulations, permits, and license requirements. The SMART database also calculates total curies released for sampled point sources and stacks. Point source effluent concentrations and releases are published annually in publicly available reports.

The BNI and PNNL operate several DOE-Hanford Field Office (HFO) stacks subject to the requirements of 40 CFR 61, Subpart H and WAC 246-247. The concentrations, curies released and dose modeling evaluation for these stacks are included in the DOE-HFO annual radionuclide NESHAP report. The sample collection, analyses and emissions estimates for these stacks are outside the scope of HMIS contracted responsibilities and not addressed further in this document.

2.0 ANALYTICAL REQUIREMENTS

Analytical criteria for radiological effluent samples originate from federal and state regulations and are specified in radioactive air emissions license or *Comprehensive Environmental Response Compensation and Liability Act* (CERCLA) air monitoring plans. The regulatory criteria for continuous sampling of release points which have a potential to discharge radionuclides into the air in quantities which could cause an effective dose equivalent greater than 0.1 mrem per year to the maximally exposed individual (MEI) are:

- All radionuclides which could contribute greater than 10% of the potential effective dose equivalent (40 CFR 61, WAC 246-247)
- Each radionuclide that could contribute greater than 0.1 mrem per year potential-to-emit effective dose equivalent (WAC 246-247)
- Each radionuclide that could contribute greater than 25% of the effective dose equivalent after abatement controls (WAC 246-247).

For other release points, periodic confirmatory measurements are made to verify low emissions (40 CFR 61, WAC 246-247).

3.0 CONTRACTED ANALYTICAL SERVICES

Analytical services for effluent radiological samples are contracted by HMIS through a statement of work with the GEL Laboratories Group. A summary of analytical laboratory procedures compared to the principles of measurement specified in the federal regulation is documented in HNF-60182, *Test Methods for Measuring Radionuclide Emissions from Stationary Sources*. Table 1 contains contract-required detection limits specified in the analytical laboratory statement of work. Appendix A calculates the minimum estimated offsite dose from a single stack assuming typical sample collection and analyses assuming all samples contain radionuclide quantities equal to the required detection limit for each isotope.

Table 1. Contract Required Detection Limits.

Chemical Abstract Services # (CAS)	Name	RDL ^a (pCi ^b /sample)	MDC ^c (μCi/mL) ^d
12587-46-1	Gross alpha	0.5	8.8E-16
12587-47-2	Gross beta	1.1	1.9E-15
14133-76-7	Technetium-99	100	1.3E-14
15046-84-1	Iodine-129	19	3.4E-14
14119-32-5	Plutonium-241	74	1.0E-14
10098-97-2	Strontium-90	1.0	1.3E-16
10045-97-3	Cesium-137	14	1.9E-15
14596-10-2	Americium-241	1.4	1.9E-16
13981-16-3	Plutonium-238	1.5	2.0E-16
PU-239/240	Plutonium-239/240	1.5	2.0E-16

^a RDL = Required detection limit *a priori* (before the fact) determination.

^b pCi = picocurie.

^c MDC = Minimum detectable concentration equals the RDL divided by typical sample volumes assuming 20,000 cubic feet for gross beta, gross alpha, and iodine analyses and 262,000 cubic feet for other isotopic analyses.

^d μCi/mL = microcurie per milliliter.

4.0 FACILITY SPECIFIC STACK INFORMATION

Tables 2 and 3 present information specific to Hanford contractor operated stacks. Table 2 shows the unique identifiers used to index the sample locations and release points. Within the SMART database, the identifiers defined as “SYS_LOC_CODE” are also sometimes referred to as ‘Location Codes’. This list of codes helps users find specific stack sample results in the database. Where possible, current location codes are identical to historical database parameters used for indexing previously called *Electronic Data Processing* (EDP) codes.

Table 2. Sample Location Codes. (3 pages)

Location Code(s)	Stack Identification Number	DOH ^a EU ID	Facility	Operations Contractor
A006	291-A-1	369	PUREX	CPCCo
A007 ^b				
B001	296-B-1	402	B Plant	CPCCo
B748	296-B-10	340	WESF	CPCCo
C601	296-H-212	435	CSB	CPCCo
E015	296-A-41	205	241-AP Tank Farm Annuli	H2C
E035 ^b	296-E-1	301	ETF	H2C
E036				
E060	296-A-18	217	241-AY-101 Annulus	H2C
E100	296-P-49	885	241-AX Tank Farm Waste Retrieval Exhauster	H2C
E102	296-P-50	886	241-AX Tank Farm Waste Retrieval Exhauster	H2C
E106	296-P-71	1524	241-A Tank Farm Waste Retrieval Exhauster	H2C
E108	296-P-75	1525	241-A Tank Farm Waste Retrieval Exhauster	H2C
E147	296-A-42	93	241-AY/AZ Tank Farm Primary Exhauster	H2C
E148	296-A-43	216	702AZ Building Exhauster	H2C
E197	296-A-20	174	241-AZ Tank Farm Annuli	H2C
E272	296-A-28	156	241-AW Tank Farm Annuli	H2C
E340	219-S	447	219-S PTRAEU	HLMI

Table 2. Sample Location Codes. (3 pages)

Location Code(s)	Stack Identification Number	DOH^a EU ID	Facility	Operations Contractor
E643	296-A-22	142	242A Evaporator Vessel Vent	H2C
E651	296-A-21A	1294	242A Building Vent	H2C
E903	296-A-30	228	241-AN Tank Farm Annuli	H2C
E920	296-A-44	735	241-AN Tank Farm Primary Exhauster	H2C
E922	296-A-45	736	241-AN Tank Farm Primary Exhauster	H2C
E924	296-A-46	855	241-AW Tank Farm Primary Exhauster	H2C
E926	296-A-47	856	241-AW Tank Farm Primary Exhauster	H2C
E986	296-A-48	1328	241-AP Tank Farm Primary Exhauster	H2C
E988	296-A-49	1329	241-AP Tank Farm Primary Exhauster	H2C
F011	FFTF-CB-EX	397	FFTF Combined Exhaust	CPCCo
F014	437-MN&ST	385	FFTF MASF	CPCCo
F019	437-1-61	399	FFTF MASF	CPCCo
F025	EP-324-01-S	N/A	324 Building	CPCCo
S006	291-S-1	N/A	S Plant	CPCCo
S032	296-S-2	N/A	S Plant	CPCCo
S264	296-S-16	337	219-S	HLMI
S289	296-S-21	254	222-S Ventilation	HLMI
T154	296-T-7	315	2706T	CPCCo
T785	291-T-1	314	T Plant	CPCCo
W123	296-W-4	193	WRAP	CPCCo
W130	CWC	439	Central Waste Complex	CPCCo
W152	296-S-26	1335	241-SY Tank Farm Primary Exhauster	H2C

Table 2. Sample Location Codes. (3 pages)

Location Code(s)	Stack Identification Number	DOH ^a EU ID	Facility	Operations Contractor
W154	296-S-27	1342	241-SY Tank Farm Primary Exhauster	H2C
W191	296-P-22	53	241-SY Tank Farm Annuli	H2C
None	EP-325-01-S	361	325 Radiochemical Processing Laboratory	PNNL
None	EP-331-01-V	412	331 Life Sciences Laboratory	PNNL
None	EP-331-09-S	1370	331 Life Sciences Laboratory	PNNL
None	LB-C2	557	WTP Analytical Laboratory, C2 Area	BNI
None	LB-S1	558	WTP Analytical Laboratory, C3 Area	BNI
None	LB-S2	559	WTP Analytical Laboratory, C5 Area	BNI
None	EM-1	1550	EMF Process Offgas	BNI
None	EM-2	2553	EMF Tank Truck Offloading	BNI
None	LV-C2	548	WTP LAW Facility, C2 Area	BNI
None	LV-S1	549	WTP LAW Facility, C3 Area	BNI
None	LV-S2	550	WTP LAW Facility, C5 Area	BNI
None	LV-S3	547	WTP LAW Facility, Melters 1 & 2	BNI

^aDOH EU ID = Department of Health Emission Unit Identification^bA007, E035 = Location codes used for Iodine-129 results

CSB = Canister Storage Building

CWC = Central Waste Complex

EMF = Effluent Management Facility

ETF = Effluent Treatment Facility

FFTF = Fast Flux Test Facility

LAW = Low Activity Waste

MASF = Maintenance and Storage Facility

PUREX = Plutonium Uranium Extraction Plant

PTRAEU = Portable Temporary Radioactive Air Emissions Unit

WESF = Waste Encapsulation and Storage Facility

WTP = Waste Treatment Plant

Table 3 lists provides an estimate of the number of samples collected and the type and number of analyses requested for the calendar year.

