Pacific Northwest NATIONAL LABORATORY

PNNL-19427, Rev 3

Data Quality Objectives Supporting Radiological Air Emissions Monitoring for the PNNL-Richland Campus

Rev. 3, North Campus Construction

January 2024

SF Snyder
LE Bisping
TR Hay
JM Barnett
LN Dinh
MC Klein

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99354

Summary

This is the third revision of the Data Quality Objectives (DQO) Supporting Radiological Air Emissions Monitoring for the Pacific Northwest National Laboratory (PNNL)-Richland Campus. Starting in fiscal year 2023, the north area of the Campus will undergo development. Initially, infrastructure (water, electrical) improvements will be installed. Later development includes the construction of several new office buildings in the north-central Campus. The area to be developed currently contains no buildings but does have two existing solar-powered ambient air sampling stations. Under the requirements of Washington State Department of Health (WDOH) Radioactive Air Emissions License (RAEL)-005, the PNNL-Richland Campus must operate and maintain a radiological air monitoring program. This revision documents and evaluates how the new North Campus construction impacts ambient air surveillance stations within the development region. This revision also considers current stack configurations and uses an updated environmental dispersion model and updated meteorological data. The DQO team concluded that one sampling station in the construction area will be relocated and the other remain in place. The evaluations conducted for this DQO also identified a third sampling station outside the development area that is recommended for relocation as a result of updated dispersion modeling performed for this DQO. Recommended sites for the relocations are presented. Considerations for sampling in and around a construction zone are also addressed. Additionally, programmatic improvements to the ambient air sampling program were identified in the DQO process.

The second revision of the DQO for the PNNL-Richland Campus was completed in 2017, when the Campus expanded to the north by 0.35 km^2 (85.6 acres). The second revision evaluated the newly acquired acreage while also removing recreational land at the southwest. It also reexamined all active radioactive emission units on Campus. The key purpose of revision 2 was to determine the adequacy of the existing environmental surveillance stations to monitor radiological air emissions in light of the northern boundary change.

In 2012, the Department of Energy (DOE) operations at the PNNL-Richland Campus expanded as a result of contractual changes that incorporated radiological operations in several facilities south of the documented Campus fence line, resulting in Revision 1 of this DQO. A new boundary that encompassed the Campus and new facilities expanded the DOE operations area from 350 acres to about 600 acres. This expansion changed the classification of facilities encompassed by the new fence line from privately licensed to DOE-permitted facilities. No new construction or newly operated sources were included within the expanded boundary, emissions sources that were added were existing but previously under a private non-DOE license. The DQO Revision 1 considered radiological emissions from two new sources—the Life Sciences Laboratory-II (LSLII) and the Research Technology Laboratory (RTL)—in light of a boundary change and recommended another ambient air monitoring station (PNL-4). During this time, relocation of the two northern stations (PNL-1 and PNL-2) was possible due to the use of solar power, which eliminated the previous limitation for access to alternating current power at these more remote locations.

The initial DQO, Revision 0, considered radiological emissions at the PNNL Site resulting from the Physical Sciences Facility major emission units, since they were deemed to have the greatest potential to impact the public, and recommended ambient air monitoring stations PNL-1, PNL-2, and PNL-3. A team was established to determine how the PNNL-Richland Campus would meet federal regulations and address guidelines developed to monitor air emissions and estimate offsite concentrations of radioactive materials. The result was a

program that monitors the impact to the public from the PNNL-Richland Campus. The team used the emission unit operation parameters and nearby meteorological data as well as information from the Potential-to-Emit documentation, Notices of Construction, Air Emission Registrations submitted to the WDOH, and the boundary conditions. The locations where environmental monitoring stations would successfully characterize emissions from the buildings were determined from these data. Table S.1 summarizes the DQO revision history.

This DQO was prepared based on the U.S. Environmental Protection Agency (EPA) *Guidance on Systematic Planning Using the Data Quality Objectives Process*, EPA QA/G-4, 2/2006, as well as several other published DQOs.

Table S.1. Revision History of PNNL-19427

PNNL-19427 Revision Number	Effective Date	Description of Change
0	May 2010	Initial document describing the initial development of the WDOH-prescribed ambient radiological surveillance program for the PNNL Site. Three particulate monitoring stations were recommended for siting (PNL-1, PNL-2, and PNL-3).
1	November 2012	Consideration for ambient radiological surveillance of the entire PNNL-Richland Campus. In June 2012, the two original air monitoring stations PNL-1 and PNL-2 were discontinued and removed. Simultaneously, two new solar-powered air monitoring stations were established on the PNNL Site; these solar-powered stations were positioned to cover the same area as the discontinued stations and continued to be called PNL-1 and PNL-2. A fourth station was recommended for siting (PNL-4), southwest of the Battelle baseball field. The Hanford Site Yakima air monitoring station continued to be used for background measurements.[a]
2	December 2017	Consideration of a 0.35 km^2 (85.6 ac) land transfer from Hanford Site DOE Office of Environmental Management ownership to DOE Office of Science/PNNL ownership, along the northern Campus boundary. The southwestern Campus boundary was also modified to exclude Battelle recreational areas. An updated air dispersion model (CAP88-PC Version 4) was used along with updated meteorological files in modeling. The DQO Revision 1, added new information in an addendum to Revision 0. The format of this revision was updated. This revision carried forward pertinent data and expanded on that information with the new boundary. While some background material was repeated, references to material in former revisions were used judiciously. In this revision, each study question, decision, and error analysis were presented together in Section 5. Two new particulate ambient monitoring program changes occurred since the publication of Revision 1. In June 2013, the original temporary PNL-4 air monitoring station was discontinued; simultaneously, a new permanent PNL-4 was established to cover the same southern extent of the Campus.[b] In December 2014, a permanent background air sampling station was recommended for the Campus and became operational in October 2016.[c] In addition, external dose monitoring was initiated in 2017. No new air monitoring stations were proposed in this revision. Additionally, no location changes to existing air monitoring were proposed.

PNNL-19427 Revision Number	Effective Date	Description of Change
3	January 2024	New utility installation and facility construction is planned for the 2023–2030 timeframe on the north end of the PNNL-Richland Campus. Activity includes surface preparation (removing vegetation and grading in preparation for groundbreaking) and below groundwork, then facility construction. These activities prompted reassessment of optional locations of all ambient air monitoring stations. PNL-1 and PNL-2 (both currently solar-powered) were of greater interest because these station locations would be impacted by construction activities. Currently permitted radioactive major emissions' unit configurations are evaluated with current dispersion modeling and all critical (i.e., non-background) surveillance station locations were reviewed against the results. Several emission units in the prior DQO are no longer registered emission units on the PNNL-Richland Campus (LSLII and RTL emission units and five laboratory hoods at the 3430 Building) and were removed from analyses in this revision. As a result of this assessment, PNL-1 will remain at its established location. PNL-2 and PNL-3 are recommended for relocation.

(a) Snyder SF, JM Barnett, and LE Bisping. 2013. *Pacific Northwest National Laboratory Site Radionuclide Air Emissions Report for Calendar Year 2012*. PNNL-20436-3, Pacific Northwest National Laboratory, Richland, Washington.

(b) Snyder SF, JM Barnett, and LE Bisping. 2014. *Pacific Northwest National Laboratory Site Radionuclide Air Emissions Report for Calendar Year 2013*. PNNL-20436-4, Pacific Northwest National Laboratory, Richland, Washington.

(c) Fritz BG, SF Snyder, JM Barnett, LE Bisping, and JP Rishel. 2014. *Establishment of a Background Environmental Monitoring Station for the PNNL Campus*. PNNL-23930, Pacific Northwest National Laboratory, Richland, Washington.

Acronyms and Abbreviations

AC	alternating current
CAP88-PC	Clean Air Act Assessment Package 1988–Personal Computer
CFR	Code of Federal Regulations
COC	chain of custody
CRD	Contractor Requirements Document
CRDL	contract-required detection limit
DOE	U.S. Department of Energy
DQO	Data Quality Objectives
EMP	Environmental Monitoring Plan
EPA	U.S. Environmental Protection Agency
ESP	Environmental Surveillance Program
ERT	Environmental Radiation Task
HMIS	Hanford Mission Integration Solutions
LSB	Laboratory Support Building
LSLII	Life Sciences Laboratory-II
MDA	minimum detectable activity
MDC	minimum detectable concentration
MEI	maximally exposed individual
NCRP	National Council on Radiation Protection & Measurements
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOC	Notice of Construction
OSL	optically stimulated luminescence
PIC	Potential Impact Category
PNNL	Pacific Northwest National Laboratory
PNSO	Pacific Northwest Site Office
PSF	Physical Sciences Facility
PTE	potential to emit
QA	quality assurance
RAEL	Radioactive Air Emissions License
RDL	required detection limit
RMT	Radioactive Materials Tracking
RPL	Radiochemical Processing Laboratory
RPT	Radiation Protection Technologist
RTL	Research Technology Laboratory
SR	service request
TED	total effective dose
TEDE	total effective dose equivalent
WAC	Washington Administrative Code
WDOH	Washington State Department of Health
X/Q	Chi-over-Q

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1.0 Introduction

This revision to the Data Quality Objectives (DQOs) addresses the radiological air quality requirements and environmental surveillance needs for the Pacific Northwest National Laboratory (PNNL)-Richland Campus (e.g., Campus), which is a research facility under the oversight of the Department of Energy's (DOE's) Office of Science, Pacific Northwest Site Office (PNSO) located in northern Richland, Washington. Future construction in the north-central Campus may impact two existing ambient air sampling locations. This DQO evaluates the need to relocate existing stations based on planned construction activities in the north Campus and also identifies how construction phase activities near station locations may impact existing operations. The PNNL-Richland Campus environmental surveillance program implements routine ambient air sampling for radioactive materials released in facility air effluent in compliance with the state permit (Radioactive Air Emissions License RAEL-005) requirements for radiological operations. Ambient air samples are collected at several sampling stations.

