RADIOLOGICAL PROTECTION TECHNICAL BASIS

Problem Identification and Resolution (PIR) Form

Document No.: PRC-1809-CDMP-0147 Revision 3	
Functional Area: Air Monitoring	**Company Technical Authority:** Sean Murphy
Title: Outdoor Air Emissions Monitoring Technical Basis Document	

Issue Summary:

This technical basis will focus on objectives related to monitoring for the dispersion of airborne radioactivity and contaminated particulate matter, while including a focus on contamination control. For completeness, outdoor air monitoring techniques found in 0904-CDMP-0011 were incorporated into this document.

Discussion and/or Requirements:

Revision 3 to this document changed CHPRC references to CPCCo references. Section 5.4, 5.5, and 5.6 for "Fugitive Dusts/Inhalation," "Soils Work Air Concentration Estimate," and "Wetting Factors," respectively, were incorporated from 0904-CDMP-0011.

RADIOLOGICAL PROTECTION TECHNICAL BASIS

Problem Identification and Resolution (PIR) Form

Document No.: PRC-1809-CDMP-0147 Revision 3					
Proposed Outcome: Approve revision 3 of this document					
Prepared By: D.W. Hearnsberger Hearnsberger, David W Digitally signed by Hearnsberger, David W Date: 2021.08.26 14:33:43 -05'00'					**Date:** 08/26/21
Complies with RPP:	**YES** ☒	**NO** ☐	**Interpretive Authority:**	Hearnsberger, David W Digitally signed by Hearnsberger, David W Date: 2021.08.26 14:34:18 -05'00' D.W. Hearnsberger	**Date:** 08/26/21

Record of Decision

☒ Approve PIR-Based Decision	☐ Approve Developing CDMP	☐ Cancel
Assigned Staff Member for CDMP: D.W. Hearnsberger		
Milestones for completing staff work: N/A		

Implementing Actions and Associated Milestones *(as applicable)*:

Prepare briefing for Project Radiological Control Managers that describes changes. Provide by September 23, 2021.

Approvals:

Project or Program Radiological Control Manager: James Gilliam	☒ Concur ☐ Disagree	Signature: JAMES GILLIAM (Affiliate) Digitally signed by JAMES GILLIAM (Affiliate) Date: 2021.08.30 15:21:19 -07'00'	Date: 08/26/21
Radiological Protection Manager *(or designee)*: Roy Lightfoot	☒ Concur ☐ Disagree	Signature: Lightfoot, Roy L Digitally signed by Lightfoot, Roy L Date: 2021.09.07 09:30:55 -07'00'	Date: 08/26/21

RADIOLOGICAL PROTECTION TECHNICAL BASIS VERIFICATION CHECKLIST
COMPLETED DECISION – MAKING PACKAGE

Document No.: PRC-1809-CDMP-0147	**Revision No.:** 3	**Date:** 08/26/2021
Title: Outdoor Air Emission Monitoring Technical Basis Document		
Verified By: D.W. Hearnsberger		

	Yes	No	N/A
1. Are the problem statement and objectives clearly defined?	[X]	[ ]	[ ]
2. Has sufficient background information been provided?	[X]	[ ]	[ ]
3. Does the recommended solution include a clear path to completion?	[X]	[ ]	[ ]
4. Are implementation actions sufficiently detailed and scheduled?	[X]	[ ]	[ ]
5. Are significant assumptions clearly stated and correct?	[X]	[ ]	[ ]
6. Are all applicable requirements identified?	[X]	[ ]	[ ]
7. Have acceptance criteria been identified?	[X]	[ ]	[ ]
8. Is this a standalone document?	[X]	[ ]	[ ]
9. Are supporting calculations mathematically correct?	[X]	[ ]	[ ]
10. Were problem input parameters appropriate?	[ ]	[ ]	[X]
11. Are detailed references included as necessary?	[X]	[ ]	[ ]
12. Is a clear and defensible analytical approach used?	[X]	[ ]	[ ]
13. Have potential impacts on company goals and objectives been addressed?	[X]	[ ]	[ ]
14. Has adequate consideration been given to external industry practices?	[ ]	[ ]	[X]
15. Have relative program/facility cost impacts of alternatives been addressed?	[ ]	[ ]	[X]
16. Have training impacts, including employee transferability, been addressed?	[ ]	[ ]	[X]
17. Have stakeholder (including worker) acceptance/cultural considerations been addressed?	[ ]	[ ]	[X]
18. Have relative risks been adequately categorized and addressed?	[X]	[ ]	[ ]
19. **Is this CDMP acceptable for distribution?**	[X]	[ ]	[ ]
20. **Would you stake your professional reputation on the quality of this work?**	[X]	[ ]	[ ]

RADIOLOGICAL PROTECTION TECHNICAL BASIS
COMPLETED DECISION MAKING PACKAGE COVER SHEET

Title: Outdoor Air Emission Monitoring Technical Basis Document

Site/Facility Applicability: All facilities

Document No.: 1809-CDMP-0147, Rev. 3

Superseded Document(s): 1809-CDMP-0147, Rev. 2

Primary RadCon Functional Area: Air Monitoring

Reference Documents:
See working references in original document.

Objective (Summary):
This technical basis will focus on objectives related to monitoring for the dispersion of airborne radioactivity and contaminated particulate matter, while including a focus on contamination control.

Revision Description:
Revision 3 to this document changed CHPRC references to CPCCo references. Section 5.4, 5.5, and 5.6 for "Fugitive Dusts/Inhalation," "Soils Work Air Concentration Estimate," and "Wetting Factors," respectively, were incorporated from 0904-CDMP-0011.

Rev. No.	Originator	Date	Verified By	Date	Approved By	Date
0	D.W. Hearnsberger	09/26/18	Chris Tiemens	09/26/18	J. Hawkins	09/26/18
1	D.W. Hearnsberger	12/17/18	Chris Tiemens	12/17/18	J. Hawkins	12/17/18
2	D.W. Hearnsberger	03/20/19	Chris Tiemens	03/20/19	J. Hawkins	03/20/19
3	D.W. Hearnsberger	08/26/21	James Menge	08/26/21	James Gilliam	08/26/21

RADIOLOGICAL PROTECTION TECHNICAL BASIS
COMPLETED DECISION MAKING PACKAGE COVER SHEET (Continued)

Document No.: 1809-CDMP-0147, Rev. 3	Revision No.: 3	Date: 08/26/2021
Originator: David W. Hearnsberger		
Verified By: James Menge		

Outdoor Air Emission Monitoring Technical Basis Document

Executive Summary

The purpose of this Completed Decision-Making Package (CDMP) is to document the technical basis of the Radiological Outdoor Workplace Air Emissions Program. This document is applicable to air monitoring for airborne and surface transported particulate contaminants during outdoor work activities that have the potential to produce airborne radioactivity and contaminated particulates such as demolition and debris removal, excavation of soil and other structures, systems, and components (SSCs), and soil disturbing activities in an Underground Radioactive Material Area (URMA) or a Soil Contamination Area (SCA). This technical basis will focus on objectives related to monitoring for the dispersion of airborne radioactivity and contaminated particulate matter, while including a focus of contamination control. Commitments regarding the Radiological Outdoor Workplace Air Emissions Program for the Occupational Radiation Protection[1] Program are integrated to the extent practicable in this technical basis document (TBD).

[1] 10 CFR 835, "Occupational Radiation Protection" *Code of Federal Regulations.*

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Abbreviations and Acronyms

AED	Aerodynamic Equivalent Diameter
ALI	Annual Limit on Intake
AMAD	Activity Mean Aerodynamic Diameter
AME	Air Monitoring Equipment
ANSI	American National Standards Institute
ARA	Airborne Radioactivity Area
ARF	Airborne Release Fraction
CDMP	Completed Decision Making Package
CPCCo	Central Plateau Cleanup Company
DAC	Derived Air Concentration
DALI	Deterministic Annual Limit on Intake
DOE	Department of Energy
DOE/RL	Department of Energy Richland Operations Office
DR	Damage Ratio
Ecology	Washington State Department of Ecology
EF	Emission Factor
EPA	Environmental Protection Agency
HPS	Health Physics Society
LPF	Leak Path Factor
MAR	Material at Risk
$PM_{2.5}$	Particulate Material (2.5 µm)
PM_{10}	Particulate Material (10 µm)
PNNL	Pacific Northwest National Laboratory
RCM	Radiological Control Manager
RF	Release Fraction
RP	Radiological Protection
SALI	Stochastic Annual Limit on intake
SCA	Soil Contamination Area
SSCs	Structures, systems, and components
ST	Source term
TBD	Technical Basis Document
TED	Technical Equivalency Determination
URMA	Underground Radioactive Material Area
WAM	Workplace Air Monitoring

1.0 Introduction

The main objective of this CDMP is to ensure that the technical aspects of outdoor air monitoring and contamination control for outdoor work activities support compliance with pertinent Department of Energy (DOE) regulations while incorporating relative DOE, Environmental Protection Agency (EPA), Washington State Department of Ecology (Ecology), and American National Standards Institute (ANSI) guidance. Specific requirements for developing a regulatory-compliant "Workplace Air Monitoring" (WAM) program technical basis for situations other than for outdoor activities can be found in a 0904-CDMP-0011, *Workplace Air Monitoring Technical Basis Document* and implemented by PRO-RP-40031, *Workplace Air Monitoring Program*. Alternatives to this CDMP should follow the process for a Technical Equivalency Determination (TED) according to PRO-RP-40022.

2.0 Program Description

10 CFR 835 (DOE 2007) establishes the basic requirements of a Workplace Air Monitoring Program. CPCCo is committed to follow 10 CFR 835, 2007 version, for DAC values. For the purpose of this document, and to be consistent with DOE nomenclature, the term "air monitoring" is used generically to include both real-time air monitoring and periodic air sampling. The term "air sampling" refers to collecting a sample for later analysis. The term "real-time" air monitoring will refer to a system that both collects and detects radioactivity on a sample (i.e., a continuous air monitor).

10 CFR 835.401 requires that:

a. Monitoring of individuals and areas shall be performed to:
    1) Demonstrate compliance with the regulations in this part;
    2) Document radiological conditions;
    3) Detect changes in radiological conditions;
    4) Detect gradual buildup of radioactive material;
    5) Verify the effectiveness of engineered and administrative controls in containing radioactive material and reducing radiation exposure; and
    6) Identify and control potential sources of individual exposure to radiation and/or radioactive material.

10 CFR 835.403 requires that:

a. Monitoring of airborne radioactivity shall be performed:
    1) Where an individual is likely to receive an exposure of 40 or more DAC-hours in a year; or
    2) As necessary to characterize the airborne radioactivity hazard where respiratory protective devices for protection against airborne radionuclides have been prescribed.
b. Real-time air monitoring shall be performed as necessary to detect and provide warning of airborne radioactivity concentrations that warrant immediate action to terminate inhalation of airborne radioactive material.

Radiological Contamination Control involves many features such as the use of engineering and administrative controls to prevent or mitigate the spread of contamination across the boundary of contamination areas, high contamination areas, or airborne radioactivity areas. This document will provide a suite of engineering control options that, when exercised with appropriate work planning and control and administrative controls, will provide effective preventative and mitigative contamination control strategies.

10 CFR 835.1102 requires that:

a. Appropriate controls shall be maintained and verified which prevent the inadvertent transfer of removable contamination to locations outside of radiological areas under normal operating conditions.

Additionally, The Radiological Control Manual (RCM), Article 555.3(a) requires that:

> Real-time air monitoring equipment should be installed where unexpected increases in airborne radioactivity levels, should they occur, are likely to result in an exposure exceeding 40 DAC-h in one week. Such exposures could result from a breakdown of engineered controls or improper establishment of boundaries during work that creates airborne radioactivity.

For air monitoring, there are four primary techniques: (1) fixed head air samplers; (2) grab air sampling; (3) lapel air sampling and (4) real-time air monitoring. While each has its primary purpose, there is overlap between some of the methods to meet facility objectives.

3.0 Establishing the Source Term and Material at Risk

Before air monitoring or air sampling protocols can be established, a source term shall first be defined. There are a variety of methods that can be used to define the source term and one such method, presented in 0904-CDMP-0011, evaluates the NUREG-1400 approach which states that when the amount of material handled/processed in a year exceeds 10,000 times the Annual Limit on Intake (ALI), the need for air sampling should be *considered*. This value is based on observing a fraction of 0.01 times the Stochastic ALI (SALI) or Deterministic ALI (DALI) and results in a TED of 50 mrem. The ANSI/HPS N13.39-2001, *Design of Internal Dosimetry Programs* guidance of 0.02 SALI, or 100 mrem as a means to determine whether air sampling should be considered, is adopted. This equates to the consideration for air sampling if the amount of material handled/processed in a year exceeds 20,000 times the ALI. From an outdoor radiological airborne perspective, this CDMP will maintain consistency with 0904-CDMP-0011, in terms of defining the amount of material handled/processed and include consideration for quantifying the material at risk (MAR) and other factors to be discussed in this section that define the source term, ST.

3.1 Source Term (ST)

The Source Term (ST) equation and term definition used in this CDMP align with DOE-STD-3009-2014, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*. In addition, Criterion 7 – Accident Scenario Analysis of 0904-CDMP-0011, uses similar formula for calculating the Source Term. The terms presented in this section have been developed from the DOE-STD-3009-2014 document and are in alignment with the 0904-CDMP-0011. There are no substantive differences in the variables.

Once a source term has been determined, consequences due to atmospheric dispersion or other relevant pathways of concern are evaluated. As with every phase of the analysis, the effort expended is a function of the estimated consequence. If the source term is small, a simple, dispersion hand calculation for consequences would be sufficient. If source terms are large, computer modeling to determine consequences may be required (DOE 2014). This CDMP applies the following approach to defining the source term because this evaluation is more appropriate for outdoor activities than the approach described in NUREG-1400 which is ostensibly developed for indoor air monitoring.