Table 3. Estimated Sample Collection and Analyses, Calendar Year 2026. (3 pages)

Location	Stack ID	Location Code	Sampling Frequency	Annual Sample Collection (Typical)	Gross Alpha Gross Beta	¹²⁹ I	Gamma Energy Analysis	⁹⁰ Sr	Isotopic Plutonium	²⁴¹ Pu	²⁴¹ Am
PUREX	291-A-1	A006 A007	Continuous	26	26	26	4	4	4	4	4
B Plant	296-B-1	B001	Continuous	20	20	0	4	4	4	0	4
WESF	296-B-10	B748	4 week sample/yr	8	8	0	4	4	4	0	4
East Tank Farms	296-A-18	E060	1 week sample/4 times per year	10	10	0	0	0	0	0	0
	296-A-20	E197	1 week sample/4 times per year	10	10	0	0	0	0	0	0
	296-A-28	E272	1 week sample/4 times per year	10	10	0	0	0	0	0	0
	296-A-30	E903	1 week sample/4 times per year	10	10	0	0	0	0	0	0
	296-A-41	E015	1 week sample/4 times per year	12	12	0	0	0	0	0	0
	296-A-42	E147	Continuous during operation	12	12	0	2	2	2	2	2
	296-A-43	E148	1 week sample/4 times per year	12	12	0	0	0	0	0	0
	296-A-44	E920	Continuous during operation	12	12	0	2	2	2	2	2
	296-A-45	E922	Continuous during operation	12	12	0	2	2	2	2	2
	296-A-46	E924	Continuous during operation	12	12	0	2	2	2	2	2
	296-A-47	E926	Continuous during operation	12	12	0	2	2	2	2	2
	296-A-48	E986	Continuous during operation	12	12	0	2	2	2	2	2
	296-A-49	E988	Continuous during operation	12	12	0	2	2	2	2	2

Table 3. Estimated Sample Collection and Analyses, Calendar Year 2026. (3 pages)

Location	Stack ID	Location Code	Sampling Frequency	Annual Sample Collection (Typical)	Gross Alpha Gross Beta	¹²⁹ I	Gamma Energy Analysis	⁹⁰ Sr	Isotopic Plutonium	²⁴¹ Pu	²⁴¹ Am
East Tank Farms	296-P-49	E100	Continuous during operation	10	10	0	2	2	2	2	2
	296-P-50	E102	Continuous during operation	10	10	0	2	2	2	2	2
	296-P-71	E106	Continuous during operation	12	12	0	2	2	2	2	2
	296-P-75	E108	Continuous during operation	12	12	0	2	2	2	2	2
242A Evaporator	296-A-21A	E651	1 week sample/4 times per year	20	20	0	0	0	0	0	0
	296-A-22	E643	1 week sample/4 times per year, continuous sampling during campaign	20	20	0	2	2	2	2	2
CSB	296-H-212	C601	Continuous	12	12	0	4	4	4	4	4
ETF	296-E-1	E035 E036	*1 week sample/4 times per year	4	4	4	0	0	0	0	0
222-S Laboratory	296-S-16	S264	1 week sample/4 times per year	26	26	0	0	0	0	0	0
	296-S-21	S289	Continuous during operation	26	26	0	2	2	2	2	2
	219S PTRAEU	E340	None	6	6	0	0	0	0	0	0
S Plant	291-S-1	S006	Continuous	26	26	0	4	4	4	0	4
T Plant	291-T-1	T785	Continuous	26	26	0	4	4	4	0	4
	296-T-7	T154	Continuous when vent is operating	12	12	0	1	1	1	0	1
West Tank Farms	296-P-22	W191	1 week sample/4 times per year	6	6	0	0	0	0	0	0
	296-S-26	W152	Continuous during operation	20	20	0	2	2	2	2	2

Table 3. Estimated Sample Collection and Analyses, Calendar Year 2026. (3 pages)

Location	Stack ID	Location Code	Sampling Frequency	Annual Sample Collection (Typical)	Gross Alpha Gross Beta	¹²⁹ I	Gamma Energy Analysis	⁹⁰ Sr	Isotopic Plutonium	²⁴¹ Pu	²⁴¹ Am
West Tank Farms	296-S-27	W154	Continuous during operation	20	20	0	2	2	2	2	2
WRAP	296-W-4	W123	4 week sample/year	10	10	0	1	1	1	1	1
Fast Flux FFTF	437-MN&ST	F014	4 week sample/year	1	1	0	0	0	0	0	0
	437-1-61	F019	4 week sample/year	1	1	0	0	0	0	0	0
324 Building	EP-324-01-S	F025	Continuous	12	12	0	4	4	4	0	4
CWC	Inside CWC building	W130	Quarterly for two week interval	4	4	0	0	0	0	0	0
Totals				498	498	30	60	60	60	39	60

* Defined as any combination of sampling periods whose sum is equivalent to 28 days of emission unit operating time.

CSB = Canister Storage Building
 CWC = Central Waste Complex
 ETF = Effluent Treatment Facility
 FFTF = Fast Flux Test Facility

PUREX = Plutonium Uranium Extraction Plant
 PTRAEU = Portable Temporary Radioactive Air Emissions Unit
 WESF = Waste Encapsulation and Storage Facility
 WRAP = Waste Receiving and Processing Facility

Table 4 presents the analytical requirements specified for radiological stack samples and the originating source document for those requirements. Analytical sample requirements come from stack specific radioactive air emission licenses, the Hanford Site Radioactive Air Emissions License, and CERCLA air monitoring plans. At a minimum, gross alpha and gross beta analyses are performed for all individual stack samples to ensure the estimated offsite doses include contributions from any radionuclides that are not specifically measured. Isotopic analyses are performed by combining individual samples into a quarterly or semi-annual composite. Compositing air samples results in larger sample collection volumes and lower detection levels for individual isotopes. As a best management practice, most samples collected from stacks with continuous sampling requirements are analyzed for a common suite of isotopes that is cesium-137, strontium-90, isotopic plutonium and americium-241.

Table 4. Radiological Stack Sample Analyses. (2 pages)

Stack ID	Facility	Individual Sample Analyses	Additional Analyses	Additional Analytical Requirements	Source Document
291-A-1	PUREX	Alpha, Beta, 129I	239/240Pu, 241Am	Sampled continuously and analyzed every two weeks for gross alpha/beta, composited quarterly and analyzed isotopically	RAEL-FF-01
296-A-18	241-AY-101 Annulus	Alpha, Beta	None	None	RAEL-FF-01
296-A-20	241-AZ Tank Farm Annuli	Alpha, Beta	None	None	RAEL-FF-01
296-A-21A	242A Building Vent	Alpha, Beta	None	None	RAEL-FF-01
296-A-22	242A Evaporator Vessel Vent	Alpha, Beta	137Cs, 90Sr, 90Y, 154Eu, 238Pu, 239/240Pu, 241Pu, 241Am	None	RAEL-FF-01
296-A-28	241-AW Tank Farm Annuli	Alpha, Beta	None	None	RAEL-FF-01
296-A-30	241-AN Tank Farm Annuli	Alpha, Beta	None	None	RAEL-FF-01
296-A-41	241-AP Tank Farm Annuli	Alpha, Beta	None	None	RAEL-FF-01
296-A-42	241-AY/AZ Tank Farm	Alpha, Beta	90Sr, 90Y, 137Cs, 154Eu, 238Pu, 239/240Pu, 241Am, 241Pu	None	RAEL-FF-01
296-A-43	702AZ Building Exhauster	Alpha, Beta	None	None	RAEL-FF-01
296-A-44	241-AN Tank Farm	Alpha, Beta	90Sr, 90Y, 137Cs, 154Eu, 238Pu, 239/240Pu, 241Am, 241Pu	None	RAEL-FF-01
296-A-45	241-AN Tank Farm	Alpha, Beta	90Sr, 90Y, 137Cs, 154Eu, 238Pu, 239/240Pu, 241Am, 241Pu	None	RAEL-FF-01
296-A-46	241-AW Tank Farm	Alpha, Beta	90Sr, 90Y, 137Cs, 154Eu, 238Pu, 239/240Pu, 241Am, 241Pu	None	RAEL-FF-01
296-A-47	241-AW Tank Farm	Alpha, Beta	90Sr, 90Y, 137Cs, 154Eu, 238Pu, 239/240Pu, 241Am, 241Pu	None	RAEL-FF-01
296-A-48	241-AP Tank Farm	Alpha, Beta	90Sr, 90Y, 137Cs, 154Eu, 238Pu, 239/240Pu, 241Am, 241Pu	None	RAEL-FF-01
296-A-49	241-AP Tank Farm	Alpha, Beta	90Sr, 90Y, 137Cs, 154Eu, 238Pu, 239/240Pu, 241Am, 241Pu	None	RAEL-FF-01
296-B-1	B Plant	Alpha, Beta	137Cs, 90Sr	Samples analyzed every two weeks for gross alpha/beta, composited quarterly and analyzed isotopically	RAEL-FF-01
296-B-10	WESF	Alpha, Beta	137Cs, 90Sr	137Cs, 90Sr	RAEL-FF-01