The DQO process has been used since the inception of the requirement for a PNNL-Richland Campus Environmental Surveillance Program (ESP, for this document). In the initial DQO (Rev. 0), three ambient air sampling locations were established (Barnett et al. 2010), and in Revision 1 a fourth sampling location was added (Barnett et al. 2012). Revision 2 determined that sampling stations in the northern Campus did not need to be relocated or supplemented as a result of a northern boundary expansion. Additionally, the background air surveillance station PNL-5 for the PNNL-Richland Campus began operations in October 2016 (Fritz et al. 2014; Snyder et al. 2017); ambient air sample data from the Hanford Site Yakima background station were previously used to define Campus background levels.

The primary radiological air emissions sources at the approximately 664-acre PNNL-Richland Campus do not differ substantially from those of the prior revision of this DQO. The Physical Sciences Facility (PSF) continues to house the predominant air effluent sources, but the Life Sciences Laboratory-II (LSLII) and Research Technology Laboratory complex (RTL) facilities were both closed in 2019 (Barnett and Snyder 2021). As a result, LSLII and RTL emission units, which are no longer part of the PNNL-Richland Campus Radioactive Air Emissions License (RAEL-005; WDOH 2021), are no longer discussed.

The PSF is a complex of research laboratories (see Figure 1.1 and Figure 1.2). Figure 1.2 is an aerial view of the current PNNL-Richland Campus boundary, which did not change since Revision 2. For the purposes of this report, the Laboratory Support Building (LSB) is considered a contiguous part of the PNNL-Richland Campus. Particulate ambient air sampling is conducted at four existing stations: PNL-1, -2, -3, and -4. Past revisions of this DQO indicated no need to sample for gaseous or iodine emissions.

When radioactive emissions to the ambient air occur as part of routine operations, DOE facilities are required to demonstrate compliance with the Clean Air Act National Emission Standards for Hazardous Air Pollutants (NESHAP) for radionuclides, as published in the 1989 amendments to Title 40 Code of Federal Regulations (CFR) Part 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities." The U.S. Environmental Protection Agency (EPA) is the federal agency tasked with oversight and implementation of the regulations. EPA has delegated regulatory authority to the Washington State Department of Health (WDOH) for facilities within Washington State.

Figure 1.1. PSF Buildings

The WDOH establishes regulations for radionuclide air emissions in Washington Administrative Code (WAC) Chapter 246-247, "Radiation Protection – Air Emissions," and adopts by reference the standards and approved methods specified in 40 CFR Part 61, Subpart H. Additional Washington State Department of Ecology regulations are found in WAC 173-480, "Ambient Air Quality Standards and Emission Limits for Radionuclides." Federal and state requirements for environmental monitoring programs applicable to this DQO report are summarized in Section 2.2. These regulations are not intended to be applied to high-level or acute (short-term) emissions from accidents, and therefore the discussions and conclusions in this document are limited to routine emissions characterized as chronic releases (occurring at substantially the same rate over a year).

Figure 1.2. Current PNNL-Richland Campus Boundary

1.1 Location

PNNL is a DOE research facility operated by Battelle-Pacific Northwest Division in the north part of Richland, Washington. As of January 2023, the 664-acre Campus consists of the following parts:

- Leased facilities on Battelle-owned land
- Other leased facilities
- DOE-owned facilities within the Campus

In addition to the 664-acre Campus, the 15-acre LSB site, located at 3350 George Washington Way, has been occupied by PNNL staff for several years and is considered part of the PNNL-Richland Campus for the purposes of this DQO revision. Several other facilities in Richland are also occupied by PNNL staff but are not considered relevant to this report because they are non-adjacent to the Campus.

1.2 Emission Points on the PNNL Campus

No new emission points were added in this DQO revision. In 2023, radioactive air emissions from the PNNL-Richland Campus may potentially come from any of the following buildings. Each PSF building is identified in Figure 1.1. PSF/3440 has no licensed emission unit for radioactive materials.

- PSF/3410, Materials Sciences and Technology Laboratory
- PSF/3420, Radiation Detection Laboratory
- PSF/3425, Underground Laboratory
- PSF/3430, Ultratrace Laboratory
- Various buildings, including the Environmental Molecular Sciences Laboratory (Building 3020), are approved for work with low-level releases of materials under Potential Impact Category (PIC) 5 permits (Barnett 2018) described in Section 3.2.

Evaluations in Revisions 1 and 2 emphasized emissions with the greatest potential to impact the offsite public. This results in the emphasis of major (PIC-1 and -2) and of minor (PIC-3, -4, and -5) emission units with the potential for impacts of significance relative to major emission units (in this revision, see Section 3.2). Planned construction at the north end of the Campus focuses the attention of this revision on PSF emission units in the northern Campus. The south end of the Campus is also considered, as necessary.

2.0 State the Problem

This section states the primary study question and discusses the preliminary data needed to answer the study question. In addition, the DQO team, available resources, and schedule for completion of the DQO report are discussed. The current PNNL-Richland Campus ESP is robust, sampling at four critical locations in the vicinity of the Campus for ambient air particulates and ambient external dose, with a fifth location used to sample background air (Figure 2.1).

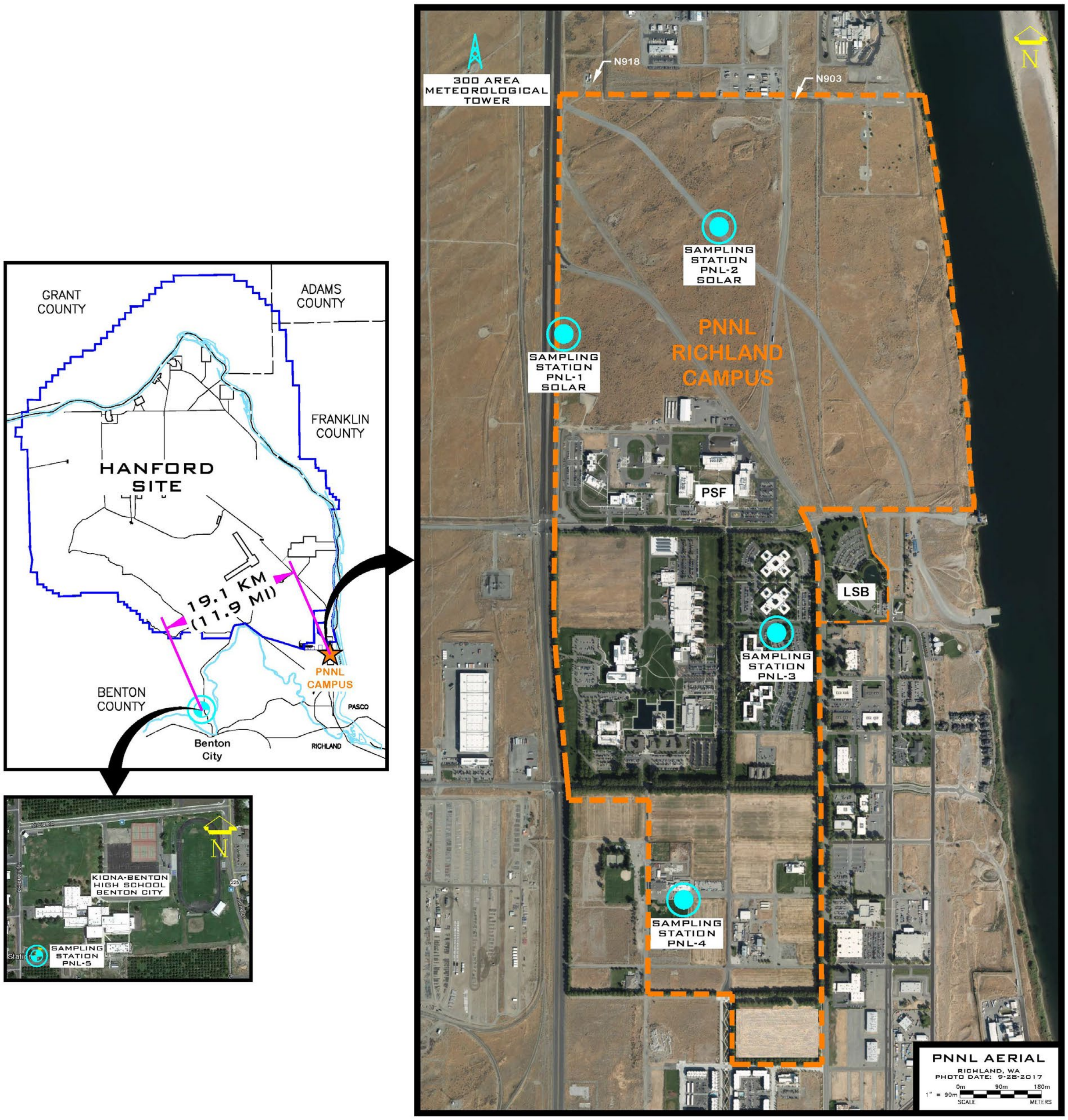

Figure 2.1. Air Surveillance Station Locations for PNNL-Richland Campus in 2023

2.1 Background and Scope

The following text was largely excerpted from Revision 2 (Snyder et al. 2017) of the DQO, and updated as appropriate. At the PNSO–WDOH interface meeting of November 12, 2008, WDOH indicated that PNNL would need to establish an ambient air ESP for the PNNL Site. WDOH stated that the agency was evaluating types of environmental monitoring that would need to be put in place. This was the first cooperative documented meeting between PNSO, WDOH, and PNNL where environmental monitoring was discussed as a condition of operation of the PNNL Site under a RAEL. In December 2009, WDOH indicated in the draft site license that a DQO process would be required to develop the environmental air monitoring program for the PNNL Site. In subsequent meetings with WDOH, it was agreed that during the interim, two environmental continuous monitoring stations (also referred to as sampling a hutch or colloquially as a “dog house”) would be sufficient to demonstrate low emissions. The two interim stations were located on the Hanford Site to the N and NNW of PSF at locations where power was readily accessible.

Conclusions of the initial DQO resulted in the relocation of the two northern interim monitoring stations to more optimized positions onsite, PNL-1 and PNL-2, and the addition of a third station, PNL-3, in the parking lot east of the National Security Building to monitor the presumed PNNL-Richland Campus maximally exposed individual (MEI) receptor (Figure 2.1). PNL-1 and PNL-2 are solar powered; PNL-3 is alternating current (AC) powered.