The source term may be quantified using the five-factor formula:

$$ST = MAR \times DR \times ARF \times RF \times LPF \qquad \text{Equation 1}$$

This equation may be reduced to the following:

$$ST = MAR \times EF \qquad \text{Equation 2}$$

Where,

ST *Source Term* **–** the total quantity of respirable material released to the atmosphere during an outdoor work activity (curies or grams);

MAR *Material-at-Risk* – the total quantity of radionuclides (in grams or curies of activity for each radionuclide) available to be acted on by a given physical stress. This term may be used in place of the value of Q_A (quantity of radioactive material processed in a year) described by the NUREG-1400 approach;

DR *Damage Ratio* – is the fraction of the MAR actually impacted by the demolition conditions;

ARF *Airborne Release Fraction* – is the coefficient or fraction of a radioactive material suspended in air as an aerosol and thus available for transport due to a physical stress from a specific activity (particle size independent);

RF *Respirable Fraction* – is the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory system and is commonly assumed to include particles 5 µm aerodynamic equivalent diameter (AED) and less, although the use of AERMOD (discussed in Section 3.4) by Pacific Northwest National Laboratory (PNNL) models 10 µm AED particles and provides a conservative upper bounds on inhalable particle sizes;

LPF *Leakpath Factor* – is the fraction of the radionuclides in the aerosol transported through some confinement system (e.g., facility rooms, ductwork), filtration mechanism (e.g., high-efficiency particulate air [HEPA] or sand filters), and emission mitigation methods (e.g., misters, foggers, or fixatives);

EF *Emission Factor* – is the product of the last four factors, where EF = DR*ARF*RF*LPF.

$$EF = DR \times ARF \times RF \times LPF \qquad \text{Equation 3}$$

As discussed above, the Emission Factor (EF) has four factors; Damage Ratio (DR), Airborne Release Fraction (ARF), Respirable Fraction (RF), and Leak Path Factor (LPF). Each of these varies depending upon the outdoor activity or process as illustrated in Table 1 below and whose ARF and RF values can be found in DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*. Note that these are example values and can be changed if the DOE-HDBK-3010-94 (or other reference material) provides values that are more applicable to the considered activity.

Table 1: Source Term Factors[2]

Activity	Impacted Structures	Type	DR (unitless)	ARF (unitless)[3]	LPF (unitless)	RF (unitless)	EF (unitless)
Shearing	Walls and Ceilings	Removable	0.9	$1x10^{-3}$	0.1	1	$9x10^{-5}$
		Fixed	0.1	$1x10^{-4}$	0.1	1	$1x10^{-6}$
Dropping of Rubble	Rubble	Removable and Fixed	0.1	$2x10^{-6}$	0.1	1	$2.0x10^{-8}$
Dropping of Soil During Excavations	Soil	Removable	0.9	$1.9x10^{-3}$	0.1	0.9	$1.54x10^{-4}$
Discrete Removal of Objects[1]	The Object	Contents	0.01	$1x10^{-6}$	0.1	1	$1x10^{-9}$
Small Equipment Removal by a person	Its Contents	Fixed	0.1	$1x10^{-4}$	0.1	1	$1x10^{-6}$
Sorting/Sizing/ Reloading	Rubble	Removable and Fixed	1	$2x10^{-6}$	0.1	1	$2x10^{-7}$
Resuspension – between shifts[2]	Rubble	Removable	0.1	$3.6x10^{-5}$ hr^{-1}	0.1	1	$3.6x10^{-7}$ hr^{-1}
	Soil	Removable	0.1	$3.6x10^{-4}$ hr^{-1}	0.1	1	$3.6x10^{-6}$ hr^{-1}

1. Object is an item that is removed by a piece of equipment such as an excavator or crane. Object can be a tank, glovebox, laboratory hood, wall of a building/room, etc.
2. Resuspension can be caused by wind when they are sustained above 15 mph or gusts that exceed 20 mph.
3. Resuspension is the exception to unitless factors. For suspension, the units are inverse time units (e.g. sec^{-1}, hr^{-1}, etc.

Shearing has the highest EF due primarily to the high DR and ARF value. The EF associated with the various activities may be used to prompt additional controls including workplace air emission monitoring and sampling.

[2] PNNL-27456, "Air Dispersion Modeling of Radioactive Releases During Proposed 234-5Z Building Demolition Activities", April 2018 and DOE-HDBK-3010-94, "*Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*.

3.2 Material at Risk (MAR)

The Material at Risk (MAR) is best described as the amount of radioactive material (in grams or curies of each radionuclide) that is available to be acted on by an external physical stress. For facilities, processes, and activities, the MAR is a value representing some maximum quantity of radionuclide present or reasonably anticipated for the process or structure being analyzed (DOE 2014). Different MARs may be assigned for different work activities (e.g. soil excavation, building demolition, vegetation removal, etc.) as it is only necessary to define the material in those discrete physical locations that are exposed to a given physical stress.

Table 2 (taken from Table 2-3 in 0903-CDMP-0008, Standard Process for Documenting PRC Facility/Project Radionuclide Characterizations) is an example of how the MAR might be described in order to apply its values to the equation used to calculate the Source Term, ST. In this example, the decay-corrected inventory of 100 KE and 100 KW reactors is used to illustrate that outdoor work activities, other than outdoor demolition, are to consider how to implement this CDMP. Table 2 consists of a specific radionuclide distribution and quantity of material. Each value will need to be entered as the MAR and an individual ST value will result.

Table 2: Example Radionuclide Content for 100 KE and 100 KW Reactors (decay-corrected for 03/01/2016)

Group	Radionuclide	KE Activity (Ci)	KW Activity (Ci)
Group 2	^{239}Pu	1.0	1.0
	^{241}Am	0.29	0.29
Group 4	^{137}Cs	15.11	15.11
	^{137m}Ba	14.3	14.3
	^{90}Sr	5.0	5.0
	^{90}Y	5.0	5.0
	^{60}Co	302	251
	^{36}Cl	54	52
	^{93}Zr	11	10
	^{93}Mo	0.26	0.26
	^{94}Nb	1.73	1.73
	^{108m}Ag	0.04	0.04
	^{152}Eu	8.70	8.70
	^{154}Eu	1.88	1.88
Group 5	^{3}H	5214	4693
Group 6	^{59}Ni	22	20
	^{63}Ni	2350	2110
	^{14}C	6974	6675
	^{99}Tc	0.03	0.03

An example calculation of the MAR for multiple radionuclides for the purposes of comparing its value to 20,000 x ALI is provided below where the following is given:

- ^{137}Cs (10.6 Ci) ALI = 192 µCi
- ^{90}Sr (8 Ci) ALI = 16.8 µCi
- ^{108m}Ag (1 Ci) ALI = 48 µCi
- ^{239}Pu (0.7 Ci) ALI = 0.012 µCi
- ^{241}Am (0.25 Ci) ALI = 0.012 µCi

$$MAR\ ratio = \sum_{i=1}^{n}\left(\frac{Cs-137\ activity}{Cs-137\ ALI} + \frac{Sr-90\ activity}{Sr-90\ ALI} + \frac{Ag-108m\ activity}{Ag-108m\ ALI} + \frac{Pu-239\ activity}{Pu-239\ ALI} + \frac{Am-241\ activity}{Am-241\ ALI}\right) \quad \text{Equation 4}$$

$$MAR\ ratio = \sum_{i=1}^{n}\left(\frac{1.06E7\ \mu Ci}{192\ \mu Ci} + \frac{8E6\ \mu Ci}{16.8\ \mu Ci} + \frac{1E6\ \mu Ci}{48\ \mu Ci} + \frac{7E5\ \mu Ci}{0.012\ \mu Ci} + \frac{2.5E5\ \mu Ci}{0.012\ \mu Ci}\right) = 7.97E+7$$

Now compare the value above with 20,000 (just as in Eq. 2.2 of 0904-CDMP-0011). Because 7.97E+7 is greater than 20,000, then air sampling should be considered and Criterion 2 evaluated to calculate the potential intake. If the MAR was calculated to be less than 20,000, then air sampling would not be needed.

3.3 Example Source Term Calculation

Now that the source term, ST, and Material at Risk, MAR, have been defined an example calculation follows to demonstrate how to implement its use.

Assumptions: The values of the radionuclides in Section 3.2 from the MAR calculation for this example ST calculation are used. Selection of the emission factors, EF originate from Table 1.

Example problem:

Suppose that an outdoor soil excavation is to occur with an excavator that will remove soil up to about 15 feet below ground surface (bgs) and empty the contents of the bucket into an ERDF can that is placed on a truck that is parked at grade level. The five (5) radionuclides from Section 3.2 are to be used this for this example.

Referring to Table 1, the EF value of 1.54×10^{-4} is selected because the job is to excavate soil and place into an ERDF container, therefore the most appropriate EF factor is taken from "Dropping of Soil from Excavation." If the soil were to be stockpiled and not loaded into containers right away, then an additional calculation related to "Resuspension between shifts" for soil would also need to be performed. If concrete or other material needs to be rubblized, then an additional EF value for "Shearing" would be needed.

Now that the MAR is identified along with its respective ALIs and the appropriate EF factor has been selected, it is now time to perform the source term calculation as presented in Equation 2:

$$ST = MAR \times EF \quad \text{Example Calculation 1}$$

$$ST = 10.6\ Ci \times 1.54E-4 = 1632\ \mu Ci\ of\ Cs-137$$

This calculation shall be performed for each radionuclide because these values will all need to be modeled for air dispersion whether by simple hand calculation or by a computer model. All ST values for each radionuclide are provided as follows:

- ^{137}Cs 1632 µCi
- ^{90}Sr 1232 µCi
- ^{108m}Ag 154 µCi
- ^{239}Pu 1.85 µCi
- ^{241}Am 1.85 µCi

The above values are all individual results needed to establish the source term. When modeling these values (either by hand calculations or by computer model), the individual results will provide a predicted dose to an individual receptor. All dose results for each radionuclide will need to be summed to determine total dose to an individual receptor.

3.4 Data for Air Dispersion Modeling

The Pacific Northwest National Laboratory (PNNL) modeled the air dispersion of radioactive releases during the proposed 234-5Z Building demolition activities. The U.S. Environmental Protection Agency's (EPA) AERMOD computer code[3] was used to estimate atmospheric dispersion and deposition of the released radioactive materials in the immediate vicinity of the demolition activities. The modeling was conducted to be fully representative of the range of the weather conditions that are possible (i.e., uses multiple full annual cycles of meteorological data) and representative of the expected demolition period (i.e., models the hours of the day that demolition activities will occur). The modeling also included the effects of local building structures on the near-field atmospheric dispersion rates due to wake effects.

Both airborne and surface concentrations were modeled with AERMOD. Hourly derived air concentrations (DAC) are modeled for an array of receptors covering the demolition site and surrounding area. Peak (95th and 99th percentile) values of time-integrated air concentrations at these receptor points are derived from these hourly values, with modeling results reported as total incremental air concentrations in DAC-h/week occurring over the selected time period. The DAC-h are integrated values. Air concentrations are expected to not be constant during the demolition processes or any other outdoor work activity. There will be transient periods with higher and lower airborne concentrations. However, since computed doses are based on integrated intake, the analysis of instantaneous airborne concentrations is not necessary in the analysis. Due to this limitation, workplace air monitoring is used to detect changes in airborne concentrations. Defining the selection and placement of air monitoring equipment (AME), and whether particulate surface deposition surfaces (e.g., cookie sheets) should be used are the primary outcomes of this TBD.

The time-integrated air concentrations at receptor points determined by an air dispersion model such as Hotspot® or AERMOD (or other software code), provide data that can be used to generate isopleth curves which support the placement and judgmental location of AME and surface deposition monitoring locations based on an understanding of location of work activities and environmental conditions. The developed isopleth curves also validate radiological zone boundaries and posting.

[3] **AERMOD Modeling System** – A steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain.

Total accumulated surface deposition amounts are also evaluated with AERMOD using the same array of receptors, with results reported as dpm per 100 cm^2. The results of this element of the evaluation provides a time-integrated surface contamination estimate. An associated isopleth presents the contour of deposition resulting in units of dpm/100 cm^2 for beta/gamma or alpha emitting radionuclides.

To be able to conduct this type of computer air modeling, the ST values calculated in the previous section will be needed. Although the use of AERMOD has been provided as an example, another type of acceptable computer air dispersion model that can be used is Hotspot®.

3.5 Predicted Impacts

Based on the results of the air dispersion modeling, the predicted impacts such as distance the plume travels, area of plume deposition, predicted air concentrations, and/or surface contamination deposition shall all be considered in terms of the time personnel spend in motion relative to the plume and its transport characteristics. It is helpful to graphically illustrate (usually on a scaled map) where the air dispersion model shows impacts relative to the work area/project. The map should include the work zone/project boundaries and the major roads/access areas. The work zones/project should be shown as colored overlays.

The air emission (dispersion and deposition) results presented by the model should aid in terms of a guide to help determine placement of AME and surface deposition survey locations (if warranted). The air monitoring stations in the immediate vicinity of the work zone/project will be only able to detect increments in air exposures from work-related activities if those increments are large enough to be distinguished from the local background. To understand how work related activities will be affected by the outdoor work activity, one should obtain meteorological data from the nearest meteorological tower that collects these data. For example, the background for 200-West is estimated to be on the order of 0.015 and 0.03 DAC-h for 1-week and 2 week background exposures, respectively.[4] Therefore, if there is a substantial increase on airborne activity of the work location relative to the historical background data measured, then the relative impact of the work can be qualified. For example, as will be discussed in Section 5.3.1, if airborne radioactivity is estimated to reach 40 DAC-hrs in one week (corresponds to about 100 mrem), then real-time air monitoring shall be performed.

3.5.1 Work Activity – Air Concentrations

This section presents an example of potential exposure due to airborne radioactivity modeling results from AERMOD.

The maximum impact modeling runs are used to define the 95th and 99th percentile time-integrated air concentrations on a weekly basis. Air concentrations are presented as isopleths of maximum values (expressed as total DAC-h) resulting from weekly demolition activities. The maximum air concentration isopleth presents the overall composite pattern of the maximum weekly air concentration at each receptor. These weekly air concentration data are helpful, in terms of meeting requirements (i.e. Article 555 of the Radiological Control Manual), to perform real-time air monitoring where unexpected increases in airborne radioactivity levels, should they occur, are likely to result in an exposure exceeding 40 DAC-hrs (about 100 mrem) in one week, or to verify posting of

[4] In an analysis of the routine air samplers (Napier et al. 2010), the mean of background air samples at the Hanford 200-West monitoring stations is shown to be about 1.2×10^{-15} µCi/ml of gross alpha-emitters. Most of the background will be natural alpha-emitting radionuclides, primarily progeny of the uranium chain.

airborne radioactivity areas when airborne radioactivity concentrations are less than 12 DAC-h/week.