Table 4. Radiological Stack Sample Analyses. (2 pages)

Stack ID	Facility	Individual Sample Analyses	Additional Analyses	Additional Analytical Requirements	Source Document
296-E-1	Effluent Treatment Facility	Alpha, Beta, 129I	None	None	RAEL-FF-01
FFTF-CB-EX	FFTF	None	Emissions estimated by calculation	Emissions will be estimated annually using the Radionuclide Air Emissions Report in lieu of monitoring	RAEL-FF-01
437-MN&ST	FFTF MASF	Alpha, Beta	None	None	RAEL-FF-01
437-1-61	FFTF MASF	Alpha, Beta	None	None	RAEL-FF-01
296-H-212	CSB	Alpha, Beta	90Sr, 137Cs, 238Pu, 239/240Pu, 241Am, 241Pu	Record sample is replaced monthly and analyzed quarterly using a gamma spectrometer calibrated to Cs-137	HNF-7880
296-P-22	241-SY Tank Farm Annuli	Alpha, Beta	None	None	RAEL-FF-01
296-P-49	241-AX Tanks Exhauster	Alpha, Beta	90Sr, 90Y, 137Cs, 154Eu, 238Pu, 239/240Pu, 241Pu, 241Am	None	RAEL-FF-01
296-P-50	241-AX Tanks Exhauster	Alpha, Beta	90Sr, 90Y, 137Cs, 154Eu, 238Pu, 239/240Pu, 241Pu, 241Am	None	RAEL-FF-01
296-P-71	241-A Tanks Exhauster	Alpha, Beta	90Sr, 90Y, 137Cs, 154Eu, 238Pu, 239/240Pu, 241Am, 241Pu	None	RAEL-FF-01
296-P-75	241-A Tanks Exhauster	Alpha, Beta	90Sr, 90Y, 137Cs, 154Eu, 238Pu, 239/240Pu, 241Am, 241Pu	None	RAEL-FF-01
291-S-1 ^a	S Plant	Alpha, Beta	90Sr, 239/240Pu	None	DOE/RL-2018-46 Rev3
296-S-16	219-S	Alpha, Beta	None	None	RAEL-FF-01
296-S-21	222-S	Alpha, Beta	90Sr, 90Y, 137Cs, 154Eu, 238Pu, 239/240Pu, 241Pu, 241Am	None	RAEL-FF-01
296-S-23	219-S Building	None	Emissions estimated by calculation	The radionuclide emissions will be determined using 40 CFR 61, Appendix D calculations in lieu of monitoring.	RAEL-FF-01
296-S-26	241-SY Tank Farm	Alpha, Beta	90Sr, 90Y, 137Cs, 154Eu, 238Pu, 239/240Pu, 241Pu, 241Am	None	RAEL-FF-01
296-S-27	241-SY Tank Farm	Alpha, Beta	90Sr, 90Y, 137Cs, 154Eu, 238Pu, 239/240Pu, 241Pu, 241Am	None	RAEL-FF-01
291-T-1	T Plant	Alpha, Beta	90Sr, 137Cs, 239/240Pu, 241Am	Samples analyzed every two weeks for gross alpha/beta, composited quarterly and analyzed isotopically	DOE/RL-2004-50 Rev0
296-T-7	2706T	Alpha, Beta	137Cs, 239/240Pu, 241Am	Samples collected monthly when ventilation system operated, samples composited and analyzed quarterly	DOE/RL-2004-76 Rev0
296-W-4	WRAP	Alpha, Beta	Each radionuclide that could contribute greater than 10% of the potential TEDE	None	RAEL-FF-01
EP-324-01-S ^a	324 Building	Alpha, Beta	90Sr, 90Y, 137Cs, 137Ba, 241Am	None	DOE/RL-2004-77 Rev3A

^aCERCLA requirements applicable.

CSB = Canister Storage Building
 PTRAEU = Portable Temporary Radioactive Air Emissions Unit
 ETF = Effluent Treatment Facility
 PUREX = Plutonium Uranium Extraction Plant

MASF = Maintenance and Storage Facility
 WRAP = Waste Receiving and Processing Facility
 FFTF = Fast Flux Test Facility
 WESF = Waste Encapsulation Storage Facility
 TEDE = Total Effective Dose Equivalent

5.0 REFERENCES

- 40 CFR 61, “National Emissions Standards for Hazardous Air Pollutants,” Subpart H “National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities,” *Code of Federal Regulations*, as amended.
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- WAC 246-247, “Radiation Protection – Air Emissions,” *Washington Administrative Code*, as amended.

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APPENDIX A

**Offsite Doses for Emissions Estimates from Samples
Containing Minimum Detectable Activity**

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The sample analysis minimum detectable activity (MDA) needed to demonstrate compliance with offsite dose limits is unique to each release point location, ventilation flow rate, sample flow rate, sample volume, and target radionuclide. The purpose of this Appendix is to illustrate the smallest offsite dose that can be estimated using typical sample collection and analysis techniques. Definitively demonstrating compliance with doses smaller than those listed in Table A-1 could potentially require longer sample collection times, larger sample volumes, longer counting times, different analytical procedures, or lower levels of ambient background radiation.

The MDA for each radionuclide can be estimated using the below formula adapted from PNNL-12157, Rev.1 *Facility Effluent Monitoring Plan for the 325 Radiochemical Processing Laboratory* published in calendar year 2001. Although the PNNL-12157 document is no longer maintained, this formula is still technically valid.

$$MDA = \frac{DOD \times SF \times FYS \times SEF \times 1E12}{DF}$$

where:

- MDA = Minimum detectable activity on a sample (pCi/sample)
- DOD = Offsite dose to be detected via sampling (mrem/year)
- SF = Sampling fraction (unitless ratio of sample volume to exhaust volume during sample collection)
- FYS = Fraction of year represented by sample (year/sample)
- SEF = Sampler efficiency factor (unitless fraction)
- 1E12 = Conversion factor from curies to picocuries
- DF = Unit release dose factor for source-receptor combination (mrem/Curie).

Rearranging the terms to solve for DOD the formula becomes:

$$DOD = \frac{MDA \times DF}{SF \times FYS \times SEF \times 1E12}$$

The assumptions used in the above formula are:

- MDA values equal Table 1 Contract Required Detection Limits
- Release rates are relatively constant throughout the year
- The radioactive decay half-life for any individual radioisotope is long enough such that ignoring decay times during sample collection, sample storage, and sample analyses does not significantly underestimate the measured value
- The offsite location of interest is the Laboratory Supply Building (LSB), an offsite business located on the PNNL Richland campus at 3350 George Washington Way, Richland, Washington
- DF values equal DOE/RL-2025-07 Table C-3
- SEF = 0.5 (minimum collection efficiency from American National Standards Institute (ANSI) N13.1 – 1999 clause 6.5)
- The isotopes of interest (Sr90, Cs137, Pu238, Pu239/240, Pu241, Am241) are assumed present at MDA quantities on all samples; I129 is assumed present only in the 200E flow rate typical of PUREX ventilation system operation
- Gross alpha and gross beta emitters are present and assumed to be Pu239/240 and Cs137 respectively, for dose calculation purposes.