Revision 1 of the DQO investigated the siting of a fourth Campus monitoring location, which resulted in the establishment of PNL-4, northwest of the RTL-520 Building. This AC-powered station monitored RTL complex emissions and the southern Campus area. The RTL complex has since been demolished. PNL-4 has been retained as a collocated sampling station with WDOH and the Hanford Site.

The current four critical ambient air sampling locations were based on Revision 1 of the DQO and confirmed as sufficient in Revision 2 of the DQO (Snyder et al. 2017). In Revision 2, the newly established PNNL-Richland Campus background monitoring station, PNL-5, was also presented. The location of the background monitoring station was determined outside of the DQO process and is described in Fritz et al. (2014). Figure 2.1 shows the current locations of the five ambient air environmental surveillance stations.

2.2 Applicable and Regulatory Requirements

Regulatory requirements for determining compliance with the radionuclide air emission standards are specified by the EPA in 40 CFR Part 61, Subpart H. Similar requirements are identified by the State of Washington in WAC 173-480 and WAC 246-247; no technical changes to these regulatory requirements have occurred since 2012. Portions of DOE Order 458.1, “Radiation Protection of the Public and Environment,” also support the Subpart H requirements.

The following excerpts from 40 CFR Part 61, Sections 61.92, 61.93, and 61.94, were deemed most pertinent to this DQO task:

> Emissions of radionuclides to the ambient air from Department of Energy facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr.

> Compliance with this standard shall be determined by calculating the highest effective dose equivalent to any member of the public at any offsite point where there is a residence, school, business, or office.
>
> …radionuclide emissions shall be determined and effective dose equivalent values to members of the public calculated using EPA-approved sampling procedures, computer models Clean Air Act Assessment Package–1988 (CAP-88) or AIRDOS-PC, or other procedures for which EPA has granted prior approval. DOE facilities for which the MEI lives within 3 kilometers of all sources of emissions in the facility, may use EPA's COMPLY model and associated procedures for determining dose for purposes of compliance.
>
> Environmental measurements of radionuclide air concentrations at critical receptor locations may be used as an alternative to air dispersion calculations in demonstrating compliance with the standard if the owner or operator meets the following criteria:

- The air at the point of measurement shall be continuously sampled for collection of radionuclides.
- Those radionuclides released from the facility that are the major contributors to the effective dose equivalent must be collected and measured as part of the environmental measurement program.
- Radionuclide concentrations that would cause an effective dose equivalent of 10% of the standard shall be readily detectable and distinguishable from background.

State agencies may also establish requirements and restrictions in addition to those specified in the federal regulation. For example, the state regulation provides that WDOH "may require the operation of any emission unit to conduct stack sampling, ambient air monitoring, or other testing" (WAC 246-247-075(9)), in addition to the requirements for stack sampling mandated by the federal regulation. The PNNL-Richland Campus conducts the ambient air ESP in response to a WDOH requirement to confirm low emissions from all significant radioactive air emission units; however, the ESP is not the primary method of demonstrating compliance with the regulatory standards for those facilities. Because of the expected low levels of radionuclide emissions from the facilities, stack sampling and dose modeling using EPA-approved software is used for that purpose.

Methods to demonstrate compliance with the dose standards were developed for effluents routinely emitted from facilities that may release radionuclides to the atmosphere. Neither the ESP nor the methods approved by regulations for estimating atmospheric dispersion and dose consequences were intended to be applied to high-level acute (short-term) emissions from accidents involving radioactive materials. Therefore, the discussions and conclusions in this DQO revision are applicable to routine emissions from facilities that may be characterized as chronic emissions (or occurring at substantially the same rate over time).

2.3 Problem Statement and Preliminary Data

The objective of this document is to consider how north campus construction may impact successful ambient air surveillance of PNNL-Richland Campus radioactive material emissions in air effluent, and determine necessary modifications to the program from updated dispersion modeling and programmatic constraints. The PSF radiological facilities and two ambient sampling stations (PNL-1 and PNL-2) are the primary focus of this document due to proximity to the north campus construction. However, this updated assessment of all PNNL-Richland Campus continuous ambient air monitoring stations is a result of updated Campus-wide dispersion modeling.

As in previous revisions, this DQO requires information on radioactive emissions, meteorological data, current environmental monitoring, emission point characteristics, and appropriate atmospheric dispersion software. The list of expected isotopes that could be emitted from the PNNL-Richland Campus can be obtained from RAEL-005 and Notices of Construction (NOCs) submitted to WDOH, as well as from the specific isotopes reported in the annual radioactive air emissions report (e.g., Snyder et. al 2022). This list does not differ substantially from that evaluated in Revision 1 of the DQO.

Meteorological data and historical background concentrations of some radionuclides for the PNNL-Richland Campus and surrounding area can be obtained from the DOE Richland Operations Office, Hanford Site programs: Meteorological/ Climatological Services[1] and the Mission Assurance programs operated by Hanford Mission Integration Solutions in Richland. These programs and their predecessors have collected data on and around the Hanford Site for several decades. Meteorological data are available in a form usable by the atmospheric dispersion software.

Current ESP information and emission point characteristics are available from PNNL-Richland Campus documentation and staff. The atmospheric dispersion software is available from the federal internet website and is accepted for use on desktop devices.

The information required to achieve the objective of this DQO includes the data and bounding conditions to identify regions that would demonstrate adequate PNNL-Richland Campus radiological air emissions sampling locations with respect to the north campus construction and Campus land-use limitations, as well as awareness of mid-construction activities that would impact continuous sampling at the existing PNL-1 and PNL-2 air monitoring locations. As with the prior DQO revisions, the Hanford Site emissions are also evaluated for their collateral impact to a PNNL sampling site, should the decision be made to move an existing monitoring location.

2.4 Participants

For Revision 3 of the DQO, the primary planning team consists of the following members:

- An environmental health physicist, able to provide oversight for dispersion and MEI dose calculations. This member is the DQO facilitator.
- An environmental radiation task (ERT) lead with background in regulatory compliance, environmental monitoring, and low-level radiation detection. In consultation with the DQO facilitator, this member is a final decision maker.

[1] In earlier DQO revisions, the Hanford Site meteorological program was referred to by its prior name in the last revision: Public Safety and Resource Protection.

- An environmental modeling subject matter expert able to perform atmospheric dispersion and MEI dose calculations appropriate to the PNNL-Richland Campus by using EPA- and WDOH-approved methods and software.
- An environmental engineer, serving as the ERT sample collection coordinator, providing technical expertise in sampling and monitoring of air and drinking water contaminants to ensure regulatory compliance, and familiar with the DQO process.
- A quality assurance engineer with experience in environmental issues and radioactive effluent quality assurance.
- An environmental engineer providing input to atmospheric dispersion modeling and conceptual adaptations.

In addition to the listed authors, necessary construction plans and schedule information were obtained from construction, project, and facilities managers at PNNL (T Haynie, M Samples, and E Cox). Their input was crucial in understanding the planning, infrastructure, and construction process specific to the PNNL-Richland Campus.

2.5 DQO Process and Schedule

The following documents were consulted for the DQO process used in this and prior revisions:

- Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4, 2/2006 (EPA 2006)
- Systematic Planning: A Case Study of Particulate Matter Ambient Air Monitoring, EPA QA/CS-2, 3/2007 (EPA 2007)
- Regulatory Data Quality Objectives Supporting Tank Waste Remediation System Privatization Project, PNNL, PNNL-12040, Rev. 0, 12/1998 (Wiemers et al. 1999)

The DQO process was facilitated by a modeling subject matter expert. Team members evaluated output from environmental models. If there was need for other specialists, the team incorporated additional resources into the process.

Team formation for the initial DQO began in January 2010. Revision 0 of the DQO was submitted to PNSO and subsequently to WDOH, which ultimately approved the document in August 2010.

Revision 1 of this DQO commenced with a new team that was formed in January 2012 and included most of the original members. The team started the addendum in February 2012 and completed the revision in November 2012.

Revision 2 of this DQO commenced in June 2017 and maintained key members of the Revision 1 team, with the addition of an environmental engineer intern. The revision was completed in December 2017.

This Revision 3 commenced in January 2023 and maintained three key members of the Revision 2 team. Hay, Dinh, and Klein are new DQO team members to this revision. Revision 3 was completed in December 2023.

3.0 Inputs

This section lists and describes the sources used to ultimately answer the objective in Section 2.3. The type of information needed to meet performance and acceptance criteria and provide directions for sampling and analysis methods is described here.

Additionally, DOE-HDBK-1216-2015 (DOE 2022), *Environmental Radiological Effluent Monitoring and Environmental Surveillance*, was published in 2015 and provides guidance for meeting the requirements of DOE Order 458.1. The handbook was reaffirmed in 2022 with editorial changes only. It includes guidance for airborne effluent monitoring and environmental surveillance. Team members referred to the DOE handbook to make certain that critical items were not omitted or overlooked.

Battelle has an 1830 contract with DOE (DOE-Battelle Prime Contract for the Management and Operation of Pacific Northwest National Laboratory DE-AC05-76RL01830) for PNNL-Richland Campus operations. The contract requirement[2] is to meet the Contractor Requirements Document (CRD) 458.1, paragraphs 2.d, 2.g, and 2.k, only. These CRD sections are related to As Low As Reasonably Achievable (ALARA) (2.d), management of radioactive liquid discharges (2.g), and release and clearance of property with the potential to contain residual radioactive materials (2.k). Although the public dose limit and air emissions requirements of DOE CRD 458.1 are not explicitly required under the current contract, the public dose standard for air emissions is regulated under the EPA in 40 CFR Part 61, Subpart H.

The data presented in this document are current as of November 2023.

3.1 North Campus Construction

The master plan (PNNL 2017) for the PNNL-Richland Campus includes improvements on the northern Campus, just below the northern boundary with the Hanford Site and west of George Washington Way (see Figure 3.1, February 2023 notional building plan). These improvements include installation of new infrastructure (e.g., water, electrical, sewer) and office building construction in currently undeveloped areas. North Campus construction will not install new radiological facilities.