Note that actual air concentrations will depend on ambient meteorological conditions that will occur, and are likely to be less than the predicted bounding values.

Air modeling results should be able to provide data that would support a predictive model of isopleths of the maximum weekly air concentration (expressed as the 99th percentile of total DAC-h/week). See an example of the isopleths provided in Figure 1.

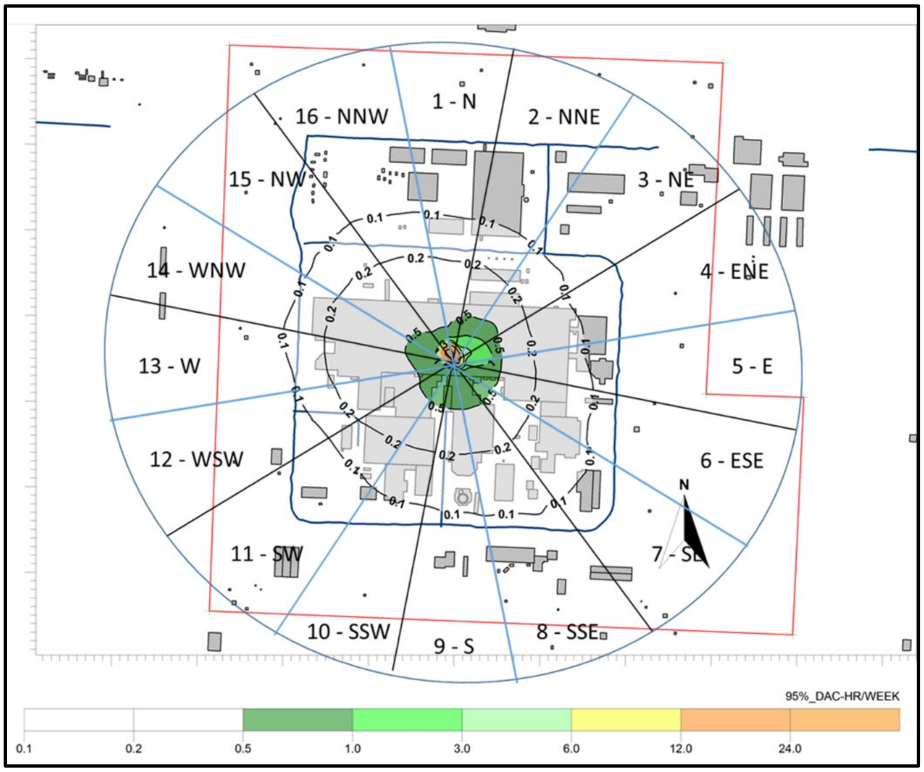

Figure 1: Predicted 99th Percentile Weekly Air Concentrations

As stated previously, computed doses are based on integrated intake. The analysis of instantaneous airborne concentrations is not determined in the analysis. Due to this limitation, workplace air monitoring is used to detect changes in airborne concentrations.

3.5.2 Maximum Concentration at the Work Zone Boundary

The air concentrations on the work zone boundaries should be modeled for a series of receptors located on that boundary. Figure 2 provides an example of highest predicted 99th percentile weekly air concentrations (with units of weekly total DAC-h) for each work zone boundary receptor. The actual exposures during work zone activities will be a function of the combinations of emission rates (inventory and mitigative efforts) and ambient atmospheric conditions that occur during those activities. Because the air concentrations are based on 95th meteorological conditions coupled with very conservative MAR estimates, the figures can be used to indicate whether there is a high likelihood that the ARA definition of 12 DAC-h/week will or will not be exceeded beyond the work zone boundary.

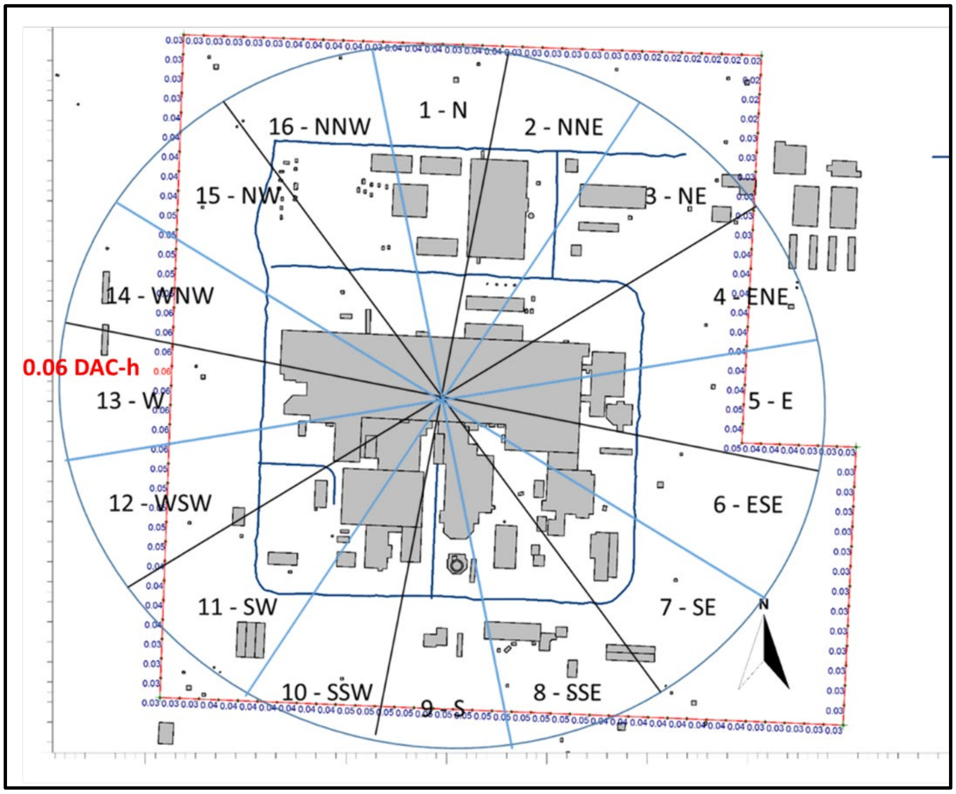

Figure 2: Example of Predicted 99th Percentile Weekly Air Concentrations at a work zone boundary (DAC-h)

3.5.3 Work Zone – Surface Deposition

Air dispersion modeling should also provide daily surface deposition values (in terms of 95th percentile isopleths) that should be summed over the actual number of days the activity is expected to be performed and the total deposition value at each receptor location retained and sorted (in units of dpm/100 cm^2). Actual surface deposition resulting from any outdoor work activity depends on the ambient meteorological conditions, movement of particles due to the use of foggers, misters, and water cannons, and other Emission Factor (EF) components that will occur during those activities. To minimize the motive force applied to particles generated during outdoor work activities, a technical evaluation for water cannons developed at PFP is included as Appendix A of this CDMP and describes how this control should be applied. Each outdoor work activity that uses foggers, misters, or water cannons to control the spread of contamination should consider using this evaluation as a basis for developing its project-specific engineering control.

Most air dispersion models will assume that the particles will have a conservative upper bounding 10 µm in aerodynamic equivalent diameter (AED). While there is no comprehensive peer-reviewed approach to developing a predictive capability for the migration of particles through saltation, surface creep, or other surface mechanisms, this document does provide some additional guidance in Section 4.

As an example, Figure 3 shows how isopleths may be utilized to show where contamination is likely to occur. However, the modeling does not specifically identify potential individual “hot particles” and cannot predict exact locations where radioactive materials of various particle sizes will actually be deposited. Therefore, efforts are undertaken to minimize the spread of contamination during and following the outdoor work activities. This includes efforts to minimize the amount of rubble/loose material available at any one time, and measures to immediately contain potentially contaminated materials through use of fixatives or other means. Surface deposition survey location "e.g., cookie sheets" may be deployed to provide an indication of deposition and to some extent migration of particulate matter across the surface.

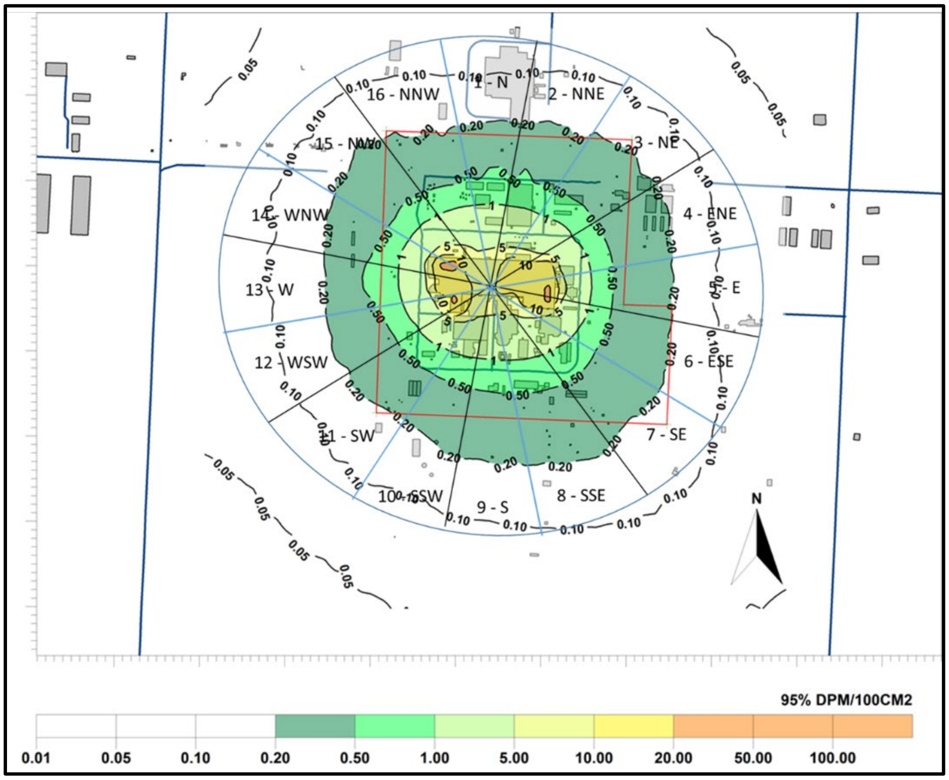

Figure 3: 95th Percentile Surface Deposition (dpm/100cm^2).

4.0 Particulate Material

Discussion of particulate material associated with outdoor work activities and debris removal includes generation, suspension, deposition, migration, and collection or sampling. The latter sampling includes both collection by AME and measurement of particulate deposition on horizontal surfaces.

Air dispersion modeling can provide detailed information regarding the generation of particulate matter and the dispersion and deposition of that material during outdoor work activities and debris removal. The MAR and the EF have been derived for use in air dispersion modeling to assist in estimating airborne radioactivity concentrations as well as surface deposition levels. Historical meteorological data in the form of wind rose data that has seasonal as well as diurnal resolution is very helpful, if not necessary, in terms of providing a robust foundation to help provide the best possible air dispersion and deposition data on which decisions can be made. These data can provide the average downwind direction, which is an important aspect in the placement of AME and surface contamination monitoring stations.

Particulate generation is related to the Damage Ratio (DR) discussed in Section 3.1. The highest DR is associated with "Sorting/Sizing/Re-loading," "Shearing," and "Dropping of Soil during Excavation Activities." These may be categorized as "intrusive" activities.

Suspension of particulate matter is related to the Airborne Release Fraction (ARF) and Leak Path Factor (LPF). The highest ARFs are associated with "Shearing" and "Dropping of Soil during Excavation Activities." LPF's for all anticipated activities are estimated to be equivalent.

4.1 General Soil and Particulate Considerations for Wind Driven Transport

Surface soils have three critical features that indicate the resistance to transport such as:

- Soil disturbance. Undisturbed soils with natural growth are very resistant to wind driven transport[5].
- Soil moisture content. Soils with greater than 13% moisture content indicate resistance to wind particle movement[6] and for the Hanford site[7], soils with 20% or greater indicate almost no particle movement with winds under 30 mph.
- Particle density. At the Hanford Site, higher density elements such as uranium, plutonium, cobalt, cesium, and strontium can cause soil particles to become more-dense than other soils that do not contain these elements and as a result, can have different wind driven transport characteristics for the same particle size.

Wind driven erosion or transport is based partially on median particle size; soils with smaller bulk aggregate are the most erodible. A soil aggregate is a group of soil particles that adhere to each through cohesive forces other more strongly that to other surrounding particles. For example,

- Soil with 99% particle aggregates under 850 µm are most erodible.
- Soils with 47% of the particle aggregates under 850 µm are 10 times less erodible than 99% under 850 µm, and
- Soil with 23 % particle aggregates under 850 µm are almost 100 times less erodible than 99%[8] under 850 µm.

[5] Soil Aggregation and Wind Erosion: Processes and Measurements", Tatarko, USDA-ARS Wind Erosion Research Unit, 2001., pg 252

[6] "Evaluation of Wind Erosion Emissions Factors for Air Quality Modeling". Sullivan, Ajwa. Soil Physics, pg 1275.

[7] "Assessment of Soil Moisture and Fixatives Performance in Controlling Wind Erosion of Contaminated Soil at the Hanford Site", Applied Research Center, Florida International University, 2008, Figure 4.

[8] "Soil Aggregation and Wind Erosion: Processes and Measurements", Tatarko, USDA-ARS Wind Erosion Research Unit, 2001.

Types of soil (e.g. sand, silt and clay) are associated with certain particle sizes and an understanding of their respective particle sizes helps one to understand how erodible the soil is. The types of soil are classified based on particle size[9].