Table A-1 displays the estimated offsite doses at the LSB MEI location for each Hanford Site operating area resulting from various ventilation flow rates typical of existing point source operations.

REFERENCES:

ANSI/HPS N13.1-1999, 1999, *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities*, Health Physics Society, McLean, Virginia.

DOE/RL-2025-07, 2025, *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2024*, Rev.0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

PNNL-12157, 2001, *Facility Effluent Monitoring Plan for the 325 Radiochemical Processing Laboratory*, Rev.1, Pacific Northwest National Laboratory, Richland, Washington.

Table A-1. Offsite Dose for Emissions Estimates from Stack Samples Containing Radionuclides at Minimum Detectable Activity

Area	Analysis Type	Minimum Detectable Activity (MDA) (pCi/sample)	Nominal Sample Period (weeks)	Sample Flow Rate (cfm)	Stack Flow Rate (cfm)	Minimum Sample Fraction (SF)	Fraction of Year Sampled (FYS)	Minimum Sampler Efficiency Factor (SEF)	Radionuclide Decay Factor (RDF)	Unit Release Dose Factor (mrem/Ci/yr) (DF)	Offsite Dose (mrem/yr) (DOD)	Offsite Dose (mrem/yr)
200E	Gross Beta	1.1E+00	4	2.0	100	2.0E-02	0.077	0.5	1	4.0E-02	5.6E-11	3.8E-09
	Gross Alpha	5.0E-01	4	2.0	100	2.0E-02	0.077	0.5	1	4.0E-01	2.6E-10	
	Sr90	1.0E+00	4	2.0	100	2.0E-02	0.077	0.5	1	3.2E-02	4.1E-11	
	Cs137	1.4E+01	4	2.0	100	2.0E-02	0.077	0.5	1	4.0E-02	7.2E-10	
	Pu238	1.5E+00	4	2.0	100	2.0E-02	0.077	0.5	1	3.6E-01	7.0E-10	
	Pu239/240	1.5E+00	4	2.0	100	2.0E-02	0.077	0.5	1	4.0E-01	7.7E-10	
	Am241	1.4E+00	4	2.0	100	2.0E-02	0.077	0.5	1	3.3E-01	6.0E-10	
	Pu241	7.4E+01	4	2.0	100	2.0E-02	0.077	0.5	1	7.2E-03	6.9E-10	
200E	Gross Beta	1.1E+00	4	2.0	500	4.0E-03	0.077	0.5	1	4.0E-02	2.8E-10	1.9E-08
	Gross Alpha	5.0E-01	4	2.0	500	4.0E-03	0.077	0.5	1	4.0E-01	1.3E-09	
	Sr90	1.0E+00	4	2.0	500	4.0E-03	0.077	0.5	1	3.2E-02	2.0E-10	
	Cs137	1.4E+01	4	2.0	500	4.0E-03	0.077	0.5	1	4.0E-02	3.6E-09	
	Pu238	1.5E+00	4	2.0	500	4.0E-03	0.077	0.5	1	3.6E-01	3.5E-09	
	Pu239/240	1.5E+00	4	2.0	500	4.0E-03	0.077	0.5	1	4.0E-01	3.9E-09	
	Am241	1.4E+00	4	2.0	500	4.0E-03	0.077	0.5	1	3.3E-01	3.0E-09	
	Pu241	7.4E+01	4	2.0	500	4.0E-03	0.077	0.5	1	7.2E-03	3.5E-09	
200E	Gross Beta	1.1E+00	4	2.0	1,000	2.0E-03	0.077	0.5	1	4.0E-02	5.6E-10	3.8E-08
	Gross Alpha	5.0E-01	4	2.0	1,000	2.0E-03	0.077	0.5	1	4.0E-01	2.6E-09	
	Sr90	1.0E+00	4	2.0	1,000	2.0E-03	0.077	0.5	1	3.2E-02	4.1E-10	
	Cs137	1.4E+01	4	2.0	1,000	2.0E-03	0.077	0.5	1	4.0E-02	7.2E-09	
	Pu238	1.5E+00	4	2.0	1,000	2.0E-03	0.077	0.5	1	3.6E-01	7.0E-09	
	Pu239/240	1.5E+00	4	2.0	1,000	2.0E-03	0.077	0.5	1	4.0E-01	7.7E-09	
	Am241	1.4E+00	4	2.0	1,000	2.0E-03	0.077	0.5	1	3.3E-01	6.0E-09	
	Pu241	7.4E+01	4	2.0	1,000	2.0E-03	0.077	0.5	1	7.2E-03	6.9E-09	

Table A-1. Offsite Dose for Emissions Estimates from Stack Samples Containing Radionuclides at Minimum Detectable Activity

Area	Analysis Type	Minimum Detectable Activity (MDA) (pCi/sample)	Nominal Sample Period (weeks)	Sample Flow Rate (cfm)	Stack Flow Rate (cfm)	Minimum Sample Fraction (SF)	Fraction of Year Sampled (FYS)	Minimum Sampler Efficiency Factor (SEF)	Radionuclide Decay Factor (RDF)	Unit Release Dose Factor (mrem/Ci/yr) (DF)	Offsite Dose (mrem/yr) (DOD)	Offsite Dose (mrem/yr)
200E	Gross Beta	1.1E+00	4	2.0	2,000	1.0E-03	0.077	0.5	1	4.0E-02	1.1E-09	7.7E-08
	Gross Alpha	5.0E-01	4	2.0	2,000	1.0E-03	0.077	0.5	1	4.0E-01	5.1E-09	
	Sr90	1.0E+00	4	2.0	2,000	1.0E-03	0.077	0.5	1	3.2E-02	8.2E-10	
	Cs137	1.4E+01	4	2.0	2,000	1.0E-03	0.077	0.5	1	4.0E-02	1.4E-08	
	Pu238	1.5E+00	4	2.0	2,000	1.0E-03	0.077	0.5	1	3.6E-01	1.4E-08	
	Pu239/240	1.5E+00	4	2.0	2,000	1.0E-03	0.077	0.5	1	4.0E-01	1.5E-08	
	Am241	1.4E+00	4	2.0	2,000	1.0E-03	0.077	0.5	1	3.3E-01	1.2E-08	
	Pu241	7.4E+01	4	2.0	2,000	1.0E-03	0.077	0.5	1	7.2E-03	1.4E-08	
200E	Gross Beta	1.1E+00	4	2.0	3,000	6.7E-04	0.077	0.5	1	4.0E-02	1.7E-09	1.2E-07
	Gross Alpha	5.0E-01	4	2.0	3,000	6.7E-04	0.077	0.5	1	4.0E-01	7.7E-09	
	Sr90	1.0E+00	4	2.0	3,000	6.7E-04	0.077	0.5	1	3.2E-02	1.2E-09	
	Cs137	1.4E+01	4	2.0	3,000	6.7E-04	0.077	0.5	1	4.0E-02	2.2E-08	
	Pu238	1.5E+00	4	2.0	3,000	6.7E-04	0.077	0.5	1	3.6E-01	2.1E-08	
	Pu239/240	1.5E+00	4	2.0	3,000	6.7E-04	0.077	0.5	1	4.0E-01	2.3E-08	
	Am241	1.4E+00	4	2.0	3,000	6.7E-04	0.077	0.5	1	3.3E-01	1.8E-08	
	Pu241	7.4E+01	4	2.0	3,000	6.7E-04	0.077	0.5	1	7.2E-03	2.1E-08	
200E	Gross Beta	1.1E+00	4	2.0	4,000	5.0E-04	0.077	0.5	1	4.0E-02	2.3E-09	1.5E-07
	Gross Alpha	5.0E-01	4	2.0	4,000	5.0E-04	0.077	0.5	1	4.0E-01	1.0E-08	
	Sr90	1.0E+00	4	2.0	4,000	5.0E-04	0.077	0.5	1	3.2E-02	1.6E-09	
	Cs137	1.4E+01	4	2.0	4,000	5.0E-04	0.077	0.5	1	4.0E-02	2.9E-08	
	Pu238	1.5E+00	4	2.0	4,000	5.0E-04	0.077	0.5	1	3.6E-01	2.8E-08	
	Pu239/240	1.5E+00	4	2.0	4,000	5.0E-04	0.077	0.5	1	4.0E-01	3.1E-08	
	Am241	1.4E+00	4	2.0	4,000	5.0E-04	0.077	0.5	1	3.3E-01	2.4E-08	
	Pu241	7.4E+01	4	2.0	4,000	5.0E-04	0.077	0.5	1	7.2E-03	2.8E-08	