Construction is addressed as three different activities, listed in order of occurrence:

1. **300 Area water line** (~ Feb 2024). Water main improvements are planned for water supply upgrades for the pipeway paralleling Stevens Drive along the western Campus border. This activity will impact operations at PNL-1 (Figure 3.1). Grubbing (clearing vegetation, discing, and stabilizing surface) for this activity was done in April 2023 (Figure 3.2).
2. **North-central infrastructure** (~2026). Installation of new infrastructure that will serve the north campus buildings. Underground electrical, public water supply, and sewer return lines will be installed. Grubbing of lands precedes actual trench work. Planning for this phase also includes planning for future (approximately 2026/2027) realignment of George Washington Way between Horn Rapids Road and Navy Haul Road intersections. The realignment options may impact options for relocation of PNL-2.

[2] The most recent Prime Contract modification related to the applicable DOE Orders in Section J, Appendix D, is M1485, June 28, 2023.

3. **North campus buildings** (~2026-2028 groundbreaking). The activity that initiated this DQO occurs after north-central infrastructure activities. Eventually eight office buildings will be constructed west of George Washington Way and south of the northern Campus border. The first building construction is anticipated about 2026-2028. This activity will impact ambient air surveillance station PNL-2 and require its relocation (see Figure 3.1).

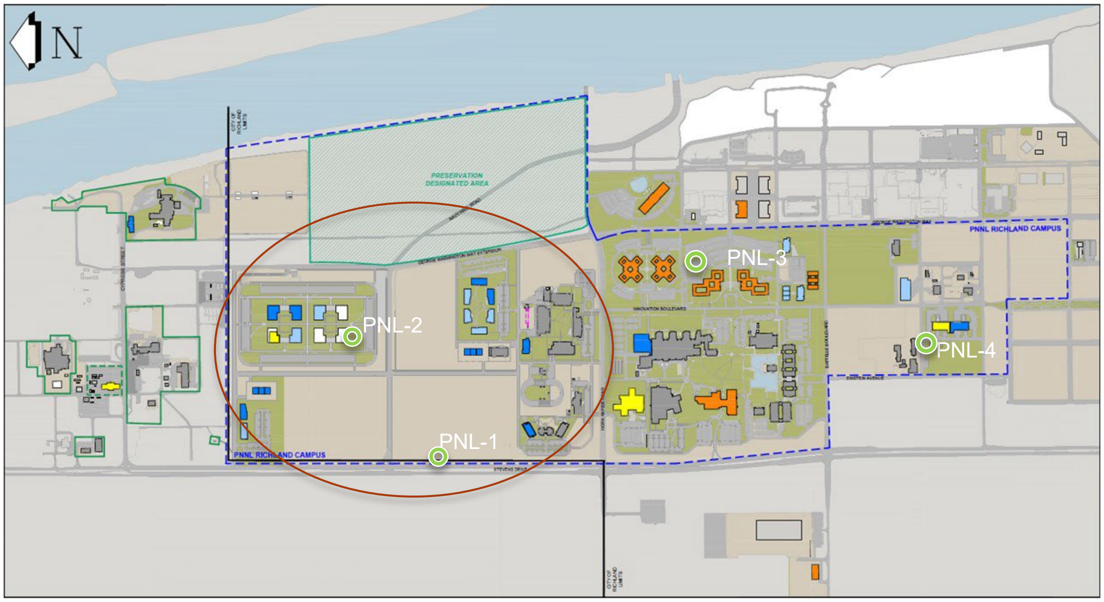

Figure 3.1. Proposed Notional North Campus Construction of Interest (Circled) with All On-Campus Ambient Air Sampling Locations Indicated

The exact schedule for the development of the north campus construction has not been finalized. The PNL-1 and PNL-2 stations are part of the ambient air ESP, sampling radioactive particulates in the ambient air under WDOH RAEL-005.

Figure 3.2. PNL-1 after Surface Soil Grading in Preparation for Waterline Improvements

Some construction activities will generate dust, involve light-duty and heavy equipment operations, or impact the ground around or under the sampling station. Airborne dust or other mass (application of dust suppressant) that may be drawn into the sampling system should be minimized. Equipment operators in the vicinity of sampling stations should maintain situational awareness to avoid collision with equipment.

Each of these factors requires consideration to continue to effectively sample the ambient air, minimize construction-related dust loading on particulate filters, and avoid damage to sampling equipment. Both PNL-1 and PNL-2 are solar-powered stations that require a larger footprint (about 6.1 x 6.1 m [20 x 20 ft]) under current configurations, compared to AC-powered stations (about 1.8 x 1.8 m [6 x 6 ft]). Minimizing filter dust loading on solar-powered stations' samples will maintain adequate air flow and significantly improve the quality of the radiological analysis results of the sample.

3.2 Emission Units

The PNNL-Richland Campus has several buildings with radioactive material emission units. In accordance with laboratory practice (Barnett 2018), emission units and Campus-wide permits are assigned a PIC according to the estimated potential impact. The range of all possible Campus PICs are defined as follows:

- PIC-1 – Operating range >5 mrem/yr (major)
- PIC-2 – Operating range >0.1 and ≤5 mrem/yr (major)
- PIC-3 – Operating range >0.001 and ≤0.1 mrem/yr (minor)
- PIC-4 – Operating range >1E-6 and ≤0.001 mrem/yr (minor)
- PIC-5 – Operating range <1E-6 mrem/yr (minor)

The current RAEL-005 permit (WDOH 2021) includes PIC-2 and PIC-4 emission units and PIC-5 permits. Table 3.1 lists the currently registered emission units: three major, two minor, and one fugitive emission units under permit, and four Campus-wide PIC-5 permits for radioactive releases. Nine minor and two fugitive emission units were closed since the prior DQO revision. Any onsite particulate radioactive emissions occurring under the PIC-5 permits could be captured by ambient air sampling; this type of permit is applied to emissions with very low potential offsite impact, so the emissions from these sources would be a negligible part of the sample results.

NOC applications indicate the potential dose to the MEI, which is used to categorize whether or not the emission units are major or minor (i.e., PIC category). The radionuclides of concern (i.e., those nuclides that most impact the categorization as major or minor emission units) are discussed in Section 3.3. Radionuclide release rates for radionuclides of concern are discussed in Section 3.4.2. The emission unit operating characteristics are discussed in the next section.

Table 3.1. PNNL-Richland Campus 2023 Registered Radioactive Air Emission Units

Building	Discharge Point ID	Discharge Point Description
3410	EP-3410-01-S	PIC-2. Major emission unit. Main stack.
3420	EP-3420-01-S	PIC-2. Major emission unit. Main stack.
	EP-3420-02-S	PIC-4. Minor emission unit. Areas not exhausted to main stack.

Building	Discharge Point ID	Discharge Point Description
3425	J-3425	PIC-4. Fugitive emissions.
3430	EP-3430-01-S	PIC-2. Major emission unit. Main stack.
	EP-3430-02-S	PIC-4. Minor emission unit. Areas not exhausted to main stack.
Campus-wide	J-VRRM	PIC-5. Volumetrically released radioactive material.
	J-NDRM	PIC-5. Non-dispersible radioactive material.
	J-Facilities Restoration	PIC-5. Facilities restoration.
	J-SOIC	PIC-5. Sources for instrument/operational checks.

J-SOIC was referred to as J-LLS Low-level Sources in DQO Revision 2. The updated ID reflects its naming convention in the current RAEL-005.

The NESHAP standard of impact is a dose standard for all Campus emissions combined. However, each Campus emission unit has a RAEL-005-limited ("Condition 1") total dose to the MEI (Table 3.2), which are state-enforceable criteria with no federal equivalent. A stack emission estimate multiplied by a site-specific dose factor (e.g., Snyder and Barnett 2016) ties activity (Ci) releases to receptor dose for planning purposes. Table 3.2 indicates current Condition 1 doses for all registered emission units. The PIC-2 (major) emission units' Condition 1 doses are two orders of magnitude or more above the minor and fugitive emission unit Condition 1 doses. Therefore, the primary focus will be on PIC-2 emission units and the area of construction activities in the north Campus. The PIC-4 and -5 sources are well below operational interest for ambient air monitoring (i.e., Condition 1 doses are well below 10% of the dose standard).

The final column of Table 3.2 provides an example of actual dose estimates from 2022 Campus operations (Snyder et al. 2023). Campus research activities could increase significantly and still remain below the regulatory dose standard.

Table 3.2. RAEL-005 and NOC Designated Abated Emission MEI Dose Limits

PIC Category	Emission Unit ID	"Condition 1" RAEL-005 abated limit for MEI dose(a) (mrem/yr)	Total Abated PTE Emission MEI dose(b) (mrem/yr)	2022 PAER reported MEI dose (mrem/yr)
2	EP-3410-01-S	0.0793	0.012	2.7E-6
2	EP-3420-01-S	0.33	0.034	1.1E-5
2	EP-3430-01-S	0.0613	0.020	2.0E-6
4	J-3425	2.7E-4	na	2.1E-7
4	3420-02-S	3.2E-4	na	5.3E-6
4	3430-02-S	3.2E-4	na	1.2E-7
5	VRRM	9.4E-7	na	9.4E-7
5	FR	8.4E-7	na	0
5	SOIC	1.0E-6	na	0
5	NDRM	6.6E-8	na	6.6E-8

(a) RAEL-005/NOC Condition 1.
(b) Sum of abated release for a radionuclide with a RAEL-005/NOC emission limit and potential-to-emit (PTE) dose factor (Snyder and Barnett 2016), conservatively assuming 99.0% abatement efficiency.

3.3 Major Emission Unit Characteristics

The stacks described in the following sections meet the criteria for major emission units. The characteristics of these units relevant to environmental dispersion modeling of effluents are tabulated (Table 3.3). The characteristics indicated are those based on recent operations, except for the EP-3430-01-S system. Since the last revision, the EP-3420-01-S system added a new fan and indicated flow rates reflect the average from the last two years of operation. The EP-3430-01-S stack is undergoing remodeling in 2023; the flow rate indicated in Table 3.3 reflects the average rate anticipated over the next several years with a final flow rate anticipated to be in the 50–58 thousand cfm range. The value indicated in the table reflect fluid dynamics modeling results for this stack. This change is also discussed in Section 3.10.