- Clay particles are less than 2 µm in diameter
- Silt particles are between 2 and 50 µm in diameter, and
- Sand particles are > 50 µm in diameter.
  - Very fine sand is between 50 and 100 µm
  - Fine sand is 100 to 250 µm
  - Medium sand is 250 to 500 µm
  - Course sand is 500 to 1,000 µm
  - Very course sand is > 1,000 µm

Hanford soils vary widely and consist of 15 soil types. The most predominate soil types are Rupert Sand, Burbank Loamy Sand and Koehler Sand[10]. Due to the high sand content the soil has larger particle sizes and are more prone to saltation and surface creep and are most erodible based on the discussion above. Particles generated during outdoor work activities, whose size falls into the categories listed above can reasonably be expected to be mechanically transported in a similar fashion.

4.2 Phases of Wind Driven Transport

There are 3 phases of wind driven transport: detachment, transport, and deposition. Detachment occurs when the force supplied by the wind overcomes the cohesive forces of the fugitive particle has to the matrix in which it is part[11]. Once detached the particle transport phase occurs. Wind driven particle transport categories are based on particle height above the ground the particle attains which is a function of particle size and wind speed.[12] Particle deposition or where the particle ends up is mainly a function of the transport category based on height above the ground, wind speed and wind persistence.

Fugitive particle transport from its place of origin is grouped into three categories or transport processes, which is a function of height above the ground the particle attains during transport[13].

- Airborne Suspension
- Saltation
- Surface Creep

Rules of thumb:

- On average, the horizontal distance a particle travels is about 10 times the vertical height the particle attains per airborne event[14].

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[9] "Sand, Silt and Clay" Michigan State University, R.W. Sheard http://archive.lib.msu.edu/tic/stnew/article/1991sep4.pdf

[10] "Hanford Site National Environmental Policy Act Characterization" Duncan, 9/2007 Section 4.39.

[11] "Evaluation of Wind Erosion Emissions Factors for Air Quality Modeling". Sullivan, Ajwa. Soil Physics, pg 1271.

[12] "Wind Erosion: Field Measurements and Analysis". Pg. 155, Fryrear, Stout, Hagen, Vories. Soil and Water Division of ASAE Vol. 34, January-February 1991.

[13] "The Physics of Wind-Blown Sand and Dust" Kok, Pareli, Michaels, Karam, Reports on Progress in Physics, October 2012.

[14] Dynamics of Wind Erosion I: Nature of Movement of Soil, W.S.Chepil, 1945.

- About 93% of the total particle mass transport from suspension, saltation and surface creep never exceeds 3 feet above the soil surface[15].

4.2.1 Airborne Suspension

Particles less than 70 µm in size are susceptible to becoming airborne. Within the category are the following particle sizes, between 30 and 70 µm, which are capable of being transported short distances. Particles ≤ 10 µm ($PM_{2.5}$ and PM_{10}) are capable of being transported great distances because they achieve vertical heights above the saltation layer and therefore are transported by air currents[16]. Generally, these airborne particles are mechanically generated during outdoor projects. Two fundamental methods of removal of suspended particles are surface deposition and gravitational settling. In low wind conditions or lack of vertical lifting from solar surface heating, most ground level mechanically generated particles are not transported far from their point of origin and are removed due to gravitational settling. General guidelines for a soil size particle mixture suspended in air are:

- About 10 to 30 percent of the total transportable particle soil mass is transported by suspension, but highly dependent on soil type, soil matrix and wind speed.
- Under dry, low moisture soil conditions with no vegetative coverage, threshold wind speeds beginning at 8 mph can start suspension.
- Wind speed affects gravitational settling, as wind speed increases, particles achieve lift, which counteracts gravitational settling, and remain suspended for longer periods of time. Overall, travel distance is dictated by wind speed which also directly impacts suspension times and wind persistence.
- At wind speeds greater than 10 mph, removal of suspended particles by surface deposition exceeds gravitational settling.
- About 50% of the mass of ground emitted PM_{10} suspended particles achieve a height greater than 6 feet above the ground[17].
- About 50% PM_{10} suspended particles that achieve a height greater than in 6 feet above the ground only travel 50 feet[18].
- PM_{10} are inhalable (not respirable) and generally deposit in the nasal region of the body.
- The mass median diameter of suspended particles is 50 µm[19].
- Particles larger than 10 µm are generally not inhalable.
- $PM_{2.5}$ are respirable into the lung.

In higher wind conditions (e.g., sustained winds greater than 15 mph and gusts greater than 20 mph), airborne suspension times increase significantly due to wind generated lift allowing suspended particles to travel further from the point of origin. Due to increased lift, and therefore suspension times, the travel distance for $PM_{2.5}$ particles in this class can be significant.

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[15] "Wind Erosion" The National Soil Erosion Research Laboratory, Purdue University. http://milford.nserl.purdue.edu/weppdocs/overview/wndersn.html
[16] "Evaluation of Wind Erosion Emissions Factors for Air Quality Modeling". Sullivan, Ajwa. Soil Physics, page 1272.
[17] "Methodology for Estimating Fugitive Windblown and Mechanically Resuspended Road Dust Emissions Applicable for Regional Scale Air Quality Modeling", WGA Contract No 30203-9, 4/1991.
[18] "Methodology for Estimating Fugitive Windblown and Mechanically Resuspended Road Dust Emissions Applicable for Regional Scale Air Quality Modeling", WGA Contract No 30203-9, 4/1991.
[19] Chepil 1957, Gillette and Walker 1977.

4.2.2 Saltation

Particles ranging from >70 µm to 500 µm are moved by wind from their point of origin primarily by saltation. Saltation is a process where larger particles are moved along near the ground by a combination of airborne and ground travel. As particles travel along the ground they can be projected (bounced) into the air, become momentarily airborne, pushed by the wind and falling back on the ground. Upon returning to the ground, saltating particles collide with larger ground particles and may break them down into smaller particles and/or provide inertia to move larger particles along the ground. Suspension-sized particles can be created by erosion due to saltation processes and division between these transport mechanisms is not discrete[20]. This cycle is repeated, moving the particle further from the point of origin. General guidelines for suspension in a mixture of soil particle sizes are:[21]

- About 50 to 60% of the original particle mass is transportable by saltation.
- Threshold wind speeds for saltation vary according to soil type; however, wind speeds as low as 13 mph are considered erosive by the US Department of Agriculture.
- About 50% of the mass of saltating particles never exceed 12 inches above the ground.
- The horizontal distance a saltating particle can travel is about 10 times the height achieved on a bounce or about 10 feet[22]. Particles can potentially travel much further due to multiple airborne events or bounces. For Hanford soil, natural vegetative coverage will limit the distance these particles can travel. Where vegetation is absent, a good estimate of movement by saltation over several weeks would be approximated at 50 feet[23].
- Saltating particles can acquire a spin, rotating at between 200 to 1,000 rpms. This spin can create additional lift called the Magnus Effect[24], which can increase horizontal transport distance.
- Most saltating particles are stopped in low spots such as a ditch, plowed fence row, or at the base of a natural or manmade windbreak[25]

4.2.3 Surface Creep

Large particles greater than 500 µm travel along the surface of the ground by a process known as surface creep. The driving force in surface creep are saltating particles colliding with larger particles and pushing them along the ground. Surface creep becomes a particle transport factor above 17 mph.

- About 25% of the original particle mass transported away from the point of origin is due to surface creep.
- Wind tunnel tests by Florida International University on Hanford soil indicate a wind threshold for creep at about 20 mph.
- Particles sizes generated at the Hanford site during outdoor work activities vary; however, due to the greater densities of plutonium, uranium, cobalt, cesium, and strontium, these

[20] "The Physics of Wind-Blown Sand and Dust" Kok, Pareli, Michaels, Karam, Reports on Progress in Physics, October 2012.
[21] "Wind Erosion" Information Sheet US Department of Agriculture https://efotg.sc.egov.usda.gov/references/public/TX/Wind_Erosion.pdf.
[22] "Wind Erosion" Information Sheet US Department of Agriculture https://efotg.sc.egov.usda.gov/references/public/TX/Wind_Erosion.pdf.
[23] "The Physics of Wind-Blown Sand and Dust" Kok, Pareli, Michaels, Karam, Reports on Progress in Physics, October 2012.
[24] "Basic Wind Erosion Processes", Lyles, Agriculture, Ecosystems and Environments 22/23 (1988) 91-101.
[25] "Basic Wind Erosion Processes" Agricultural Ecosystems Environ, Leon Lyles, 1988, page 94.

elements do not remain suspended in air. Their primary mode of wind driven transport is surface creep along ground. During the December 2017 event at the Plutonium Finishing Plant, persistent wind speeds of 23 mph were recorded for over 10 hours, likely resulting in the contamination spread pattern over the ground driven by surface creep.

4.3 Wind Driven Soil Characteristics

Field conditions conducive to wind driven transport include[26]:

- Loose dry and finely granulated soil
- Smooth soil surface that has little or no vegetation
- Sufficiently large open area exposed to the wind with no barriers.
- Sufficient wind velocity or energy to move soil

Field conditions at Hanford show that roadways and developed areas have artificial large coarse aggregate brought in, which line the roadways and other buildings and facilities. Most of the large coarse aggregate is not prone to wind driven erosion, which is why it is widely used on site. The natural Hanford soil is very sandy and somewhat resistant to wind driven erosion due to natural coverage from sagebrush and bunch grasses, which reduce wind speed at the soil surface. Without this natural coverage, the soil would be highly prone to wind erosion. Wind tunnel tests performed on Hanford soil for effectiveness of man-made soil fixatives was conducted by Florida International University[27]. The following generalities can be taken away from these wind tunnel tests.

- Uncontaminated Hanford soil was determined to be on average 96.2% sand, 3% silt and 0% clay with an average moisture content of 2.7%.
- Due to the fine sand and low moisture content, these unprotected (without vegetation coverage) soils would be highly prone to wind driven erosion.

Based on these results, the following conclusions can be made from the wind tunnel tests on Hanford unprotected soil.

- Soil with a 2.7% moisture content had a threshold wind speed of 20 mph to become erodible.
- Soil with a 20% moisture content was not erodible up to 25 mph.

4.4 Example Application of Outdoor Contamination Survey Strategy

The number of surface deposition survey locations (e.g., cookie sheets or other designated survey locations) used for surface sampling is driven by the physical size and layout of the project footprint. The larger, more complex the project footprint the more sample locations are needed. Using other surfaces (e.g. flagpoles, trash cans, etc.) as surrogate indicators of contamination spread is also helpful in determining when/if contamination has spread. Two types of survey locations are systematic and biased (professional judgement).

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[26] "Wind Erosion" Information Sheet US Department of Agriculture https://efotg.sc.egov.usda.gov/references/public/TX/Wind_Erosion.pdf

[27] "Assessment of Soil Moisture and Fixatives Performance in Controlling Wind Erosion of Contaminated Soil at the Hanford Site", Applied Research Center, Florida International University, 2008.

4.4.1 Systematic Placement of Designated Survey Locations

The following approach is recommended for projects of varying sizes where a small project is about 1,000 ft^2. At Hanford it can be assumed that saltation will be the dominate mode of surface particle transport. Using a compass rose configuration centered on the project footprint, routine designated survey locations (in this example, cookie sheets will be used as the designated survey location; however, they are not required) can be placed as follows:

- Place routine cookie sheets approximately 10 to 15 feet beyond the project operational work zone because the stated estimate of travel by way of saltation is about 10 feet (see section 4.2.2).
- For small projects like the one noted above, with a sampling perimeter smaller than 400', a minimum of 8 routine cookie sheets/designated survey locations is recommended, at 45 degree intervals around the project (dividing a compass rose into 8 sectors).
- For medium projects where the sampling perimeter is 400 to 800 feet, the recommendation is to use about 12 routine cookie sheets/designated survey locations, or every 30 degrees. On average 50' between cookie sheets.
- For large projects where the sampling perimeter is larger than 800 to 2,000 feet, the recommendation is to use no less than 16 routine cookie sheets/designated survey locations, one in each wind sector or 22.5 degrees. On average about 100' between cookie sheets.

4.4.2 Biased Placement of Cookie Sheets

Biased cookie sheets can be placed for reasons of professional judgement. Some of the factors for placing biased cookie sheets include:

- Prevalent down-wind direction and wind speed.
- Other transportability factors such as potential for water run-off, walkways, animal pathways, Hanford roadways and parking lots.
  - Placing a cookie sheet on a common walk way provides feedback on potential transport via foot traffic and should be implemented provided it does not create a tripping hazard.
  - Parking lots provide a potential vector off site, so attention to personal vehicle proximity down wind is important.
- Sensitive natural receptors such as rivers require increased monitoring.
- Terrain features such as low spots and wind breaks where saltating and surface creep particles accumulate.
- Sensitive human receptors such as habited work force trailers.

The wind-rose compass in Figure 4 of Section 7 indicates that the predominate down-wind sector is southeast of the project (but does change based on the season). Increased number of biased cookie sheets should be placed in the prominent downwind section and adjacent sectors.

Saltating particles and surface creep, however, involve higher wind speeds above 14 mph. Therefore, based on a combination of wind direction and speed influencing saltation the important downwind sectors can vary.

Once the applicable sectors have been selected for monitoring by cookie sheets, these would be considered the biased sectors. For a small project, an additional two to four biased cookie sheets should be used. Likewise, for the medium and large sized projects, approximately 8 to 12 (or more if needed) biased cookie sheets can be used, based on the discretion of the project Radiological Control Manager (RCM).

4.4.3 Designated Survey Location (e.g., Cookie Sheet) Placement Considerations

The RCM should consider distances (horizontal and vertical) that Hanford soil particles can travel via saltation and surface creep when evaluating bias placement of designated survey locations (e.g., cookie sheets). As was discussed in Section 4.2.2, the minimum wind speed to observe transport due to saltation is about 13 mph, and once it occurs, saltating particles can travel vertically up to about 1 foot in air and about 10 feet horizontally. As stated in Section 4.4.2, saltating particles can travel up to about 50 horizontal feet when vegetation is not present, but that would require multiple bounces with the unobstructed trajectory. Therefore, an average estimated horizontal distance for placement of cookie sheets beyond work zone boundaries should be about 10 feet. In terms of vertical placement, if cookie sheets are used then they should not be placed greater than 12 inches above the ground and a vertical location closer to the ground is better because surface creep can also occur, and needs to be considered as well.