Table A-1. Offsite Dose for Emissions Estimates from Stack Samples Containing Radionuclides at Minimum Detectable Activity

Area	Analysis Type	Minimum Detectable Activity (MDA) (pCi/sample)	Nominal Sample Period (weeks)	Sample Flow Rate (cfm)	Stack Flow Rate (cfm)	Minimum Sample Fraction (SF)	Fraction of Year Sampled (FYS)	Minimum Sampler Efficiency Factor (SEF)	Radionuclide Decay Factor (RDF)	Unit Release Dose Factor (mrem/Ci/yr) (DF)	Offsite Dose (mrem/yr) (DOD)	Offsite Dose (mrem/yr)
200E	Gross Beta	1.1E+00	4	2.0	5,000	4.0E-04	0.077	0.5	1	4.0E-02	2.8E-09	1.9E-07
	Gross Alpha	5.0E-01	4	2.0	5,000	4.0E-04	0.077	0.5	1	4.0E-01	1.3E-08	
	Sr90	1.0E+00	4	2.0	5,000	4.0E-04	0.077	0.5	1	3.2E-02	2.0E-09	
	Cs137	1.4E+01	4	2.0	5,000	4.0E-04	0.077	0.5	1	4.0E-02	3.6E-08	
	Pu238	1.5E+00	4	2.0	5,000	4.0E-04	0.077	0.5	1	3.6E-01	3.5E-08	
	Pu239/240	1.5E+00	4	2.0	5,000	4.0E-04	0.077	0.5	1	4.0E-01	3.9E-08	
	Am241	1.4E+00	4	2.0	5,000	4.0E-04	0.077	0.5	1	3.3E-01	3.0E-08	
	Pu241	7.4E+01	4	2.0	5,000	4.0E-04	0.077	0.5	1	7.2E-03	3.5E-08	
200E	Gross Beta	1.1E+00	4	2.0	10,000	2.0E-04	0.077	0.5	1	4.0E-02	5.6E-09	3.8E-07
	Gross Alpha	5.0E-01	4	2.0	10,000	2.0E-04	0.077	0.5	1	4.0E-01	2.6E-08	
	Sr90	1.0E+00	4	2.0	10,000	2.0E-04	0.077	0.5	1	3.2E-02	4.1E-09	
	Cs137	1.4E+01	4	2.0	10,000	2.0E-04	0.077	0.5	1	4.0E-02	7.2E-08	
	Pu238	1.5E+00	4	2.0	10,000	2.0E-04	0.077	0.5	1	3.6E-01	7.0E-08	
	Pu239/240	1.5E+00	4	2.0	10,000	2.0E-04	0.077	0.5	1	4.0E-01	7.7E-08	
	Am241	1.4E+00	4	2.0	10,000	2.0E-04	0.077	0.5	1	3.3E-01	6.0E-08	
	Pu241	7.4E+01	4	2.0	10,000	2.0E-04	0.077	0.5	1	7.2E-03	6.9E-08	
200E	Gross Beta	1.1E+00	4	2.0	15,000	1.3E-04	0.077	0.5	1	4.0E-02	8.5E-09	5.8E-07
	Gross Alpha	5.0E-01	4	2.0	15,000	1.3E-04	0.077	0.5	1	4.0E-01	3.9E-08	
	Sr90	1.0E+00	4	2.0	15,000	1.3E-04	0.077	0.5	1	3.2E-02	6.1E-09	
	Cs137	1.4E+01	4	2.0	15,000	1.3E-04	0.077	0.5	1	4.0E-02	1.1E-07	
	Pu238	1.5E+00	4	2.0	15,000	1.3E-04	0.077	0.5	1	3.6E-01	1.1E-07	
	Pu239/240	1.5E+00	4	2.0	15,000	1.3E-04	0.077	0.5	1	4.0E-01	1.2E-07	
	Am241	1.4E+00	4	2.0	15,000	1.3E-04	0.077	0.5	1	3.3E-01	8.9E-08	
	Pu241	7.4E+01	4	2.0	15,000	1.3E-04	0.077	0.5	1	7.2E-03	1.0E-07	

Table A-1. Offsite Dose for Emissions Estimates from Stack Samples Containing Radionuclides at Minimum Detectable Activity

Area	Analysis Type	Minimum Detectable Activity (MDA) (pCi/sample)	Nominal Sample Period (weeks)	Sample Flow Rate (cfm)	Stack Flow Rate (cfm)	Minimum Sample Fraction (SF)	Fraction of Year Sampled (FYS)	Minimum Sampler Efficiency Factor (SEF)	Radionuclide Decay Factor (RDF)	Unit Release Dose Factor (mrem/Ci/yr) (DF)	Offsite Dose (mrem/yr) (DOD)	Offsite Dose (mrem/yr)
200E	Gross Beta	1.1E+00	4	2.0	20,000	1.0E-04	0.077	0.5	1	4.0E-02	1.1E-08	7.7E-07
	Gross Alpha	5.0E-01	4	2.0	20,000	1.0E-04	0.077	0.5	1	4.0E-01	5.1E-08	
	Sr90	1.0E+00	4	2.0	20,000	1.0E-04	0.077	0.5	1	3.2E-02	8.2E-09	
	Cs137	1.4E+01	4	2.0	20,000	1.0E-04	0.077	0.5	1	4.0E-02	1.4E-07	
	Pu238	1.5E+00	4	2.0	20,000	1.0E-04	0.077	0.5	1	3.6E-01	1.4E-07	
	Pu239/240	1.5E+00	4	2.0	20,000	1.0E-04	0.077	0.5	1	4.0E-01	1.5E-07	
	Am241	1.4E+00	4	2.0	20,000	1.0E-04	0.077	0.5	1	3.3E-01	1.2E-07	
	Pu241	7.4E+01	4	2.0	20,000	1.0E-04	0.077	0.5	1	7.2E-03	1.4E-07	
200E	Gross Beta	1.1E+00	4	2.0	25,000	8.0E-05	0.077	0.5	1	4.0E-02	1.4E-08	1.6E-06
	Gross Alpha	5.0E-01	4	2.0	25,000	8.0E-05	0.077	0.5	1	4.0E-01	6.4E-08	
	Sr90	1.0E+00	4	2.0	25,000	8.0E-05	0.077	0.5	1	3.2E-02	1.0E-08	
	I129	1.9E+01	4	2.0	25,000	8.0E-05	0.077	0.5	1	1.1E-01	6.7E-07	
	Cs137	1.4E+01	4	2.0	25,000	8.0E-05	0.077	0.5	1	4.0E-02	1.8E-07	
	Pu238	1.5E+00	4	2.0	25,000	8.0E-05	0.077	0.5	1	3.6E-01	1.8E-07	
	Pu239/240	1.5E+00	4	2.0	25,000	8.0E-05	0.077	0.5	1	4.0E-01	1.9E-07	
	Am241	1.4E+00	4	2.0	25,000	8.0E-05	0.077	0.5	1	3.3E-01	1.5E-07	
	Pu241	7.4E+01	4	2.0	25,000	8.0E-05	0.077	0.5	1	7.2E-03	1.7E-07	
200E	Gross Beta	1.1E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	4.0E-02	2.8E-08	1.9E-06
	Gross Alpha	5.0E-01	4	2.0	50,000	4.0E-05	0.077	0.5	1	4.0E-01	1.3E-07	
	Sr90	1.0E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	3.2E-02	2.0E-08	
	Cs137	1.4E+01	4	2.0	50,000	4.0E-05	0.077	0.5	1	4.0E-02	3.6E-07	
	Pu238	1.5E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	3.6E-01	3.5E-07	
	Pu239/240	1.5E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	4.0E-01	3.9E-07	
	Am241	1.4E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	3.3E-01	3.0E-07	
	Pu241	7.4E+01	4	2.0	50,000	4.0E-05	0.077	0.5	1	7.2E-03	3.5E-07	