Table 3.3. Major Emission Unit Operation Parameters

Unit Type/ Emission Point ID	Average Flow Rate	Total Annual Flow	Average Temper-ature	Physical Discharge Height	Physical Discharge Diameter	Effective Discharge Height
EP-3410-01-S	21,000 ft^3/min ($9.91\ m^3/s$)	1.10E+10 ft^3 (3.13E+08 m^3)	75 °F (23.9 °C)	44 ft (13.4 m)	3.3 ft (1.0 m)	103 ft (31.5 m)
EP-3420-01-S[(a)]	65,280 ft^3/min ($30.8\ m^3/s$)	2.59E+10 ft^3 (7.33E+08 m^3)	76 °F (24.2 °C)	51 ft (15.5 m)	4.3 ft (1.3 m)	160 ft (48.8 m)
EP-3430-01-S[(b)]	50,000 ft^3/min ($23.6\ m^3/s$)	2.6E+10 ft^3 (7.44E+08 m^3)	71 °F (21.7 °C)	53 ft (16.1 m)	3.8 ft (1.2 m)	148 ft (45.2 m)

(a) EP-3420-01-S was remodeled in 2020. Flow, temperature, height, and diameter values reflect 2021 and 2022 operations.
(b) EP-3430-01-S parameters reflect conditions after the remodel, estimated years 2023-25.

3.4 Radionuclides of Concern

If the estimated dose to the maximally exposed member of the public exceeds the regulatory standard of 10 mrem/yr (40 CFR 61.92, WAC 173-480-040), site radiological operations would be impacted. While the exact emissions from radiological research are impossible to anticipate ahead of time, the RAEL-005 permit and annual NESHAP Assessments, as well as knowledge of near-term significant research changes and conservative assumptions, allow good (or bounding) approximations of the types and quantities of radionuclides expected in air effluent. Compared to the full list of authorized radionuclides handled, the Campus-specific radionuclides of concern for air effluent is rather brief, typically containing some alpha emitters and larger activities of gamma emitters.

The radionuclides of concern for stack sampling are based on the annual NESHAP Assessment. The radionuclides of concern for ambient air sampling may differ. For ambient air sampling, the list of nuclides of concern is based on the radionuclides listed in the RAEL-005.

3.4.1 List of Radionuclides of Concern

The following text was excerpted from Revision 2 (Snyder et al. 2017) and updated, as appropriate.

For a radionuclide meeting one of the conditions, below, it is required to describe the method for monitoring or calculating those radionuclide emissions in sufficient detail to demonstrate compliance with the applicable state requirements. The RAEL-005 and any updated NOC application contain the following information (WAC 246-247):

1. The indicated annual possession quantity for each radionuclide that meet at least one of the following criteria:

   a. Radionuclides that could contribute >10% of PTE total effective dose equivalent (TEDE) to the MEI.
   b. Radionuclides that could contribute >0.1 mrem/yr PTE TEDE to the MEI.
   c. Radionuclides that could contribute >25% of the PTE TEDE to the MEI with effluent controls in place.
2. The physical form of each radionuclide (solid, particulate solid, liquid, or gas).
3. Release rates (PTE), including both abated emissions (potential releases with effluent controls in place) and unabated emissions (assuming no effluent controls, but that facility operations are otherwise normal).

The criteria indicated in item 1 above are also applied in the annual NESHAP Assessment (DI-AIR-001) to identify the stack radionuclides of concern for the upcoming year. The NESHAP Assessment also indicates sampling for radionuclides with very low dose impacts (less than 1% of the MEI dose standard, typically far less). Given the short list of both RAEL-005 activity-limited radionuclides and facility emission units, using the RAEL-005 list of radionuclides for ambient sampling will appropriately indicate nuclides potentially significantly impacting the MEI.

In determining the PTE, PNNL currently uses the EPA-approved CAP88-PC Version 4.0.1.17 (EPA 2015) software package to develop dose-per-unit release factors for radionuclide air emissions (Snyder and Barnett 2016). The dose is estimated using the release rates in Ci/yr for radionuclides expected to be present in the facility multiplied by the corresponding dose-per-unit release factor. The doses for all radionuclides potentially released are combined to estimate the total annual PTE total effective dose (TED) to the MEI. Results are used to determine if any of the above PTE criteria are met when submitting an NOC application or verifying an air emission registration for an existing emission unit.

Table 3.4 provides the results of a review to determine which nuclides remain potentially >0.1 mrem/yr contributors using current RAEL-005 and NOCs and the Snyder and Barnett 2016 dose factors. The tabulated list maintains the appropriate operational envelope to provide the flexibility required for Campus research activities.[3] Table 3.4 indicates the radionuclides of concern for each major emission unit on the PNNL-Richland Campus. The first two columns indicate nuclides that are RAEL-005- or NOC-limited. The final column indicates the NESHAP Assessment-identified nuclides requiring sampling for the current year, where Al-26 and Th-229 stack sampling were added. For nuclides that are NOT required to be sampled in the current year's NESHAP Assessment, stack sample analysis is not requested and the nuclide emissions rate is estimated with Appendix D methods. This supersedes the RAEL-005/NOC-based requirement for sampling because it better reflects current research operations in each facility.

[3] "2022 NESHAP Assessment for PNNL-DOE Facilities," Memo from PM Daling to JM Barnett (PNNL), dated February 2, 2023, memo number EHSS-EPRP-23-015.

Table 3.4. Campus Radionuclides of Interest for Major Emission Units

Radioisotope	Current RAEL-005 and NOCs >10% PTE TED to the MEI without controls in place(a,b) (PIC-2 stacks at 3410/3420/3430)	Current RAEL-005 and NOCs > 0.1 mrem/yr PTE TED to the MEI(b) (PIC-2 stacks at 3410/3420/3430)	2022 NESHAP Assessment >10% PTE TED to the MEI without controls in place(b) (PIC-2 stacks at 3410/3420/3430)
Al-26	-	-	-/X/-
Am-241	-/-/X	-/X/X	-/-/-
Am-243	-/-/-	-/X/-	-/-/-
Cm-244	X/X/-	X/X/-	-/-/X
Co-60	X/-/-	X/X/X	X/-/-
Pu-238	X/X/-	X/X/-	-/-/-
Pu-239	X/X/X	X/X/X	X/-/-
Pu-240	X/X/-	X/X/X	-/-/-
Th-229	-	-	X/-/-
U-233	-/-/-	-/-/X	-/-/-

(a) Information is not applicable for >25% PTE TEDE to the MEI with controls in place.
(b) X = Criteria met in current RAEL-005, 2022 NOC for 3430-01-S, or 2022 NESHAP Assessment.
"-" = Criteria not met.

Currently, PNNL administrative levels for minor, nonsampled emission units are limited to <0.001 mrem/yr PTE to the MEI (Barnett 2018). The PNNL-Richland Campus does not currently have any PIC-3 category emission units. Therefore, because the potential impacts from radionuclides emitted from a PIC-4 (or PIC-5) permit are four orders of magnitude below the regulatory standard, only the radioisotopes released from the major emission units are considered to be candidate radionuclides of concern (40 CFR 61; HPS 1999; Barnett 2018).

3.4.2 Radionuclide Release Quantities

The RAEL-005 and more recent 3430-01-S NOC (RAEL-005 NOC 1675, October 2022) provides information regarding maximum permitted releases of the radionuclides of concern from the major (PIC-2) emission units (Table 3.5). The unabated releases of radionuclides from the major stacks are indicated in Table 3.5; unabated releases take into account the release fraction of the radioactive material (solids, particulate/liquids, and gases). Abated release rates from the single-stage HEPA filtered emission units are conservatively estimated; a release fraction is applied (i.e., 1%) to estimate the abated release rates.

Table 3.5. RAEL-005/NOC Approved Unabated Potential Release Rates for Major Emission Units

Radioisotope	Emission Type	3410-01-S Unabated Release Estimate (Ci/yr)	3420-01-S Unabated Release Estimate (Ci/yr)	3430-01-S Unabated Release Estimate (Ci/yr)[(a)]	Abated Release Fraction for Single-stage HEPA[(b)]
Am-241	Alpha	5.0E-04	1.8E-03	3.0E-03	1E-02
Am-243	Alpha	5.0E-04	1.7E-03	n/a	1E-02
Cm-244	Alpha	1.2E-03	4.6E-03	n/a	1E-02
Co-60	Gamma	3.0E-02	1.3E-02	2.0E-02	1E-02
Pu-238	Alpha	1.4E-03	5.4E-03	n/a	1E-02
Pu-239	Alpha	1.2E-03	4.5E-03	4.7E-03	1E-02
Pu-240	Alpha	2.0E-04	7.4E-04	7.5E-04	1E-02
U-233	Alpha	n/a	n/a	9.8E-03	1E-02

(a) Unabated release estimates per 3430-01-S NOC (RAEL-005 NOC 1675, OCT 2022).
(b) The single-stage HEPA collection efficiency of 99% (40 CFR 61, Appendix D).

Release rates for the additional radionuclides requiring stack sampling, as identified in the annual NESHAP Assessment, are determined based on inventory levels in the Radioactive Materials Tracking (RMT) system. These additional radionuclides typically do not meet the PTE requirements for obtaining a new permit.

3.5 Meteorological Data for Dispersion Modeling

Meteorological conditions for the PNNL-Richland Campus and surrounding area can be obtained from the Hanford Site Meteorological/Climatological Services, which has been in operation since 1944 (Hoitink et al. 2005). Meteorological measurements are taken to support Hanford Site emergency preparedness and response, operations, and atmospheric dispersion calculations for dose assessments. Support is provided through weather forecasting and by maintaining and distributing climatological data. Forecasting is provided to help manage weather-dependent operations. Climatological data are used to plan weather-dependent activities and as a resource to assess the environmental effects of site operations. The Hanford Site Meteorological Services rely on data collected by the Hanford Meteorological Monitoring Network. This network consists of 30 remote monitoring stations that transmit data to the central Hanford Meteorology Station via radio telemetry every 15 minutes. There are twenty-seven 9 m (30 ft) towers and three 61 m (200 ft) towers. Meteorological information collected at these stations includes wind speed, wind direction, temperature, precipitation, atmospheric pressure, and relative humidity; however, not all of these data are collected at all stations.