When considering surface creep, as stated in section 4.2.3, the minimum wind velocity threshold for this phenomenon to occur is about 17 mph, but at Hanford, the threshold is about 20 mph based on testing by the Florida International University. Surface creep involves particles much larger than saltating particles and whose motive force is often saltating particles colliding with other particles. By inference, it can be assumed that these larger particles are highly susceptible to gravitational settling (unlike those much smaller ones that are suspended – see Section 4.2.1) and as a result do not travel vertically or horizontally over long distances for short duration winds greater than threshold velocities. Mesh wind screens placed on fence structures that surround outdoor work activities can be particularly useful in terms of minimizing the potential spread of contamination by saltation and surface creep.

4.5 Example Outdoor Engineering Contamination Control Strategy

The strategy for monitoring for the potential spread of radiological contamination during outdoor work activities, described in Section 4.4, should be supplemented by radiological work planners with a well-considered engineering control strategy. Engineering controls are primarily used to prevent or mitigate the inadvertent transfer of removable contamination outside of radiological areas under normal operating conditions (satisfying 10 CFR 835.1102(a)).

In consideration for the types of engineering controls to select for the prevention or minimization of soil erosion and transport of particles, several best management practice options exist. These options (not an exhaustive list) are provided based on the best management practices described by the Washington State Department of Ecology's Stormwater Management Manual for Eastern Washington:

- Windbreaks,
- Large aggregate,
- Silt Fences, and/or
- Dust Suppression

4.5.1 Windbreaks

Typically used for smaller scale outdoor projects such as removal of soil, crib excavations, replacement of service lines, etc., natural or artificial windbreaks/windscreens may be designed as enclosures. Examples of windbreaks for the smaller projects can be board fences, tarp curtains, bales of hay, earthen berms of clean fill covered with a wind-impervious fabric, or equivalent material, etc.

4.5.2 Large Aggregate

Large aggregate, commonly seen at the Hanford Site, are not erodible and resist the movement of water, wind, and some human activity. Using large aggregate maintains surface porosity, allowing better movement of water and wind without eroding the surface soil (located underneath the aggregate). Moreover, when used in concert with dust suppression, the particles generated during outdoor work activities will be less susceptible to transport by saltation since the impact on the surface of the aggregate will resist subsequent horizontal movement due to the large differences in size of the smaller impacting particle(s) onto the much larger aggregate material.

4.5.3 Dust Suppression

Dust suppression techniques, when correctly applied, help to prevent wind transport of dust from disturbed soil surfaces and assist with gravitational settling of particles generated during outdoor work activities at Hanford. Flocculants can be used to assist with keeping dust concentrations to a minimum by increasing the gravitational settling rate, but there are limitations to its use and working with the Environmental Management System to understand its impacts will be needed.

Use of water cannons, foggers, and/or misters should be applied in such a way that application of water is used to minimize the motive force applied to particles generated during outdoor work activities. A technical evaluation for water cannons was developed at PFP and is included as Appendix A of this CDMP. This evaluation describes how this control may be applied. Each outdoor work activity that uses foggers, misters, or water cannons to control the spread of contamination should consider using this evaluation as a basis for developing its project-specific engineering control.

4.5.4 Silt Fences

Although typically used to protect against the transport of coarse sediment from a construction site due to surface water runoff and overland flows, the intended purpose for the use of silt fences here is to guard against transporting contaminated soils by the saltation and creep mechanisms described in this section of the technical document. While traditional silt fences are designed to permit water flow through a geotextile fabric, the pore size of most of these fabrics are not sufficiently small to restrict the movement of soil particles below about 150 μm in size (using #100 sieve), based on recommendations by the Washington State Department of Ecology's Stormwater Management Manual for Eastern Washington. In this regard, the radiological work planners should carefully consider type of material to be used.

Design and Installation Specifications

Once material type of selected, the silt fence should follow some basic design and installation specifications. Referring to the Washington State Department of Ecology's Stormwater Management Manual for Eastern Washington for these recommendations is most helpful.

- The silt fence should be attached to posts and supported with wire mesh, chicken wire, 2-inch x 2-inch wire, additional safety fence, or other type of wire mesh to increase the strength of the fabric.

- The silt fence fabric should contain ultra violet ray inhibitors and stabilizers to provide a minimum of six months of expected usable construction life at a temperature range of 0°F to 120°F.
- The minimum height of the top of the silt fence should be 2 feet above the ground surface.
- When attaching to the posts, the silt fence fabric/material should be attached in a manner that reduces the potential for tearing.
- The silt fence material should be buried to a minimum depth of 4 inches below grade surface to prevent forces due to heavy winds from creating gaps through which potentially contaminated soils can transport.
- The fence posts should be placed or driven 12 to 18 inches below the surface of the soil and be placed between 6 and 8 feet apart.
- Wooden, steel, or equivalent posts should be used and should have a minimum length of 3 feet and be wide enough to attached the silt fence fabric and strong enough to stand erect without additional bracing after placement.

See figure below as an example of silt fence construction.

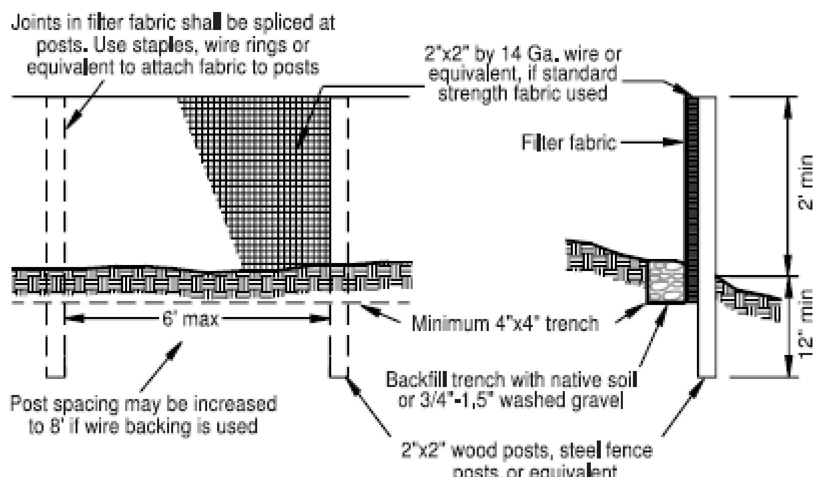

Figure 7.3.20 – Silt Fence

5.0 Need for Air Sampling

In this section, the need for radiological outdoor workplace air monitoring in general and the need for continuous air monitoring are addressed. 10 CFR 835.403 requires monitoring of airborne activity where an individual is likely to receive an exposure of 40 DAC-h in a year and as necessary to characterize the airborne radioactivity hazard where respiratory protective devices have been prescribed. The Radiological Protection Program uses approved AME to meet this requirement. An analysis of the need for AME sampling is performed below but varies somewhat from the criteria provided in 0904-CDMP-0011 and NUREG-1400 by using MAR and ST for the values used in CDMP-0011 represented by Q_A (amount of material used/processed in a year) and I_P (potential for intake), respectively. The reason for the variance is that 0904-CDMP-0011 specifically includes an evaluation of the need for air monitoring based on the criteria specified in NUREG-1400, which was developed for indoor workplace air monitoring and is not necessarily applicable to outdoor activity. Because the approach shown in Section 3.1 and 3.2 is approved by DOE in DOE-STD-3009-2014, it will be likewise used in a similar fashion as that provided in NUREG-1400. Using the values of Q_A and I_P and the approach described by 0904-CDMP-0011 and NUREG-1400 is also a valid method because it does evaluate potential for work-specific activities that can increase the likelihood of generating airborne radioactivity.

5.1 Criterion 1 – Amount of Material Handled/Processed in a Year

0904-CDMP-0011 evaluates the NUREG-1400 approach and discusses when the amount of material handled/processed in a year exceeds 10,000 times the Annual Limit on Intake (ALI), the need for air sampling should be *considered*. This value is based on observing a fraction of 0.01 times the Stochastic ALI (SALI) or Deterministic ALI (DALI) and results in a TED of 50 mrem. CPCCo has elected to incorporate the ANSI/HPS N13.39-2001, *Design of Internal Dosimetry Programs* guidance of 0.02 SALI, or 100 mrem as a means to determine whether air sampling should be considered. This equates to the consideration for air sampling if the amount of material handled/processed in a year exceeds 20,000 times the ALI.

It has been discussed in Section 3.2 how the MAR is used to determine whether Criterion 1 is met.

To reiterate:
An example calculation of the MAR for multiple radionuclides for the purposes of comparing its value to 20,000 x ALI is provided below where the following is given:

- ^{137}Cs (10.6 Ci) ALI = 192 µCi
- ^{90}Sr (8 Ci) ALI = 16.8 µCi
- ^{108m}Ag (1 Ci) ALI = 48 µCi
- ^{239}Pu (0.7 Ci) ALI = 0.012 µCi
- ^{241}Am (0.25 Ci) ALI = 0.012 µCi

$$MAR\ ratio = \sum_{i=1}^{n}\left(\frac{Cs-137\ activity}{Cs-137\ ALI} + \frac{Sr-90\ activity}{Sr-90\ ALI} + \frac{Ag-108m\ activity}{Ag-108m\ ALI} + \frac{Pu-239\ activity}{Pu-239\ ALI} + \frac{Am-241\ activity}{Am-241\ ALI}\right) \quad \text{Equation 4}$$

$$MAR\,ratio = \sum_{i=1}^{n}\left(\frac{1.06E7\,\mu Ci}{192\,\mu Ci} + \frac{8E6\,\mu Ci}{16.8\,\mu Ci} + \frac{1E6\,\mu Ci}{48\,\mu Ci} + \frac{7E5\,\mu Ci}{0.012\,\mu Ci} + \frac{2.5E5\,\mu Ci}{0.012\,\mu Ci}\right) = 7.97E + 7$$

Now compare the value above with 20,000 (just as in Eq. 2.2 of CDMP-0011). Because 7.97E+7 is clearly greater than 20,000, then **Criterion 1 is met and air sampling should be considered**. Criterion 2 shall be evaluated to determine the potential intake. If the MAR ratio was calculated to be less than 20,000 then air sampling would not be needed.

5.2 Criterion 2 – Potential Intakes

P0904-CDMP-0011 uses the method for evaluating the need for workplace air sampling based predominantly on NUREG-1400 guidance as modified by ANSI/HPS N13.39-2001. These documents were developed and designed for facility based workplace air monitoring and NUREG-1400 specifically excludes “effluent monitoring.” Open-air work activities are a hybrid between facility workplace air monitoring and effluent monitoring. It is analogous to workplace air monitoring in that the primary concern is the exposure of a worker to airborne radioactivity. It is analogous to effluent monitoring in that the dispersion and deposition of airborne radioactivity is dependent upon the ambient environmental conditions at the time of emission.

With this conundrum in mind, substitution of relevant factors associated with the EF may be made. If the potential for intake, I_P, is greater than 0.02 times the ALI (in this example, ^{239}Pu with 0.012 µCi ALI is used), then air sampling is required.

If I_p >0.02 ALI

If I_p >(0.02)(0.012 µCi)

If I_p >2.40E-04 µCi, then air sampling is required.

Consideration is given to the potential for intake of material by a worker. The potential for intake (I_p) is the same as the source term, ST, when addressing potential for intake as a result of outdoor airborne concentration(s). The example calculations provided in Section 3.3 show the results of calculating ST, which is equivalent to I_P. As a reminder, the results of this calculation are listed as follows:

- ^{137}Cs 180 µCi
- ^{90}Sr 136 µCi
- ^{108m}Ag 17 µCi
- ^{239}Pu 11.9 µCi
- ^{241}Am 4.25 µCi

If I_P (or ST) > 0.02 x ALI, then air sampling is required. In this example, the following calculations are made for each radionuclide:

- ^{137}Cs
  - 0.02 x 192 µCi = 3.84 µCi.
  - ST = 180 µCi and IS > 3.84µCi, therefore air sampling ***is required***.
- ^{90}Sr
  - 0.02 x 16.8 µCi = 0.34 µCi.

    - ST = 136 µCi and IS > 0.34µCi, therefore air sampling ***is required***.
- ^{108m}Ag
    - 0.02 x 48 µCi = 0.96 µCi.
    - ST = 17 µCi and IS > 0.96 µCi, therefore air sampling ***is required***.
- ^{239}Pu
    - 0.02 x 0.012 µCi = 2.4E-4 µCi.
    - ST = 11.9 µCi and IS > 2.4E-4 µCi, therefore air sampling ***is required***.
- ^{241}Am
    - 0.02 x 0.012 µCi = 2.4E-4 µCi.
    - ST = 4.25 µCi and IS > 2.4E-4 µCi, therefore air sampling ***is required***.

Because at least one (in this case 5 out of 5) of the radionuclides of interest results in a potential for intake greater than 0.02 ALI, then **Criterion 2 is met and air sampling is required**.

5.3 Criteria 5, 6, and 7 (Need for Real Time Monitoring)

Criteria 5, 6 (if data are available) and 7 shall always be used to determine whether real-time air monitoring is required. Criteria 5 or 6 evaluate if air monitoring is required based on the amount of material handled or processed in a week and potential intakes. Criterion 7 evaluates accident scenarios.

5.3.1 Criterion 5 – Amount of Material Handled or Processed

Real-time air monitoring shall be performed as necessary to detect and provide warning of airborne radioactivity concentrations that warrant immediate action to terminate inhalation of airborne radioactive material. This criterion is derived from NUREG-1400 guidance utilized in Criterion 1. Real-time air monitoring should be considered when the quantity, Q_W, of radioactive material being processed/handled in a week (40 hours.) can potentially result in an exposure of 40 DAC-h, where Q_W is defined by the equation below. Criterion 1 is based off quantity of material processed in a year (Q_A) which has the potential to result in an intake of 100 mrem; therefore, real time air monitoring is required (when the quantity processed in a week (Q_W) meets or exceeds 20,000 ALI limit of Criterion 1.