Table A-1. Offsite Dose for Emissions Estimates from Stack Samples Containing Radionuclides at Minimum Detectable Activity

Area	Analysis Type	Minimum Detectable Activity (MDA) (pCi/sample)	Nominal Sample Period (weeks)	Sample Flow Rate (cfm)	Stack Flow Rate (cfm)	Minimum Sample Fraction (SF)	Fraction of Year Sampled (FYS)	Minimum Sampler Efficiency Factor (SEF)	Radionuclide Decay Factor (RDF)	Unit Release Dose Factor (mrem/Ci/yr) (DF)	Offsite Dose (mrem/yr) (DOD)	Offsite Dose (mrem/yr)
200E	Gross Beta	1.1E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	4.0E-02	3.4E-08	3.9E-06
	Gross Alpha	5.0E-01	4	2.0	60,000	3.3E-05	0.077	0.5	1	4.0E-01	1.5E-07	
	Sr90	1.0E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	3.2E-02	2.5E-08	
	I129	1.9E+01	4	2.0	60,000	3.3E-05	0.077	0.5	1	1.1E-01	1.6E-06	
	Cs137	1.4E+01	4	2.0	60,000	3.3E-05	0.077	0.5	1	4.0E-02	4.3E-07	
	Pu238	1.5E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	3.6E-01	4.2E-07	
	Pu239/240	1.5E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	4.0E-01	4.6E-07	
	Am241	1.4E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	3.3E-01	3.6E-07	
200E	Pu241	7.4E+01	4	2.0	60,000	3.3E-05	0.077	0.5	1	7.2E-03	4.2E-07	2.9E-06
	Gross Beta	1.1E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	4.0E-02	4.2E-08	
	Gross Alpha	5.0E-01	4	2.0	75,000	2.7E-05	0.077	0.5	1	4.0E-01	1.9E-07	
	Sr90	1.0E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	3.2E-02	3.1E-08	
	Cs137	1.4E+01	4	2.0	75,000	2.7E-05	0.077	0.5	1	4.0E-02	5.4E-07	
	Pu238	1.5E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	3.6E-01	5.3E-07	
	Pu239/240	1.5E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	4.0E-01	5.8E-07	
	Am241	1.4E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	3.3E-01	4.5E-07	
200W	Pu241	7.4E+01	4	2.0	75,000	2.7E-05	0.077	0.5	1	7.2E-03	5.2E-07	4.6E-09
	Gross Beta	1.1E+00	4	2.0	100	2.0E-02	0.077	0.5	1	4.7E-02	6.7E-11	
	Gross Alpha	5.0E-01	4	2.0	100	2.0E-02	0.077	0.5	1	4.7E-01	3.1E-10	
	Sr90	1.0E+00	4	2.0	100	2.0E-02	0.077	0.5	1	3.7E-02	4.8E-11	
	Cs137	1.4E+01	4	2.0	100	2.0E-02	0.077	0.5	1	4.7E-02	8.5E-10	
	Pu238	1.5E+00	4	2.0	100	2.0E-02	0.077	0.5	1	4.3E-01	8.5E-10	
	Pu239/240	1.5E+00	4	2.0	100	2.0E-02	0.077	0.5	1	4.7E-01	9.2E-10	
	Am241	1.4E+00	4	2.0	100	2.0E-02	0.077	0.5	1	3.9E-01	7.2E-10	
	Pu241	7.4E+01	4	2.0	100	2.0E-02	0.077	0.5	1	8.6E-03	8.3E-10	

Table A-1. Offsite Dose for Emissions Estimates from Stack Samples Containing Radionuclides at Minimum Detectable Activity

Area	Analysis Type	Minimum Detectable Activity (MDA) (pCi/sample)	Nominal Sample Period (weeks)	Sample Flow Rate (cfm)	Stack Flow Rate (cfm)	Minimum Sample Fraction (SF)	Fraction of Year Sampled (FYS)	Minimum Sampler Efficiency Factor (SEF)	Radionuclide Decay Factor (RDF)	Unit Release Dose Factor (mrem/Ci/yr) (DF)	Offsite Dose (mrem/yr) (DOD)	Offsite Dose (mrem/yr)
200W	Gross Beta	1.1E+00	4	2.0	500	4.0E-03	0.077	0.5	1	4.7E-02	3.3E-10	2.3E-08
	Gross Alpha	5.0E-01	4	2.0	500	4.0E-03	0.077	0.5	1	4.7E-01	1.5E-09	
	Sr90	1.0E+00	4	2.0	500	4.0E-03	0.077	0.5	1	3.7E-02	2.4E-10	
	Cs137	1.4E+01	4	2.0	500	4.0E-03	0.077	0.5	1	4.7E-02	4.2E-09	
	Pu238	1.5E+00	4	2.0	500	4.0E-03	0.077	0.5	1	4.3E-01	4.2E-09	
	Pu239/240	1.5E+00	4	2.0	500	4.0E-03	0.077	0.5	1	4.7E-01	4.6E-09	
	Am241	1.4E+00	4	2.0	500	4.0E-03	0.077	0.5	1	3.9E-01	3.6E-09	
	Pu241	7.4E+01	4	2.0	500	4.0E-03	0.077	0.5	1	8.6E-03	4.2E-09	
200W	Gross Beta	1.1E+00	4	2.0	1,000	2.0E-03	0.077	0.5	1	4.7E-02	6.7E-10	4.6E-08
	Gross Alpha	5.0E-01	4	2.0	1,000	2.0E-03	0.077	0.5	1	4.7E-01	3.1E-09	
	Sr90	1.0E+00	4	2.0	1,000	2.0E-03	0.077	0.5	1	3.7E-02	4.8E-10	
	Cs137	1.4E+01	4	2.0	1,000	2.0E-03	0.077	0.5	1	4.7E-02	8.5E-09	
	Pu238	1.5E+00	4	2.0	1,000	2.0E-03	0.077	0.5	1	4.3E-01	8.5E-09	
	Pu239/240	1.5E+00	4	2.0	1,000	2.0E-03	0.077	0.5	1	4.7E-01	9.2E-09	
	Am241	1.4E+00	4	2.0	1,000	2.0E-03	0.077	0.5	1	3.9E-01	7.2E-09	
	Pu241	7.4E+01	4	2.0	1,000	2.0E-03	0.077	0.5	1	8.6E-03	8.3E-09	
200W	Gross Beta	1.1E+00	4	2.0	2,000	1.0E-03	0.077	0.5	1	4.7E-02	1.3E-09	9.2E-08
	Gross Alpha	5.0E-01	4	2.0	2,000	1.0E-03	0.077	0.5	1	4.7E-01	6.2E-09	
	Sr90	1.0E+00	4	2.0	2,000	1.0E-03	0.077	0.5	1	3.7E-02	9.7E-10	
	Cs137	1.4E+01	4	2.0	2,000	1.0E-03	0.077	0.5	1	4.7E-02	1.7E-08	
	Pu238	1.5E+00	4	2.0	2,000	1.0E-03	0.077	0.5	1	4.3E-01	1.7E-08	
	Pu239/240	1.5E+00	4	2.0	2,000	1.0E-03	0.077	0.5	1	4.7E-01	1.8E-08	
	Am241	1.4E+00	4	2.0	2,000	1.0E-03	0.077	0.5	1	3.9E-01	1.4E-08	
	Pu241	7.4E+01	4	2.0	2,000	1.0E-03	0.077	0.5	1	8.6E-03	1.7E-08	

Table A-1. Offsite Dose for Emissions Estimates from Stack Samples Containing Radionuclides at Minimum Detectable Activity