For this DQO revision, CAP88-PC V4.1.1 (EPA 2022) calculations were performed using historical meteorological data for the 300 Area (station 11) averaged from 2012–2021 (see Appendix A). This is updated information from the 1983–2006 or 2004-13 data used in earlier DQOs. Because the 300 Area is located about 1.4 km (0.87 mi) NNW of the PSF complex and about 0.75 km (0.47 mi) WNW of the north campus construction, the 300 Area dataset was determined to be the most suitable meteorological data available to determine atmospheric dispersion of releases in the PNNL-Richland Campus. Other potential meteorological stations are located farther away from the source facilities (e.g., Richland airport, near Horn Rapids, or across the Columbia River to the north of the 300 Area) and are separated from those facilities by topographical features that would likely alter the wind directions. Therefore, the 300 Area meteorological dataset reflects atmospheric conditions most appropriate to select the location for an environmental monitoring station over the long term.

The frequency at which the winds blow in a particular direction can indicate the direction of maximum impact. The average frequency at which the wind blew toward a particular direction for the 300 Area from the 1983–2006, 2004–2013, current 2012-2021 datasets is shown in Figure 3.3. Any frequency over 6.25% is greater than an evenly distributed frequency (100% divided by 16 compass points). However, the stack height, wind speed, and stability class also influence atmospheric dispersion, hence the need for modeling of estimated downwind concentrations of radionuclides potentially released from the PNNL-Richland Campus.

For the 2004–2013 dataset, the average annual precipitation rate was 17.10 cm/yr (6.7 in.), the average temperature was 12.01°C (53.6°F), and average wind speed was 3.532 m/s (7.9 mph). For the 2012–2021 dataset, the average annual precipitation rate was 17.27 cm/yr (6.8 in./yr), the average temperature was 12.86°C (55.14°F), and the average wind speed was 3.596 m/s (8.0 mph). Mixing height and humidity parameters were set to default values as a conservative assumption (overestimating results) for the PNNL-Richland Campus region.

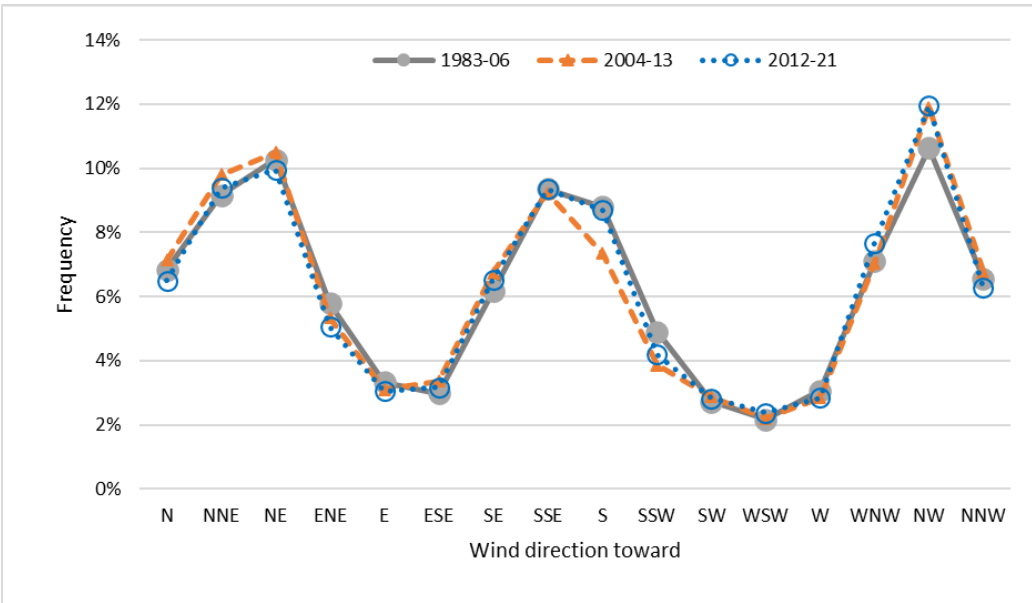

Figure 3.3. Average Frequency of Wind Direction for the 300 Area Station, Previous DQOs (1983-2006 data; 2004-2013 data) and Current Report (2012-2021 data)

3.6 Air Dispersion Modeling, CAP88-PC Model

Air dispersion modeling for this DQO uses the most recent CAP88-PC V4.1.1 computer code (EPA 2022). Any version of this model is EPA-approved for the determination of 40 CFR 61, Subpart H, compliance. CAP88-PC V4.0 is used currently for PNNL-Richland Campus compliance reporting (e.g., see Snyder et al. 2023), to align with the code use for the site PTE basis (Snyder and Barnett 2016). CAP88-PC V4.1 was first authorized for use in March 2020 (FR Vol 85, No.44, p 12917) and V4.1.1 is a minor revision of V4.1, released for use November 2022. CAP88-PC V4.1.1 retains the major architectural, data handling, and user interface updates introduced in Versions 4.0 and 4.1, and no changes were made to the transport and dose models or to the reporting functions.

The software uses a Gaussian plume model to estimate atmospheric transport for chronic releases of radionuclides. It has been used for this evaluation to determine the dispersion of radionuclide emissions from the Campus facilities. Input parameters required for the atmospheric dispersion calculations include the following:

- Population parameters
  - Age, size, and locations of target population
  - Direction and distance to MEI, if known
  - Buildup time (100 years assumed)
- Local meteorological data
  - Data array of wind frequency by direction, speed, and atmospheric stability
  - Annual average precipitation rate
  - Annual average ambient temperature
  - Lid height
  - Absolute humidity
- Stack parameters
  - Height
  - Diameter
- Plume rise parameters
  - Momentum plume – exit velocity
  - Buoyant plume – heat release rate
- Radionuclide data
  - List of radionuclides in effluent stream
  - Release rates by radionuclide (required for dose, not required for dispersion estimate)
  - Radionuclide chemical/physical form

For this revision, additional CAP88-PC V4.1.1 calculations were performed to consider the current fence line, with distances to fence line verified with the current version of Google Maps. Entering stack release characteristics and the long-term average meteorological dataset from the 300 Area into a CAP88-PC V4.1.1 case provides dispersion calculations for 16 compass sectors (e.g., N, NNE, NE) at up to 20 user-specified distances from the release point. The results are calculated as a normalized air concentration (radioactivity per cubic meter per radioactivity released per second, or sec/m3) also referred to as the Chi-over-Q (X/Q) in the indicated sector for each distance. High X/Q values indicate a sector with greater potential dose compared to lower X/Q values. The goal of the current assessment is a review of the monitoring location, as opposed to receptor locations. Higher X/Q values remain indicative of higher air concentrations of materials at evaluated locations. X/Q values were determined for dispersion from each of the three PIC-2 PSF emission units.

3.7 MEI Exposure Characteristics

This information is excerpted from Snyder et al. 2022 and updated as needed. The MEI dose is determined from the radionuclide releases, environmental dispersion of the release, and MEI pathways of exposure. The exposure pathways considered for the MEI are inhalation, ingestion, and external exposure. Businesses, schools, and residences (apartments and townhouses) are located offsite. Most Campus-adjacent development has been along the south Campus with some new business construction east of the Campus. A daycare facility is adjacent to the SW boundary.

The inhalation and external pathways are the most likely routes of exposure for offsite receptors. The ingestion pathways would apply to individuals who consumed food produced in the immediate vicinity. However, subsistence farming is minimal near the PNNL-Richland Campus, and modeled estimates of radiation doses to these individuals would be conservatively high because of that assumption, as well as the assumption of 24/7 occupancy at nearby office and apartment facilities. No crops are grown onsite for public (personal/commercial) consumption.

3.8 Relevant Maximum Air Concentration Location(s)

The stack operating characteristics (Table 3.3) and meteorological data (Section 3.5 and Appendix A) were used in the CAP88-PC V4.1.1 model to determine locations of maximum air concentrations for each of the PNNL-Richland Campus major emission units. This same process was used in past DQO revisions.

CAP88-PC V4.1.1 was used to model the air concentrations at various radial sectors from the PSF major emission units. The maximum air concentration sector(s) indicates the location where a person would receive the maximum dose from stack emissions. For a given nuclide emission, dose is linearly related to the air concentration at the receptor location when all receptors are assumed to have the same exposure and intake parameters. Tables of the X/Q values from each PSF major emission unit are provided in Appendix B. For a given particulate emission from each major emission unit, the 3410-01-S emission would generate the highest offsite X/Q due to its lower effective release height compared to the other major emission units. However, the type and quantity of emissions from each stack drives the receptor dose contributed by stack effluents.

Figure 3.4 indicates the fractions of the total major emission unit MEI dose from each PSF radiological facility for the last five years. Among the major stacks, the 3420-01-S emission unit accounted for the predominant MEI dose contribution for the last five years, with 3420-01-S MEI dose contributions 60%–450% greater than those of the other major stacks.

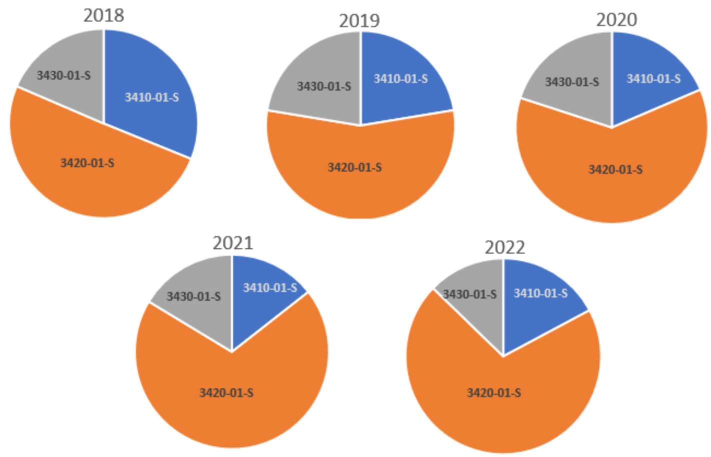

Figure 3.4. Relative MEI Dose Contributions from PSF Major Stacks (2018–2022)

Figure 3.5, Figure 3.6, and Figure 3.7 demonstrate dispersion patterns reflected in X/Q results from the use of updated stack parameters, the updated CAP88-PC V4 model, and updated meteorology. The figures graphically present the X/Q values (s/m3) at the indicated location for several distances from each PSF building. The higher X/Q values predominant in the NW, SSE, and NNE/NE directions reflect the higher wind frequency directions of Figure 3.3.