As a reminder, the amount of material processed in a year was previously defined by the MAR as follows:

- ^{137}Cs (10.6 Ci) ALI = 192 µCi
- ^{90}Sr (8 Ci) ALI = 16.8 µCi
- ^{108m}Ag (1 Ci) ALI = 48 µCi
- ^{239}Pu (0.7 Ci) ALI = 0.012 µCi
- ^{241}Am (0.25 Ci) ALI = 0.012 µCi

A calculation for each radionuclide shall be performed. For example, please see the calculation for ^{239}Pu below:

$$Q_W > 20{,}000 \text{ ALI} \qquad \text{Equation 5}$$

$$Q_W = \frac{\text{MAR (Material handled in a year)}}{\text{50 weeks/yr}} > (20{,}000)(0.012\ \mu\text{Ci})$$

$$Q_W = \frac{0.7\ \text{Ci/year}}{50\ \text{weeks/yr}} > (20{,}000)(0.012\ \mu\text{Ci})$$

Q_W = 14,000 µCi/week and is >240 µCi

If the calculation is performed for all five radionuclides, then the results are listed below:

- ^{137}Cs (10.6 Ci) ALI = 192 µCi
  - 20,000 x 192 µCi = 3.84 Ci
  - Q_W = 0.212 Ci/week and IS NOT > 3.84 Ci, therefore real-time air monitoring **is not required**
- ^{90}Sr (8 Ci) ALI = 16.8 µCi
  - 20,000 x 16.8 µCi = 0.34 Ci
  - Q_W = 0.16 Ci/week and IS NOT > 0.34 Ci, therefore real-time air monitoring **is not required**
- ^{108m}Ag (1 Ci) ALI = 48 µCi
  - 20,000 x 48 µCi = 0.96 Ci
  - Q_W = 0.02 Ci/week and IS NOT > 0.96 Ci, therefore real-time air monitoring **is not required**
- ^{239}Pu (0.7 Ci) ALI = 0.012 µCi
  - 20,000 x 0.012 µCi = 240 µCi
  - Q_W = 14,000 µCi/week and IS > 240 µCi, therefore real-time air monitoring **is required**
- ^{241}Am (0.25 Ci) ALI = 0.012 µCi
  - 20,000 x 0.012 µCi = 240 µCi
  - Q_W = 5,000 µCi/week and IS > 240 µCi, therefore real-time air monitoring **is required**

As a result, **Criteria 5 is met and real time air monitoring is required for alpha** airborne radioactivity**.**

5.3.2 Criterion 6 – Potential Intakes

$$I_W > 0.02\ \text{ALI}$$

Consideration is given to the potential for intake of material by a worker. The potential for intake (I_W) is calculated by taking into account several modifying factors as follows;

$$I_W = Q_W \times \text{EF} \qquad \text{Equation 6}$$

The values for Q_W were calculated in Section 5.3.1 and are presented here:

- ^{137}Cs 0.212 Ci/week
- ^{90}Sr 0.16 Ci/week
- ^{108m}Ag 0.02 Ci/week
- ^{239}Pu 14,000 µCi/week
- ^{241}Am 5,000 µCi/week

For ^{239}Pu, the following calculation using Equation 5 is made, where the value for EF is taken from Table 1:

$$I_W = 14{,}000\mu Ci/wk \times 1.54E\text{-}4$$

$$I_W = 2.2\ \mu Ci$$

As a result, 2.2 µCi > 2.40E-04 µCi, Therefore, Criterion 6 is met and real-time air monitoring is required.

If the calculation is performed for all five radionuclides, then the results are listed below:

- ^{137}Cs
  - 0.02 x ALI = 0.02 x 192 µCi = 3.84 µCi
  - I_W = 32.6 µCi and IS NOT > 3.84 Ci, therefore real-time air monitoring **is not required**
- ^{90}Sr
  - 0.02 x ALI = 0.02 x 16.8 µCi = 0.34 µCi
  - I_W = 24.6 µCi and IS > 0.34 µCi, therefore real-time air monitoring **is required**
- ^{108m}Ag
  - 0.02 x ALI = 0.02 x 48 µCi = 0.96 µCi
  - I_W = 3.1 µCi and IS > 0.96 Ci, therefore real-time air monitoring **is required**
- ^{239}Pu
  - 0.02 x ALI = 0.02 x 0.012 µCi = 2.4E-04 µCi
  - I_W = 0.24 µCi/week and IS > 2.4E-04 µCi, therefore real-time air monitoring **is required**
- ^{241}Am (0.25 Ci)   ALI = 0.012 µCi
  - 0.02 x ALI = 0.02 x 0.012 µCi = 2.4E-04 µCi
  - I_W = 0.77 µCi/week and IS > 2.4E-04 µCi, therefore real-time air monitoring **is required**

As a result, **Criteria 6 is met and real time air monitoring is required for alpha and beta** airborne radioactivity**.**

5.3.3 Criterion 7 – Accident Scenario Analysis

Real-time air monitoring shall be performed as necessary to detect and provide warning of airborne radioactivity concentrations that warrant immediate action to terminate inhalation of airborne radioactive material. Such events, should they occur, are likely to result in an exposure exceeding 40 DAC-h in one week, which may be evaluated as the potential to exceed 8 DAC-h in a single work shift. This criterion is qualitatively evaluated based on a selection of accident scenarios that could potentially result in an increase in airborne radioactivity.

Examples of discrete events that may occur that are likely to result in an exposure exceeding 40 DAC-h in one week, or 8 DAC-h in a single work shift should be identified and discussed to ensure this criterion is appropriately evaluated. Accident analysis with subsequent dose determinations, including frequency of risk, have already been performed for nuclear facilities and are documented in project/facility – specific Documented Safety Analyses (DSA)/Basis for Interim Operations (BIO) documents.

When Criterion 5, 6 and 7 have been evaluated and real-time for alpha and beta is required by at least one of these criteria), then Criterion 8 is not required to be evaluated as stated in 0904-CDMP-0011, Section 2.2.2.

5.4 Fugitive Dusts/Inhalation

This scenario assumes that a worker will not inhale more than 360 mg of particulates in a day. The ANSI/HPS N13.39-2001 uses the value of 400 mg of particulates in a day. This value was rounded up from 360 mg of particulates in a day which was determined from a tolerance for breathing dust in air (Carbaugh 1993). A value of 360 mg of particulates in a day is used for consistency with the Radiological Control Manual Table 5.2. Applying Equation 7 below shows how to estimate the specific activity (SA) of the fugitive dusts inhaled by a worker.

$$SA < \frac{DF \ x \ ALI_{inh} \ x \, WF}{0.36 \ x \ O} \quad \text{(Eq. 7)}$$

Where:

SA = specific activity of the material

DF = dose fraction, which is typically set to 0.02 (2 % of the ALI)

O = occupancy factor from Table 2.3 of 0904-CDMP-0011

WF = Wetting Factor of 6 (CPCC 2012d)

If the specific activity is equal to or exceeds the condition then air sampling is recommended. However, if the condition holds true (i.e. doesn't exceed the condition) then monthly or quarterly grab samples may be appropriate to confirm that airborne levels are low.

The following is an example of determining routine air sampling needs when a mixture of radionuclides is present.

Table 3: Example Soil Mixture

Nuclide	Specific Activity (µCi/g)	ALI_{inh} (µCi)
H-3	5.5	75,000
Pu-239	3E-06	0.012
Cs-137	0.015	200

Apply Eq. 7:

H-3: $\frac{0.02 \times 75{,}000}{0.36 \times 250} = 16.67$ µCi/g

Pu-239: $\frac{0.02 \times 0.012}{0.36 \times 250} = 2.67E - 06$ µCi/g

Cs-137: $\frac{0.02 \times 200}{0.36 \times 250} = 4.44E-02$ µCi/g

The fraction of the specific activity measured by the data sample to the criterion is calculated below:

H-3: 5.5/16.67 = 0.330

Pu-239: (3E-06)/(2.67E-06) = 1.124

Cs-137: 0.015/0.0444 = 0.338

The sum of the fractions is (0.330 + 1.124 + 0.338 = 1.79) is greater than 0.9; therefore, air sampling is required.

NOTE: Changing the dose fraction, DF, is permissible as long as the technical justification is documented and approved in a project/facility technical evaluation. The DF may be changed in conjunction with the occupancy factor, O, to provide added realism to workplace conditions.

Table 4 provides soil concentrations which will require air monitoring at different thresholds of the deterministic ALI for Pu-239.

Table 4: Example – ^{239}Pu Soil Concentrations

Above Which Air Sampling is Required

^{239}Pu Soil Concentration (pCi/g)		
2% ALI	**20% ALI**	**30% ALI**
2.67	26.67	40

5.5 Soils Work Air Concentration Estimate

The air concentration for work evolutions can be estimated from the specific activity of the soil and from the dust loading factor which was used to determine the 360 mg/d value in equation 2.17. Those dust loading values were used to keep consistency throughout this document.

$$C_{air}\left[\frac{\mu Ci}{ml}\right] = \frac{C_{Soil}\left[\frac{pCi}{g}\right] \times DL\left[\frac{g}{m^3}\right]}{K\left[\frac{\frac{pCi}{m^3}}{\frac{\mu Ci}{ml}}\right] x\, WF} \quad \text{(Eq. 8)}$$

Where:

C_{air} = specific activity in the air (µCi/ml)

C_{soil} = specific activity in the soil (pCi/g)

DL = dust loading factor (g/m^3) – See Table 5

K = conversion factor, 1E+12 (pCi/m^3 /µCi/ml)

WF = Wetting factor of 6 (CPCC 2012d)

Table 5 displays the different dust loading factors which can be used (Carbaugh 1993).

Table 5: – Dust Loading Factors

Dust Loading Factor (g/m^3 air)	Applicable Situation
0.020	Dust particles would be visible on clothing, hair, and glasses (etc.)
0.150	Unmitigated dust cloud generated from excavation by heavy equipment.

5.6 Wetting Factors

Evaluation of the WCH demolition wetting factors (WCH 2010) for use is based on a review of cited references, especially the Florida International University study in 1996. The study was performed with the purpose of evaluating effectiveness of dust aerosol abatement during the demolition of nuclear facilities and determining mathematical correlations that can be applied during these demolitions. The study focused on a broad range particle sizes (Ebadian, et al 1996).

The researchers evaluated various publications on dust suppression and methods of demolition from both government and industry, however one publication from the Environmental Protection Agency (EPA 2006) was not evaluated by them. While this publication is based on determining emission factors, not reduction factors, it does discuss control methods for general construction activities to control emissions. The recommended control methods in that publication are wind speed reduction and wet suppression. The idea of wind speed reduction is the application of a barrier to break the wind as it travels, not a limitation on wind speed. However, use of a wind speed limitation could serve as a control method by increasing the travel time of emissions, which would increase the contact time of wet suppression methods. The tests conducted by Florida International University did evaluate suppression with and without wind.

PBS and water are routinely used at Hanford in suppression/fixative applications. 28Coherex® is a dust retardant that is similar to soil cement in its application and properties and is commonly used in road construction. It forms a solid, dense, waterproof base.

The tests performed resulted in a dust suppression wetting factor for water of 1.796 (1.8 rounded). This correlates with the wetting factor detailed in the WCH-82 document. However, this was based on early data performed in 1996, which was based on a broad range of particle sizes. In 1997, additional tests were performed on a narrower range of particle sizes more applicable to deposition in the human respiratory tract and with refinements in test methods and data acquisition systems (Ebadian, et al 1997). The 1997 study determined overall dust suppression by wet suppression methods for particle sizes >0.3 um.

[28] Coherex is a registered trademark of Tricor Refining, LLC.

The same study identifies suppression based on particle size ranges. Absent from the particle size study is the effect of water spray as a suppression agent. Whereas the overall suppression does indicate an effectiveness for particles >0.3 µm, In general, as particle size increases the effectiveness of suppression increases. Based on the overall evaluation, water spray is 10% more effective than water soaking, which should hold true for specific particle ranges that are respirable.

Since the radiological area of concern is the 5 µm particle size, the range of 4.0 to 7.0 µm is considered for the purposes of this evaluation. Since water is the most commonly used suppression agent during demolition, the 73.1% effectiveness of water-soaked materials cited in the Florida International University study is key in the 4.0 to 7.0 µm range (Ebadian, et al 1997). Applying the 10% greater effectiveness of the water spray as compared to water soaking from particle size specific effectiveness would bring the estimated effectiveness of water spray in the 4.0 to 7.0 um particle size range to 83.1%.

Using a standard reduction equation, the calculated wetting factor is 5.92 for the range of particles between 4.0 and 7.0 um during demolition activities. When reviewing the statistical variation of the study, rounding the wetting factor to 6 is reasonable (Ebadian, et al 1997).

Soil work presents a much bigger problem in that the current documentation does not identify the effectiveness of suppression methods as was done for the demolition example. WCH-82 identifies a wetting factor of 10 for soils work is based on an EPA document (EPA 2006) where fugitive dust emissions were evaluated by road traffic on unpaved roads. The only data presented as to effectiveness of a control measure consists of a graph of control efficiency to moisture ratio for water. WCH used these data to determine that a moisture ratio of 4.5 average (3-6% moisture (Bond and Casbon 2003)) results in a 90% control efficiency or a wetting factor of 10 (WCH 2010). This study was based on a PM10 or particle size of 10 µm, which is above our 5.0 µm reference standard (EPA 2006).

Since we do not measure moisture in the soils we work with, the difference in particle size indicates the application of this wetting factor is not valid for work planning purposes. This is not to say that no factor can be determined for this purpose, but it must be defined within what we know using the demolition studies above.

Using the demolition study information (Ebadian, et al 1997), the effectiveness of water-soaked materials for the 7.0 to 10.0 µm range is 78%. With the correction of 10% greater effectiveness for water spray, this brings the result to 88% suppression in the 7.0 to 10.0 µm range which correlates well with the 90% cited above in the EPA study (EPA 2006). This indicates a relationship exists between the demolition example and soils work that has been done.

Applying the same evaluation to the 4.0 to 7.0µm range, the overall suppression effectiveness would be 83.1% or a wetting factor of 6.

6.0 Exceptions to Air Sampling and Real-Time Air Monitoring Requirements

There are no exceptions to Air Sampling and Real-Time Air Monitoring Requirements.