Area	Analysis Type	Minimum Detectable Activity (MDA) (pCi/sample)	Nominal Sample Period (weeks)	Sample Flow Rate (cfm)	Stack Flow Rate (cfm)	Minimum Sample Fraction (SF)	Fraction of Year Sampled (FYS)	Minimum Sampler Efficiency Factor (SEF)	Radionuclide Decay Factor (RDF)	Unit Release Dose Factor (mrem/Ci/yr) (DF)	Offsite Dose (mrem/yr) (DOD)	Offsite Dose (mrem/yr)
200W	Gross Beta	1.1E+00	4	2.0	3,000	6.7E-04	0.077	0.5	1	4.7E-02	2.0E-09	1.4E-07
	Gross Alpha	5.0E-01	4	2.0	3,000	6.7E-04	0.077	0.5	1	4.7E-01	9.2E-09	
	Sr90	1.0E+00	4	2.0	3,000	6.7E-04	0.077	0.5	1	3.7E-02	1.5E-09	
	Cs137	1.4E+01	4	2.0	3,000	6.7E-04	0.077	0.5	1	4.7E-02	2.5E-08	
	Pu238	1.5E+00	4	2.0	3,000	6.7E-04	0.077	0.5	1	4.3E-01	2.5E-08	
	Pu239/240	1.5E+00	4	2.0	3,000	6.7E-04	0.077	0.5	1	4.7E-01	2.8E-08	
	Am241	1.4E+00	4	2.0	3,000	6.7E-04	0.077	0.5	1	3.9E-01	2.1E-08	
	Pu241	7.4E+01	4	2.0	3,000	6.7E-04	0.077	0.5	1	8.6E-03	2.5E-08	
200W	Gross Beta	1.1E+00	4	2.0	4,000	5.0E-04	0.077	0.5	1	4.7E-02	2.7E-09	1.8E-07
	Gross Alpha	5.0E-01	4	2.0	4,000	5.0E-04	0.077	0.5	1	4.7E-01	1.2E-08	
	Sr90	1.0E+00	4	2.0	4,000	5.0E-04	0.077	0.5	1	3.7E-02	1.9E-09	
	Cs137	1.4E+01	4	2.0	4,000	5.0E-04	0.077	0.5	1	4.7E-02	3.4E-08	
	Pu238	1.5E+00	4	2.0	4,000	5.0E-04	0.077	0.5	1	4.3E-01	3.4E-08	
	Pu239/240	1.5E+00	4	2.0	4,000	5.0E-04	0.077	0.5	1	4.7E-01	3.7E-08	
	Am241	1.4E+00	4	2.0	4,000	5.0E-04	0.077	0.5	1	3.9E-01	2.9E-08	
	Pu241	7.4E+01	4	2.0	4,000	5.0E-04	0.077	0.5	1	8.6E-03	3.3E-08	
200W	Gross Beta	1.1E+00	4	2.0	5,000	4.0E-04	0.077	0.5	1	4.7E-02	3.3E-09	2.3E-07
	Gross Alpha	5.0E-01	4	2.0	5,000	4.0E-04	0.077	0.5	1	4.7E-01	1.5E-08	
	Sr90	1.0E+00	4	2.0	5,000	4.0E-04	0.077	0.5	1	3.7E-02	2.4E-09	
	Cs137	1.4E+01	4	2.0	5,000	4.0E-04	0.077	0.5	1	4.7E-02	4.2E-08	
	Pu238	1.5E+00	4	2.0	5,000	4.0E-04	0.077	0.5	1	4.3E-01	4.2E-08	
	Pu239/240	1.5E+00	4	2.0	5,000	4.0E-04	0.077	0.5	1	4.7E-01	4.6E-08	
	Am241	1.4E+00	4	2.0	5,000	4.0E-04	0.077	0.5	1	3.9E-01	3.6E-08	
	Pu241	7.4E+01	4	2.0	5,000	4.0E-04	0.077	0.5	1	8.6E-03	4.2E-08	

Table A-1. Offsite Dose for Emissions Estimates from Stack Samples Containing Radionuclides at Minimum Detectable Activity

Area	Analysis Type	Minimum Detectable Activity (MDA) (pCi/sample)	Nominal Sample Period (weeks)	Sample Flow Rate (cfm)	Stack Flow Rate (cfm)	Minimum Sample Fraction (SF)	Fraction of Year Sampled (FYS)	Minimum Sampler Efficiency Factor (SEF)	Radionuclide Decay Factor (RDF)	Unit Release Dose Factor (mrem/Ci/yr) (DF)	Offsite Dose (mrem/yr) (DOD)	Offsite Dose (mrem/yr)
200W	Gross Beta	1.1E+00	4	2.0	10,000	2.0E-04	0.077	0.5	1	4.7E-02	6.7E-09	4.6E-07
	Gross Alpha	5.0E-01	4	2.0	10,000	2.0E-04	0.077	0.5	1	4.7E-01	3.1E-08	
	Sr90	1.0E+00	4	2.0	10,000	2.0E-04	0.077	0.5	1	3.7E-02	4.8E-09	
	Cs137	1.4E+01	4	2.0	10,000	2.0E-04	0.077	0.5	1	4.7E-02	8.5E-08	
	Pu238	1.5E+00	4	2.0	10,000	2.0E-04	0.077	0.5	1	4.3E-01	8.5E-08	
	Pu239/240	1.5E+00	4	2.0	10,000	2.0E-04	0.077	0.5	1	4.7E-01	9.2E-08	
	Am241	1.4E+00	4	2.0	10,000	2.0E-04	0.077	0.5	1	3.9E-01	7.2E-08	
	Pu241	7.4E+01	4	2.0	10,000	2.0E-04	0.077	0.5	1	8.6E-03	8.3E-08	
200W	Gross Beta	1.1E+00	4	2.0	15,000	1.3E-04	0.077	0.5	1	4.7E-02	1.0E-08	6.9E-07
	Gross Alpha	5.0E-01	4	2.0	15,000	1.3E-04	0.077	0.5	1	4.7E-01	4.6E-08	
	Sr90	1.0E+00	4	2.0	15,000	1.3E-04	0.077	0.5	1	3.7E-02	7.3E-09	
	Cs137	1.4E+01	4	2.0	15,000	1.3E-04	0.077	0.5	1	4.7E-02	1.3E-07	
	Pu238	1.5E+00	4	2.0	15,000	1.3E-04	0.077	0.5	1	4.3E-01	1.3E-07	
	Pu239/240	1.5E+00	4	2.0	15,000	1.3E-04	0.077	0.5	1	4.7E-01	1.4E-07	
	Am241	1.4E+00	4	2.0	15,000	1.3E-04	0.077	0.5	1	3.9E-01	1.1E-07	
	Pu241	7.4E+01	4	2.0	15,000	1.3E-04	0.077	0.5	1	8.6E-03	1.2E-07	
200W	Gross Beta	1.1E+00	4	2.0	20,000	1.0E-04	0.077	0.5	1	4.7E-02	1.3E-08	9.2E-07
	Gross Alpha	5.0E-01	4	2.0	20,000	1.0E-04	0.077	0.5	1	4.7E-01	6.2E-08	
	Sr90	1.0E+00	4	2.0	20,000	1.0E-04	0.077	0.5	1	3.7E-02	9.7E-09	
	Cs137	1.4E+01	4	2.0	20,000	1.0E-04	0.077	0.5	1	4.7E-02	1.7E-07	
	Pu238	1.5E+00	4	2.0	20,000	1.0E-04	0.077	0.5	1	4.3E-01	1.7E-07	
	Pu239/240	1.5E+00	4	2.0	20,000	1.0E-04	0.077	0.5	1	4.7E-01	1.8E-07	
	Am241	1.4E+00	4	2.0	20,000	1.0E-04	0.077	0.5	1	3.9E-01	1.4E-07	
	Pu241	7.4E+01	4	2.0	20,000	1.0E-04	0.077	0.5	1	8.6E-03	1.7E-07	

Table A-1. Offsite Dose for Emissions Estimates from Stack Samples Containing Radionuclides at Minimum Detectable Activity