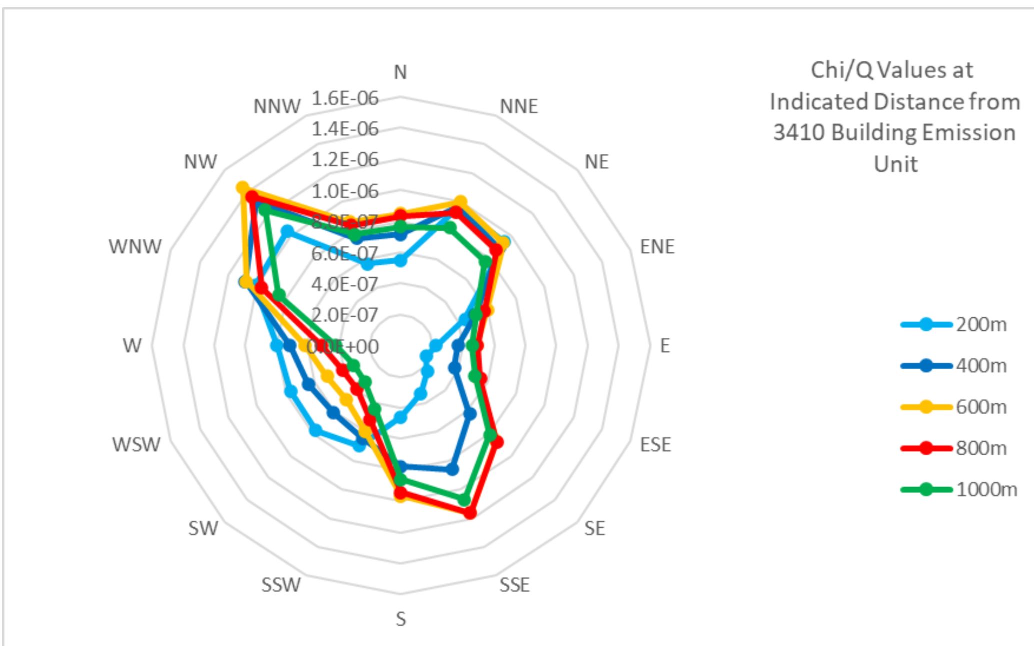

Figure 3.5. X/Q Values (s/m3) for Five Distances from the 3410-01-S Emission Unit

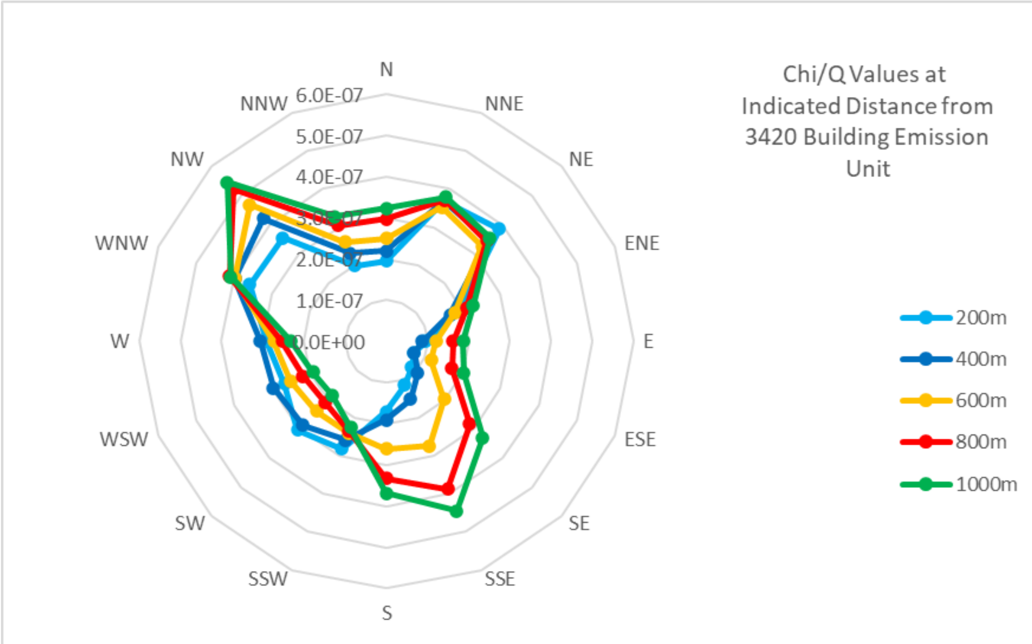

Figure 3.6. X/Q Values (s/m3) for Five Distances from the 3420-01-S Emission Unit

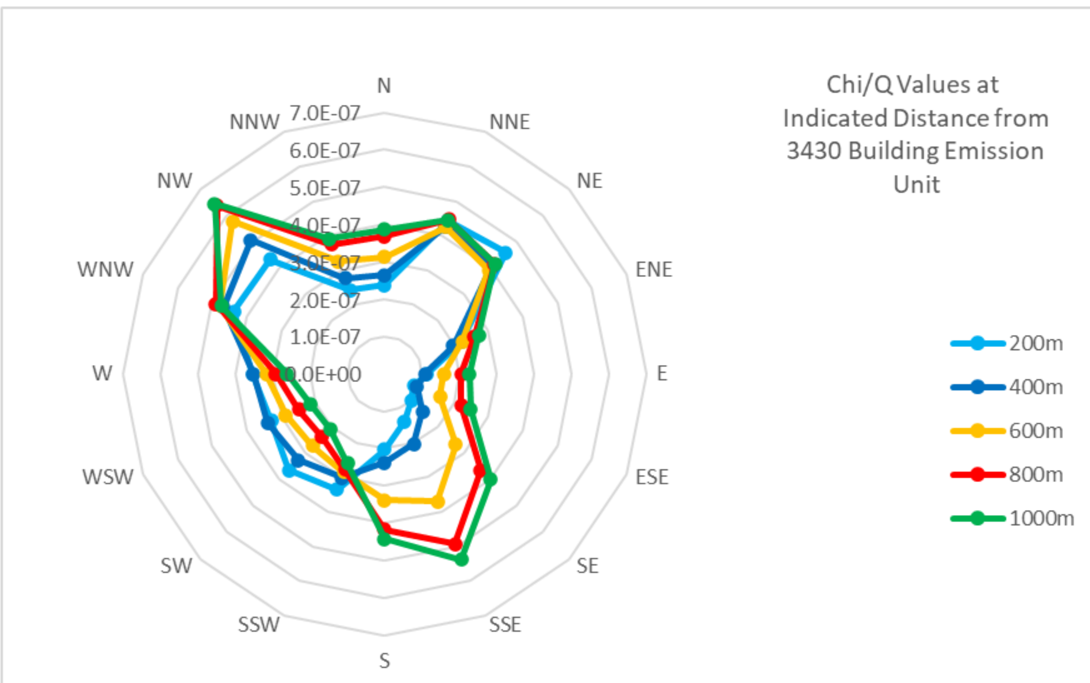

Figure 3.7. X/Q Values (s/m3) for Five Distances from the 3430-01-S Emission Unit

The higher effective release heights of the 3420-01-S and 3430-01-S stacks resulted in maximum air concentrations of lower magnitude and farther from the facility than those of the 3410-01-S Building (Figure 3.8). This also resulted in lower X/Q values in all directions for the 3420 and 3430 emissions. Particulate concentrations remain highest in the NW and SSE directions in the older and newer analyses, with a less prominent peak in the NNE/NE direction.

Figure 3.8 shows the location of the maximum air concentration from CAP88-PC modeling of each PSF major emission unit.

To provide a convenient reference, Figure 3.9 shows approximately where a PSF building emission reaches the boundary in each of 16 compass directions. The figure originates from a central PSF location rather than providing similar graphics for each of the three PSF facilities.

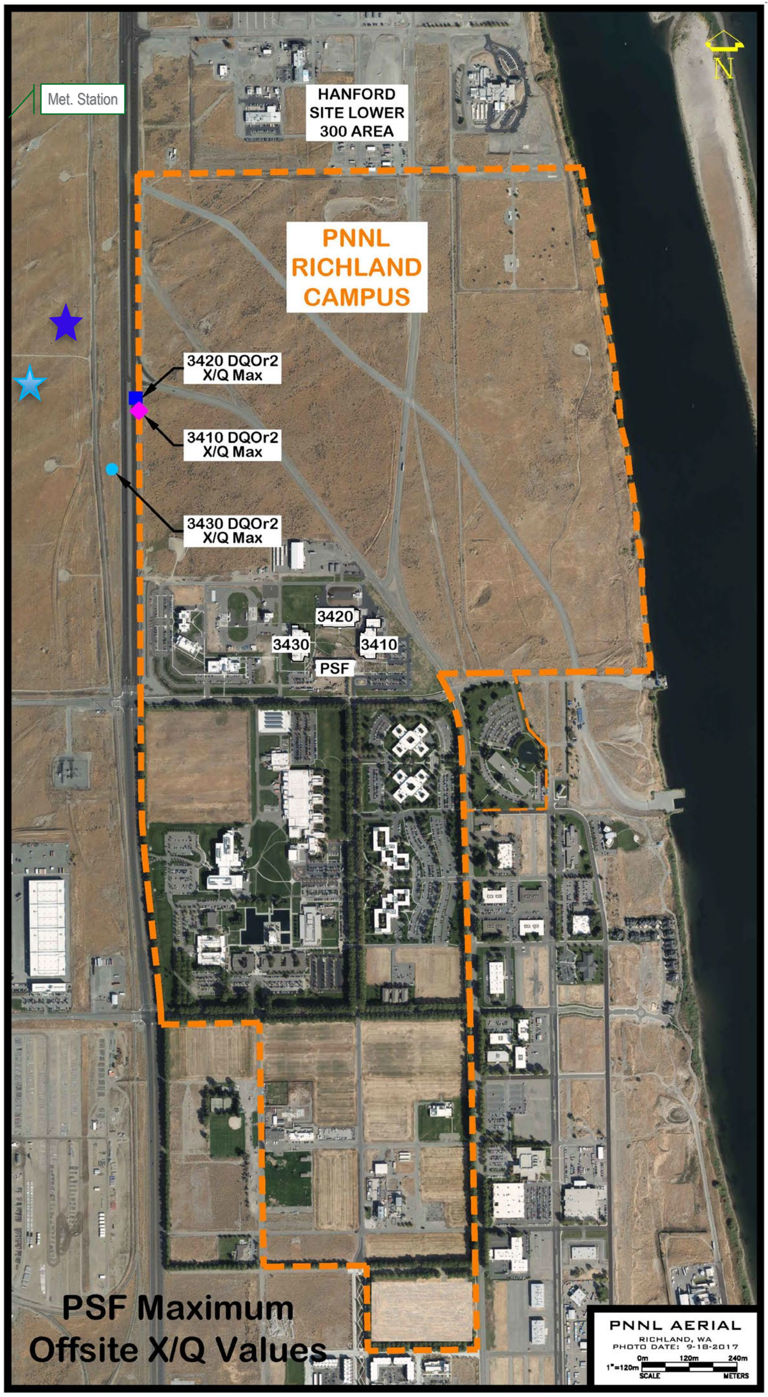

Figure 3.8. Location of Maximum Offsite Air Concentrations from Modeled PSF Major Emission Units (star marker if new for Revision 3)