7.0 Airflow Studies

For outdoor work activities, there is rarely, if ever, any ventilation engineered control available. Therefore, air flow studies are not appropriate. Instead, anticipated dispersion and deposition modeling should be based on meteorological patterns identified from historical hourly meteorological measurements from the nearest/representative met station and include other supporting data from the Hanford Meteorological Station. The meteorological data include wind direction, wind speed, precipitation rate, and data from which to calculate location dependent degree of dispersion. The historical weather patterns are assumed representative of conditions that will occur during the period of time the outdoor work activity will be performed. Some of the hourly data may include wind velocities at >15 mph. Even though outdoor work activities should typically occur when winds are <15 mph, the high wind speed data should not be excluded. This is because the 95^{th}percentile dispersion conditions are based on a cumulative distribution function where only 5% of the cases result in less dispersion. That is, only the upper 5% of the dispersion coefficients impact the final 95% value. Since winds >15 mph result in less concentrated plumes (greater dispersion), air concentrations computed for those conditions do not impact the final 95^{th}percentile value because they fall in the bottom 95% of the values. The same logic applies to 99^{th} percentile conditions.

With regard to planning and strategically determining how contamination is potentially spread due to air suspension of particles, wind conditions (e.g. speed, direction, and elevation) from the nearest/representative met station can provide historical information to help understand where dispersion and deposition will likely occur and aid in understanding how particles travel via this modality. In terms of wind-driven migration of soils and other particles, a more localized understanding of wind conditions is needed to understand how saltation and creep affect the potential spread of contamination. Based on discussion in Section 4.2.2 and 4.2.3, the saltation and creep threshold wind speeds for outdoor work activities at Hanford are 15 mph and 20 mph, respectively. These wind speeds and directions should be measured at near surface elevations and represent wind conditions to which workers are exposed, thus providing a conservative view of any prospective dose determination.

Figure 4 on the following page illustrates that the applicable blue colored region on the wind rose diagram ranges from 13 mph to 20 mph and envelopes threshold wind velocities applicable for outdoor work activities. This figure represents historical data and provides an indication of general wind conditions based on a six-year average. Wind gusts can occur from non-dominant directions, which is why timely, localized, project-specific considerations shall also be made to account for seasonal and acute weather pattern changes.

As an example of what historical wind data will look like, the following figure graphically presents the wind rose data resulting from an analysis of historical data. Although there is some variability between seasons and shifts, these composite data provide an indication of the dominant wind direction for the given example. AME is located to monitor each compass sector with emphasis on the down-wind direction, but the number and placement of these AME can be similar to the systematic and biased placement of designated surface deposition survey locations (e.g., cookie sheets) described in Section 4.4.1 and 4.4.2. Co-location of AME and designated survey locations sheets is encouraged, but placement of real-time monitoring equipment should follow suggestions is Section 8.

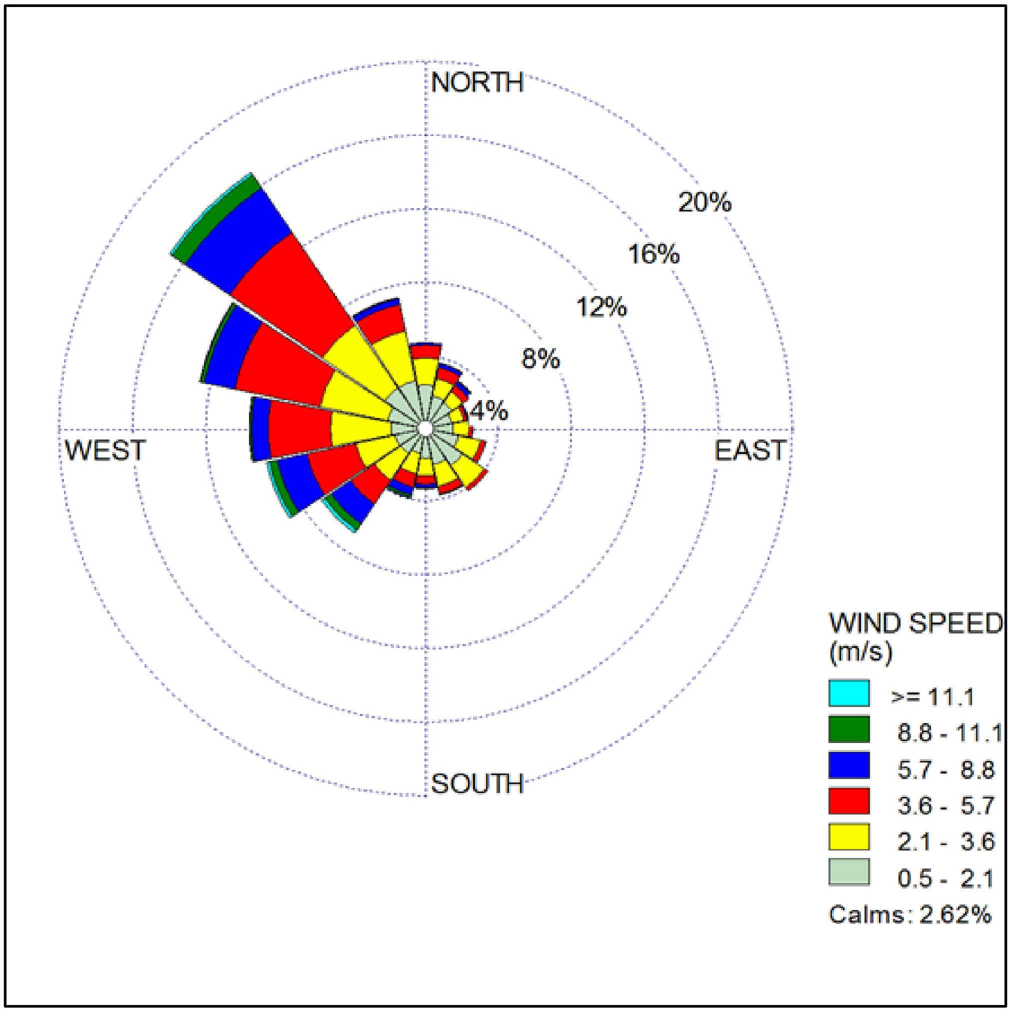

Figure 4: Average Six Year (2004–2009) Wind Rose (wind from) for the 16 defined compass sectors – All Conditions

8.0 Placement of Air Emission Sampling/Monitoring Equipment

Placement of AME around outdoor work activities requires a paradigm shift. Static worker body position that may be found inside of a facility building/room is supplanted by dynamic daily changes in work scope actively excavating soil, moving rubble, demolishing structures, and filling waste containers in preparation for transport and disposal. No longer is there a fixed air sampling system to monitor specific locations which reflect worker location and associated breathing zone in relation to potential release and/or intake.

Open-air work presents a challenge in anticipating air flow patterns during work activities. In order to address these challenges, it is necessary to shift from in-facility paradigms having retrospective or real-time AME in assigned locations to monitor predictable air flows and consequently worker breathing zone concentrations. The dynamic nature of wind flow pattern negates the ability to locate air emission monitoring equipment in defined air flow paths.

The objectives of air emission sampling/monitoring are: (1) to establish, with reasonable confidence, that individual radiological workers are not exposed to radioactive materials at levels in excess of 10 CFR 835 occupational radiation protection requirements; (2) to protect the environment and members of the public from unnecessary radiation exposure; and, (3) to control radiation doses received by members of the public as a result of outdoor work activities.

Four types of air emission monitoring are used to support these objectives:

- retrospective air samplers (at prescribed locations and as “grab samples” for task specific support),
- real-time monitoring with alarm/alert capability,
- breathing zone monitoring, and
- surface deposition collection and monitoring.

Examination of parameters involved in release mechanisms, transport models and exposure pathways for airborne releases from nuclear facilities reveals that population exposure calculations (both collocated worker and Maximum Exposed Individual (MEI)) are based upon demography and meteorology. These site-specific attributes lead to expert-based, weighted judgmental placement of air samplers.

AME location incorporates historical meteorological data related to potentially affected workers and individuals. This “weighted judgmental” method focuses retrospective air samplers and surface contamination deposition monitoring locations in the predominant down wind direction with a demographic bias. Air dispersion and deposition models can be used to place samplers. The models incorporate source information, surrounding topography, and meteorological data to predict the general distance and directions of maximum ambient concentrations. Modeling results are used to select sampling locations in areas of maximum pollutant concentrations. Weather monitoring becomes critical where complex terrain and local meteorological effects frequently change wind direction. Sampling locations may have to ring the site to measure the wind's impact.[29]

Real-time AME location is optimized to provide an early warning to individuals of a significant increase in levels of airborne radioactivity that warrant immediate action to terminate exposure to airborne

[29] Scientific Engineering Response and Analytical Services, Standard Operating Procedure 2008, *General Air Sampling Guidelines*

radioactivity. Typically, real-time air monitoring should be used in areas where unexpected increases in airborne radioactivity levels could result in an exposure to an individual exceeding 40 DAC-h in one week. Radiological Work Planners calculate potential airborne radioactivity concentrations from work activities. When predicted airborne radioactivity concentrations and durations from these planned activities are such that an individual will likely exceed 40 DAC-h/week then the Radiological Work Planner prescribes additional real-time air monitoring when no suitable CAM is in place. When selecting locations for AME and real-time AME, consideration is given to the locations of possible release point and workers, the purpose of the sample and current environmental airflow patterns. Real-time air monitor alarm set points (ASP) reflect work site conditions and the criteria warranting immediate termination of exposure. As an example, default Alpha Sentry CAM chronic ASP are presented below for each respiratory protection factor (PF) utilized.

Table 6: Default CAM Chronic Alarm Set Points

CAM	No Respirator	PF of 1,000	PF of 10,000
Canberra Sentry (Chronic)	8 DAC-h	80 DAC-h	800 DAC-h

Alpha Sentry CAMs are typically set at these values; however, the ASP can be adjusted to provide an early warning that the applicable respiratory protection factor may be exceeded. When the ASP is adjusted based on respiratory protection factors, the justification should be documented in an internal memorandum, included as part of a facility procedure, or in the applicable facility Technical Evaluation (TE).

The default ASP for CAMs during demolition activities is typically 8 DAC-h based on implementation guidance for 10 CFR 835, DOE G 441.1-1C. In some unique circumstances, it may be necessary to establish ASPs at 24 DAC-h based on guidance from DOE G 441.1-1C for limiting nuisance alarms, but this should be addressed in a project/facility TE. Any CAM with an ASP of 24 DAC-h (or higher) shall have an 8 DAC-h CAM located at a greater distance from the work zone boundary in the same direction as the 24 DAC-h CAM.

9.0 Task Specific Air Emission Sampling and Monitoring

Notwithstanding the air emission air monitoring network, additional regulatory drivers exist from the U.S. Department of Energy (DOE) and the Washington State Department of Ecology (Ecology) as will be discussed in the following sections.

9.1 Department of Energy

In terms of requirements hierarchy, the flow down is from 10 CFR 835, *Occupational Radiation Protection,* Central Plateau Cleanup Company *Radiation Protection Program* and to the *Radiological Control Manual*. 10 CFR 835 establishes the basic requirements of a Workplace Air Monitoring Program. CPCCo is committed to follow 10 CFR 835, 2007 version (as amended), for DAC values.

For air emission sampling, CPCCo uses four primary techniques: retrospective air samplers and grab air sampling; lapel air sampling; real-time air monitoring; and, surface deposition collection and monitoring. While each has its primary purpose, there is overlap between some of the methods to meet facility/project objectives. For deposition of radioactive particulates on horizontal surfaces, CPCCo typically uses “cookie sheets” which are generally located adjacent to either air samplers or real-time air monitors.

Open-air work activities create some challenges to direct implementation of 0904-CDMP-0011. This document is designed for prescribing the air monitoring system for a facility/project within which engineered controls exist (i.e. facility ventilation and containments). For some projects, such as open-air demolition, engineered controls have essentially been eliminated. A level of "confinement" is established by application of fixatives to serve as an additional hazard control or quasi-"engineered barrier." The same logic of compromising an engineered barrier or performing "intrusive" work is appropriate in planning work and instituting job or task-specific air emission monitoring.

In addition, without the rigor of facility engineered controls, the identification of air sampler location to adequately monitor the individual worker's breathing zone remains a significant challenge with air samplers or real-time air monitors.

Surface deposition monitoring is also complicated due to the conflicting contamination mechanism of particle migration. Windblown particles can readily move across a surface by being "re-suspended" briefly and then depositing on another downwind surface. Particle transport is a function of size. Particles move through the processes of saltation, surface creep, and air suspension. There is not necessarily a direct correlation between air sample results and surface contamination results. It is appropriate to relate these results as each may be an indicator of potential elevation of the other.

9.2 Washington State Department of Ecology

Many outdoor/open-air activities (e.g. PFP and others) are performed in a manner consistent with the planned final remedial action under authority of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA). Additionally, under the authority of the *Hanford Federal Facility Agreement and Consent Order,* also known as the Tri-Party Agreement (TPA). Under this agreement, the Washington State Department of Ecology (Ecology) is the lead regulatory agency.

The DOE is committed to performing the intrusive outdoor work based on the Remedial Action Work Plan (RAWP). Within this framework is discussion of "Airborne Emission Monitoring". In particular, there is recognition of the challenges of diffuse and fugitive monitoring. Point source, diffuse, and fugitive source monitoring are prescribed. Monitoring activities include:

- Real time and periodic radiological monitoring using temporary ambient monitors as prescribed by the Radiological Protection Program as a primary method for evaluating compliance with the action levels and void limits.

- Radiological smear surveys as an indicator of air emission rates based on gross residual contamination levels.

These two sampling and monitoring activities are directly related to this TBD and are appropriately included as regulatory requirements to be addressed. It is recognized that workplace monitoring is the primary indicator of effectiveness of abatement and ALARA control methods during outdoor work activities. Workplace monitoring includes using temporary ambient air monitors (real time CAMs with alarms, ambient air samplers, and personnel samplers) and contamination surveys.

In addition to workplace monitoring, ambient air program stations nearest the facility/project provide a secondary layer of monitoring. These stations do not provide real time data. Their data are used as indicators along with workplace monitoring data for overall trending of potential diffuse and fugitive emissions. These air monitoring stations are operated by other Hanford contractors and do not fall within occupational radiation protection program requirements.