Area	Analysis Type	Minimum Detectable Activity (MDA) (pCi/sample)	Nominal Sample Period (weeks)	Sample Flow Rate (cfm)	Stack Flow Rate (cfm)	Minimum Sample Fraction (SF)	Fraction of Year Sampled (FYS)	Minimum Sampler Efficiency Factor (SEF)	Radionuclide Decay Factor (RDF)	Unit Release Dose Factor (mrem/Ci/yr) (DF)	Offsite Dose (mrem/yr) (DOD)	Offsite Dose (mrem/yr)
200W	Gross Beta	1.1E+00	4	2.0	25,000	8.0E-05	0.077	0.5	1	4.7E-02	1.7E-08	1.1E-06
	Gross Alpha	5.0E-01	4	2.0	25,000	8.0E-05	0.077	0.5	1	4.7E-01	7.7E-08	
	Sr90	1.0E+00	4	2.0	25,000	8.0E-05	0.077	0.5	1	3.7E-02	1.2E-08	
	Cs137	1.4E+01	4	2.0	25,000	8.0E-05	0.077	0.5	1	4.7E-02	2.1E-07	
	Pu238	1.5E+00	4	2.0	25,000	8.0E-05	0.077	0.5	1	4.3E-01	2.1E-07	
	Pu239/240	1.5E+00	4	2.0	25,000	8.0E-05	0.077	0.5	1	4.7E-01	2.3E-07	
	Am241	1.4E+00	4	2.0	25,000	8.0E-05	0.077	0.5	1	3.9E-01	1.8E-07	
	Pu241	7.4E+01	4	2.0	25,000	8.0E-05	0.077	0.5	1	8.6E-03	2.1E-07	
200W	Gross Beta	1.1E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	4.7E-02	3.3E-08	2.3E-06
	Gross Alpha	5.0E-01	4	2.0	50,000	4.0E-05	0.077	0.5	1	4.7E-01	1.5E-07	
	Sr90	1.0E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	3.7E-02	2.4E-08	
	Cs137	1.4E+01	4	2.0	50,000	4.0E-05	0.077	0.5	1	4.7E-02	4.2E-07	
	Pu238	1.5E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	4.3E-01	4.2E-07	
	Pu239/240	1.5E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	4.7E-01	4.6E-07	
	Am241	1.4E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	3.9E-01	3.6E-07	
	Pu241	7.4E+01	4	2.0	50,000	4.0E-05	0.077	0.5	1	8.6E-03	4.2E-07	
200W	Gross Beta	1.1E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	4.7E-02	4.0E-08	2.8E-06
	Gross Alpha	5.0E-01	4	2.0	60,000	3.3E-05	0.077	0.5	1	4.7E-01	1.8E-07	
	Sr90	1.0E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	3.7E-02	2.9E-08	
	Cs137	1.4E+01	4	2.0	60,000	3.3E-05	0.077	0.5	1	4.7E-02	5.1E-07	
	Pu238	1.5E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	4.3E-01	5.1E-07	
	Pu239/240	1.5E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	4.7E-01	5.5E-07	
	Am241	1.4E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	3.9E-01	4.3E-07	
	Pu241	7.4E+01	4	2.0	60,000	3.3E-05	0.077	0.5	1	8.6E-03	5.0E-07	

Table A-1. Offsite Dose for Emissions Estimates from Stack Samples Containing Radionuclides at Minimum Detectable Activity

Area	Analysis Type	Minimum Detectable Activity (MDA) (pCi/sample)	Nominal Sample Period (weeks)	Sample Flow Rate (cfm)	Stack Flow Rate (cfm)	Minimum Sample Fraction (SF)	Fraction of Year Sampled (FYS)	Minimum Sampler Efficiency Factor (SEF)	Radionuclide Decay Factor (RDF)	Unit Release Dose Factor (mrem/Ci/yr) (DF)	Offsite Dose (mrem/yr) (DOD)	Offsite Dose (mrem/yr)
200W	Gross Beta	1.1E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	4.7E-02	5.0E-08	3.4E-06
	Gross Alpha	5.0E-01	4	2.0	75,000	2.7E-05	0.077	0.5	1	4.7E-01	2.3E-07	
	Sr90	1.0E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	3.7E-02	3.6E-08	
	Cs137	1.4E+01	4	2.0	75,000	2.7E-05	0.077	0.5	1	4.7E-02	6.4E-07	
	Pu238	1.5E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	4.3E-01	6.3E-07	
	Pu239/240	1.5E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	4.7E-01	6.9E-07	
	Am241	1.4E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	3.9E-01	5.4E-07	
	Pu241	7.4E+01	4	2.0	75,000	2.7E-05	0.077	0.5	1	8.6E-03	6.2E-07	
300	Gross Beta	1.1E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	3.1E+00	2.2E-06	1.7E-04
	Gross Alpha	5.0E-01	4	2.0	50,000	4.0E-05	0.077	0.5	1	3.7E+01	1.2E-05	
	Sr90	1.0E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	2.5E+00	1.6E-06	
	Cs137	1.4E+01	4	2.0	50,000	4.0E-05	0.077	0.5	1	3.1E+00	2.8E-05	
	Pu238	1.5E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	3.4E+01	3.3E-05	
	Pu239/240	1.5E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	3.7E+01	3.6E-05	
	Am241	1.4E+00	4	2.0	50,000	4.0E-05	0.077	0.5	1	3.0E+01	2.8E-05	
	Pu241	7.4E+01	4	2.0	50,000	4.0E-05	0.077	0.5	1	6.7E-01	3.2E-05	
300	Gross Beta	1.1E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	3.1E+00	2.6E-06	2.1E-04
	Gross Alpha	5.0E-01	4	2.0	60,000	3.3E-05	0.077	0.5	1	3.7E+01	1.4E-05	
	Sr90	1.0E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	2.5E+00	1.9E-06	
	Cs137	1.4E+01	4	2.0	60,000	3.3E-05	0.077	0.5	1	3.1E+00	3.4E-05	
	Pu238	1.5E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	3.4E+01	3.9E-05	
	Pu239/240	1.5E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	3.7E+01	4.3E-05	
	Am241	1.4E+00	4	2.0	60,000	3.3E-05	0.077	0.5	1	3.0E+01	3.3E-05	
	Pu241	7.4E+01	4	2.0	60,000	3.3E-05	0.077	0.5	1	6.7E-01	3.9E-05	

Table A-1. Offsite Dose for Emissions Estimates from Stack Samples Containing Radionuclides at Minimum Detectable Activity

Area	Analysis Type	Minimum Detectable Activity (MDA) (pCi/sample)	Nominal Sample Period (weeks)	Sample Flow Rate (cfm)	Stack Flow Rate (cfm)	Minimum Sample Fraction (SF)	Fraction of Year Sampled (FYS)	Minimum Sampler Efficiency Factor (SEF)	Radionuclide Decay Factor (RDF)	Unit Release Dose Factor (mrem/Ci/yr) (DF)	Offsite Dose (mrem/yr) (DOD)	Offsite Dose (mrem/yr)
300	Gross Beta	1.1E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	3.1E+00	3.3E-06	2.6E-04
	Gross Alpha	5.0E-01	4	2.0	75,000	2.7E-05	0.077	0.5	1	3.7E+01	1.8E-05	
	Sr90	1.0E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	2.5E+00	2.4E-06	
	Cs137	1.4E+01	4	2.0	75,000	2.7E-05	0.077	0.5	1	3.1E+00	4.2E-05	
	Pu238	1.5E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	3.4E+01	4.9E-05	
	Pu239/240	1.5E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	3.7E+01	5.4E-05	
	Am241	1.4E+00	4	2.0	75,000	2.7E-05	0.077	0.5	1	3.0E+01	4.1E-05	
	Pu241	7.4E+01	4	2.0	75,000	2.7E-05	0.077	0.5	1	6.7E-01	4.8E-05	
400	Gross Beta	1.1E+00	4	2.0	5,000	4.0E-04	0.077	0.5	1	2.2E-01	1.5E-08	9.4E-08
	Gross Alpha	5.0E-01	4	2.0	5,000	4.0E-04	0.077	0.5	1	2.4E+00	7.9E-08	
400	Gross Beta	1.1E+00	4	2.0	10,000	2.0E-04	0.077	0.5	1	2.2E-01	3.1E-08	1.9E-07
	Gross Alpha	5.0E-01	4	2.0	10,000	2.0E-04	0.077	0.5	1	2.4E+00	1.6E-07	
400	Gross Beta	1.1E+00	4	2.0	15,000	1.3E-04	0.077	0.5	1	2.2E-01	4.6E-08	2.8E-07
	Gross Alpha	5.0E-01	4	2.0	15,000	1.3E-04	0.077	0.5	1	2.4E+00	2.4E-07	

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