9.3 Basis and Decision-Making Process for Additional Air Emission Sampling

Both the requirements of 10 CFR 835 and the expectations and direction from Ecology lead to the documentation of the decision process and basis for prescribing additional air sampling beyond the established area air emission monitoring network.

Relevant technical basis and guidance exists in radiological protection documents. Specifically, “Intrusive Work” has been recognized as an activity with potential to expose workers and/or members of the public to a hazard that previously had barriers or controls in place. The Radiological Control Manual defines intrusive activities as follows:

- Intrusive Activity: Any activity that disturbs a surface or barrier that is intended to protect the worker or workplace from the underlying or contained radioactive materials.

- Soil intrusive activity: Any human activity that disturbs the surface and/or subsurface of the soil which has a reasonable possibility of increasing the amount of transferable contamination within a soil contamination area or an underground radioactive material area.

Although this definition originated to address work within URMA or SCA’s, the concept is appropriate for most any outdoor work during which barriers such as fixatives or layers of soil will be disturbed.

PRO-RP-40031 provides guidance for selection of the type of air sampler and the placement thereof. The following table presents this guidance.

Table 7: Air Sampling Placement Criteria

Purpose of Sampling/Monitoring	**General Placement of Samplers/Monitors**	**Type of Sampler**
Estimate worker's intake for calculating internal dose	Sampler located in worker's breathing zone, near nose and mouth (within one foot)	Breathing Zone
Identify area needing confinement control	Sampler in airflow pathway near actual or potential release point	Grab, fixed location, and CAMs
Provide early warning of elevate airborne release	Continuous air monitors placed between workers and release point(s), or downstream of wind direction, or as determined through air-flow studies	CAMs
Test for leakage of radioactive materials from sealed confinement system	Samplers located downstream of confinement-control area	Grab, fixed location, and CAMs
Determine total concentration from many potential release points	Downstream of wind direction or exhaust points	Grab, fixed location, and CAMs
Determine if an airborne radioactivity area exists and adequacy of radiological work planning	Samplers as close to workers' locations as possible	Grab, fixed location, and CAMs
Determine adequacy of ARA boundaries	Samplers at ARA boundary	Grab, fixed location, and CAMs
Special purposes, e.g., determining particle size	Case by case, depending on airflow patterns	Cascade impactors for particle size studies
Ensure respiratory protection factors were not exceeded	Sampler's at worker's location as close to the breathing zone as reasonably possible	Grab air sampler, breathing zone

In concert with 0904-CDMP-0011, the requirements and guidance in the previous subsections provide the technical basis for prescribing additional air sampling beyond the established area air emission monitoring network during intrusive work associated with outdoor work activities.

In addition to air sampling, boundary deposition or surface contamination migration monitoring should occur during intrusive work. Designated survey locations (e.g., cookie sheets) and adjacent soil or surfaces should be included in support to active work and post-work condition confirmation.

Additional boundary air sampling for intrusive activities should be performed based on the information presented in this TBD.

10.0 Continuous Air Monitoring (CAM) Configuration

The Canberra Alpha Sentry CAM is a semi-portable device designed to monitor alpha radioactivity in the air. The Alpha Sentry CAM consists of two components: a sampling head, and controller.

Figure 5: Typical Canberra Alpha Sentry (Sampling Head and Controller)

The CAM sampler can be used for ambient air or to monitor a process system such as an effluent duct. An in-line adapter is available for the sampling head to allow for direct connection to a pipe or duct (See Figure 8). Use of the CAMs in an outdoor environment requires a level of environmental conditioning which is provided by an enclosure (referred to as a “dog house”), that maintains temperature within operational ranges as well as protecting the instrument from the environment. The use of the in-line adapter configuration supports sampling the ambient air around the enclosure while accurately analyzing the constituents of that air. The sample is uniformly deposited on a filter encased in a cartridge. Use of the CAM sampling head and in-line adapter placed inside the “doghouse” was evaluated and determined adequate for its intended purpose.

Figure 6: CAM Sampling Head and In-Line Adapter

11.0 "Cookie Sheet" Configuration

It is common for cookie sheets to be deployed adjacent to other air sampling equipment (CAMs or retrospective air samplers). These deposition monitors should be located at ground level (not > 12 inches and generally within ~6 inches), to more closely simulate deposition and migration that would take place at this elevation. The surface does not replicate the ground surface but is configured to support the measurement of removable surface contamination in a manner consistent with surface contamination monitoring techniques to achieve compliance with 10 CFR 835, Appendix D, footnote 4:

"*The amount of removable radioactive material per 100 cm^2 of surface area should be determined by swiping the area with dry filter or soft absorbent paper, applying moderate pressure, and then assessing the amount of radioactive material on the swipe with an appropriate instrument of known efficiency*."

If the smooth reproducible horizontal surface of a cookie sheet is not appropriate, guidance from 0901-CDMP-0004, *Process for Performing Transferability Surveys* should be used as appropriate. Modification of surfaces to enhance deposition or collection should be avoided when the purpose of the survey is to assess the removable contamination against regulatory-based surface contamination values.

12.0 Instrumentation

Hanford Instrument Evaluation Committee (HIEC) approved bench top counting instrumentation (e.g., Ludlum 2929/3030, SAC-4) is typically utilized to quantify radioactivity on air sample media obtained during air emissions monitoring. High activity air sample media may be counted with a field instrument if field counts indicate that activity is in excess of levels allowed to be placed in a bench counter.

HIEC approved portable instrumentation (e.g., Ludlum 2360 w/ 43-93 detector) is typically utilized to quantify smear media obtained during monitoring of designated survey locations (e.g., cookie sheets) used to determine removable contamination due to surface deposition levels.

Tennelec gas flow proportional counting systems, available at the Central or Project Radiological Count Rooms, may be used to count batch samples and complete calculations. Additional count room equipment is available and may be utilized as needed. Alpha spectroscopy / Alpha Energy Analysis (AEA) and Gamma spectroscopy / Gamma Energy Analysis (GEA) are available. Though generally not quantitative in nature for emissions monitoring, this instrumentation may be used to discriminate between radon progeny and radionuclides of concern. AEA allows for both the determination of magnitude and energy of alpha emissions. GEA is typically used as a general indicator for the presence of natural radioactivity on sample media. In addition, samples may be sent to an analytical laboratory for analysis.

Sample counting protocols are outlined in the instrument specific operating procedure.

13.0 Particle Size Study Results

The activity median aerodynamic diameter (AMAD) of an inhaled particle can play a significant role in the deposition of particulate material in the lungs. The Hanford Internal Dosimetry Program (HIDP) position is to follow recommendations of 10 CFR 835, Appendix A and ICRP 66 with respect to particle size and assume radioactive aerosols of a 5 µm AMAD particle size, unless exposure information suggests otherwise.

Some particles associated with the spread of surface contamination beyond radiological control zone boundaries can be >10 µm and are non-respirable. This should not be construed to indicate that respirable particles couldn't be present, however. Most air dispersion and deposition models assume that all airborne radioactivity normally consists of 10 µm aerodynamic equivalent diameter (AED) particles, or less. Based on this, real-time contamination monitoring during active outdoor work activity should be performed to ensure the migration of large particles is detected in a timely manner.

14.0 Systematic Review Results

The systematic review approach to Workplace Air Emission Monitoring is based on expected material at risk, emission factors, prevailing wind directions and local worker population distribution. The technique described by Waite[30] (1973a, 1973b) for placement of air samplers, based on average meteorological conditions and existing worker population distributions is considered for determining both airborne radioactivity and surface deposition monitoring. The objectives of air emission monitoring include: to test compliance with the relevant regulatory requirements (10 CFR 835); to establish, with reasonable confidence, that collocated workers and members of the public, as a result of outdoor work activities, are not exposed to radioactive materials at levels in excess of appropriate standards; and, to protect the environment and the public from unnecessary exposure to radioactive materials.

Economic and operationally practical constraints limit the number of air emission sampling and monitoring locations. The lack of engineered controls directing air flow patterns challenge the ability of detecting short-term releases. It is possible that some atmospheric releases will pass between prescribed air emission sampling stations without being detected at all.

The systematic review includes two basic Integrated Safety Management System (ISMS) core functions: 2 – Identification, and 5 – Analysis of the Hazard and Analyzing the Data for continuous improvement and feedback.

Evaluation of the Material At Risk (MAR), Source Term, historical meteorological data, and potentially impacted near-facility workforce population can confirm the number and placement of air emission monitoring stations. This effort should be on going throughout the proposed work activities. Modifications to the number and placement of monitoring equipment would be one example of results from this evaluation.

Analysis methods and data collation (unbiased representative samples being analyzed in accordance with requirements and stored in a format that allows inferences to be drawn from data trends) support the identification of trends and changes in conditions. Tracking and trending reports are generated that includes results of routine air monitoring. The purpose of the tracking and trending report is to provide indication of the continued effectiveness of existing exposure controls, warn of deterioration of control equipment or operating procedures, identify long-term variations in airborne radioactivity levels, and provide indication of improper radiation work practices.

15.0 Waite Method Evaluation of Ambient Air Monitoring Network

Using the PFP project as an example, air sampler locations were evaluated using the Waite analytical technique for distributing air sampling locations around nuclear facilities.

[30] DOE-HDBK-1216-2015, DOE Handbook, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*, Washington, D.C. 20585.

Based upon near facility site workforce population estimates and the frequency of wind direction, a weighting factor can be developed to promote distribution of sample locations based on these two factors. The following equation is used to develop the sector or quadrant weighting factor:

$$W = \frac{Fraction\ of\ Population}{Distance} + Fraction\ of\ time\ sector\ is\ downwind \qquad \text{Equation 7}$$

The near-facility workforce population was estimated based upon the number of individuals listed in the Site Directory as being assigned to a facility, e.g., MO 287 and other mobile offices. Facilities within a sector or quadrant were summed and then divided by the total workforce estimate. An average distance for the occupied facilities was estimated providing the numerator and denominator for the first part of the equation. The joint frequency information for fraction of time a sector was downwind was estimated from the six-year average meteorological data.

The next step was to determine the number of samples or samplers by type and by sector. The following figures provide the data from these calculations including the actual number of samples by type in comparison to the evaluation results.

Calculation of weighting factor for Quadrant air sample locations.								
95% Windrose - 6 year average								
Sector	**Distance (km)**	**Estimated Staff**	**Fraction of pop/distance**	***Fraction of time downwind***	**W**	**Scaled W**	**Number of Air Samplers (a)**	**Assigned**
Northeast	2.8	287	0.11	24.00%	0.35	9.86	10	19
Southeast	3.8	247	0.07	47.00%	0.54	15.12	15	9
Southwest	0.8	20	0.03	14.75%	0.18	4.89	5	7
Northwest	2.08	347	0.19	14.25%	0.33	9.14	9	4
	Population	**901**		**100.00%**	**1.40**	**39.00**	**39**	**39**
Number of Air Samplers		**39**						
W value		**1.40**						
Scaling Factor		**27.88**						

Figure 7: Quadrant Air Sample Evaluation Results

The agreement between the weighted sample number and assigned or deployed air samplers is reasonable. This data clearly illustrates that the Northeast and Southeast quadrants have the largest fraction of downwind conditions (~71%) and also have the majority of the air samplers (72%). The current retrospective air sampler locations are considered appropriate.

Calculation of weighting factor for Quadrant CAM locations.								
95% Windrose - 6 year average								
Sector	**Distance (km)**	**Estimated Staff**	**Fraction of pop/distance**	***Fraction of time downwind***	**W**	**Scaled W**	**Number of CAMs**	**Assigned**
Northeast	2.8	287	0.11	24.00%	0.35	3.54	4	2
Southeast	3.8	247	0.07	47.00%	0.54	5.43	5	7
Southwest	0.8	20	0.03	14.75%	0.18	1.75	2	2
Northwest	2.08	347	0.19	14.25%	0.33	3.28	3	3
	Population	**901**		**100.00%**	**1.40**	**14.00**	**14**	**14**
Number of CAMs		**14**						
W value		**1.40**						
Scaling Factor		**10.01**						

Figure 8: Quadrant CAM Evaluation Results

This evaluation also presents a reasonable deployment of CAMs. 64% are deployed to the two highest downwind quadrants with the highest quadrant, southeast, having the greatest deployment. The distribution in a more even fashion is viewed as prudent in that these instruments are intended to provide an alert and alarm when increases in airborne radioactivity occur in an acute fashion. The current deployment of the networked CAMS is appropriate and adequate to meet Ecology requirements and to provide a reasonable assurance of detecting an upset condition and is consistent with the Waite Method of deployment.

Calculation of weighting factor for Quadrant "cookie sheet" locations.								
95% Windrose - 6 year average								
Sector	**Distance (km)**	**Estimated Staff**	**Fraction of pop/distance**	***Fraction of time downwind***	**W**	**Scaled W**	**Number of Cookie Sheets**	**Assigned**
Northeast	2.8	287	0.11	24.00%	0.35	20.49	20	28
Southeast	3.8	247	0.07	47.00%	0.54	31.39	31	27
Southwest	0.8	20	0.03	14.75%	0.18	10.15	10	17
Northwest	2.08	347	0.19	14.25%	0.33	18.97	19	9
	Population	**901**		**100.00%**	**1.40**	**81.00**	**80**	**81**
Number of "Cookie Sheets"		**81**		[a] Total number cookie sheets (80) less than total number available and assigned (81) due to rounding.				
W value		**1.40**						
Scaling Factor		**57.91**						

Figure 9: Quadrant Cookie Sheet Evaluation Results

Again there is a bias toward the downwind quadrants aligning with the weighted analysis results. These devices are similar to CAMs in that their distribution is more even than air samplers. This deployment provides data regarding radioactive particulate material deposition and movement. These devices are not intended to be a retrospective integrated sample in that a known volume has passed by these surfaces. They have no warning or alarm function and are subject to fugitive particulate depositing by mechanisms other than airborne deposition. They also are not discriminatory with regard to particle size.

The current distribution of air samplers, CAMs, and designated surface deposition survey locations (e.g., cookie sheets) in this example is consistent with the Waite Method weighted distribution and was determined to be adequate for the resumption of 234-5Z demolition activities. Future rearrangement and deployment should incorporate the weighted distribution to the extent practicable.

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