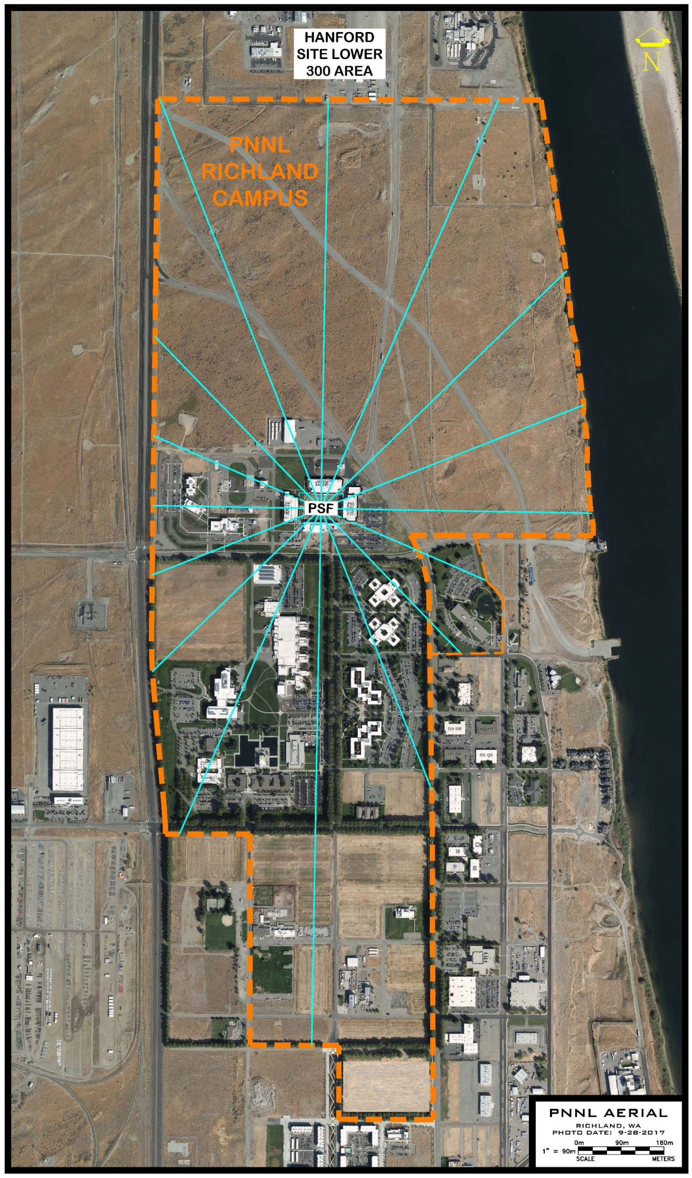

Figure 3.9. Boundary Visual with Blue Lines Indicating Centerline Compass Directions from PSF

For each major emission unit, the X/Q at the fence line and the X/Q at each ambient monitoring station are considered. The model also provides X/Q information at any requested distance from the emission unit (e.g., see Figure 3.10, reproduced from DQO Revision 0). If X/Q values of monitoring stations are equal to or greater than the current fence line value, the modeling indicates that the monitoring station will adequately capture and characterize offsite annual radioactive emissions in the direction of the fence line and monitoring station.

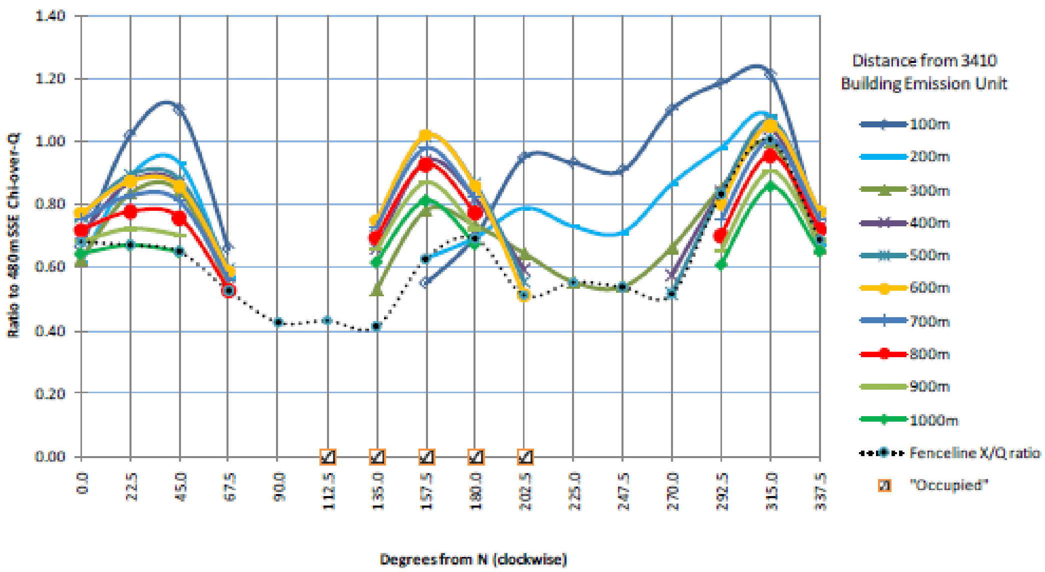

Figure 3.10. Example of Results Presentation Used in Barnett et al. (2010)

Section 3.10 provides more details regarding the X/Q values resulting from modeling conducted for this DQO revision. X/Q values are determined at the fence line in each direction from the evaluated facility, based on their current configurations. X/Q values are determined for each monitoring location based on a particulate emission. The information is presented in graphics.

The standard established in prior revisions was that monitoring should capture 50% or more of the maximum fence line or offsite concentration from a release point (see Decision #4 of Barnett et al. 2010). A location with an X/Q value that is 50% or more than that of an X/Q for a location of interest is considered to be reasonably equivalent when the uncertainties in the determination of air concentrations are considered. This capture percentage was restricted further, to a minimum of 65%, to narrow and improve possible monitoring location options in both earlier DQO revisions. This DQO revision also adopted the criterion where candidate locations for ambient air sampling are considered acceptable if the ratio of the location's X/Q to the maximum X/Q is 0.65 or more. These criteria are referred to as the "**65%+ Criteria**" in the remainder of this document.

3.9 Adequate Monitoring Program

The approach used to monitor Campus radioactive air emissions, described in the Environmental Monitoring Plan (EMP) (Snyder et al. 2020 and Attachments Meier 2011, Bisping 2011, and Snyder 2021), meets the guidance of DOE-HDBK-1216-2015 CN1 (DOE 2022). The PNNL approach grew from the methods and strategy used for the ESP deployed at the Hanford Site. The PNNL ESP meets policy and guidance requirements established by the WDOH for air emissions monitoring. To summarize important aspects of the PNNL environmental surveillance ambient air monitoring program:

1. The air at the point of measurement shall be continuously sampled for the collection of radionuclides. This is defined as 85% of the operational sample collection time. Compositing frequency cannot exceed 6 months.
2. Radionuclides released from the facility that are the major contributors to the effective dose (RAEL-005 and annual NESHAPs Assessment, see Table 3.4) must be collected and

measured as part of the environmental measurement program at a concentration consistent with the minimum detectable amount criteria (Table 3.6).

3. Radionuclide concentrations that would cause an effective dose equivalent of 10% of the standard shall be readily detectable and distinguishable from background.
4. Environmental optically stimulated luminescence (OSL) dosimeters are used for x-ray, beta-, and gamma-radiation monitoring. This external dose monitoring was added in late 2016 to acquire baseline data specific to the PNNL-Richland Campus and the Campus background location. The first full calendar year of environmental OSL monitoring was 2017. Quarterly station results, with annual average background normalized to 91-d quarters, are provided in Figure 3.11.
5. A quality assurance (QA) program and analytical methods shall be implemented that are consistent with performance requirements for effluent monitoring (e.g., NQA-1 or EPA QA/R-5 for QA program; and 40 CFR Part 61, Appendix B, Method 114 for analytical procedures).

Table 3.6. Radionuclides to be Monitored at the PNNL-Richland Campus based on RAEL-005

Radioisotope Analysis	Approximate Half-life (yr)[(a)]	Table 2 Concentration (pCi/m^3)[(b)]	Notification Concentration (10% Table 2)[(b)]
Am-241	432	1.9E-03	1.9E-04
Am-243	7,370	1.8E-03	1.8E-04
Cm-244	18	2.6E-03	2.6E-04
Co-60	5.3	1.7E-02	1.7E-03
Pu-238	88	2.1E-03	2.1E-04
Pu-239	24,110	2.0E-03	2.0E-04
Pu-240[(c)]	6,560	2.0E-03	2.0E-04
U-233	159,200	7.1E-03	7.1E-04

(a) ICRP 2008
(b) Table 2 of 40 CFR Part 61, Appendix E
(c) While Pu-240 is NOT indicated in the RAEL-005, Pu-240 is included in results for Pu-239 sample analyses. Data provided for information purposes.

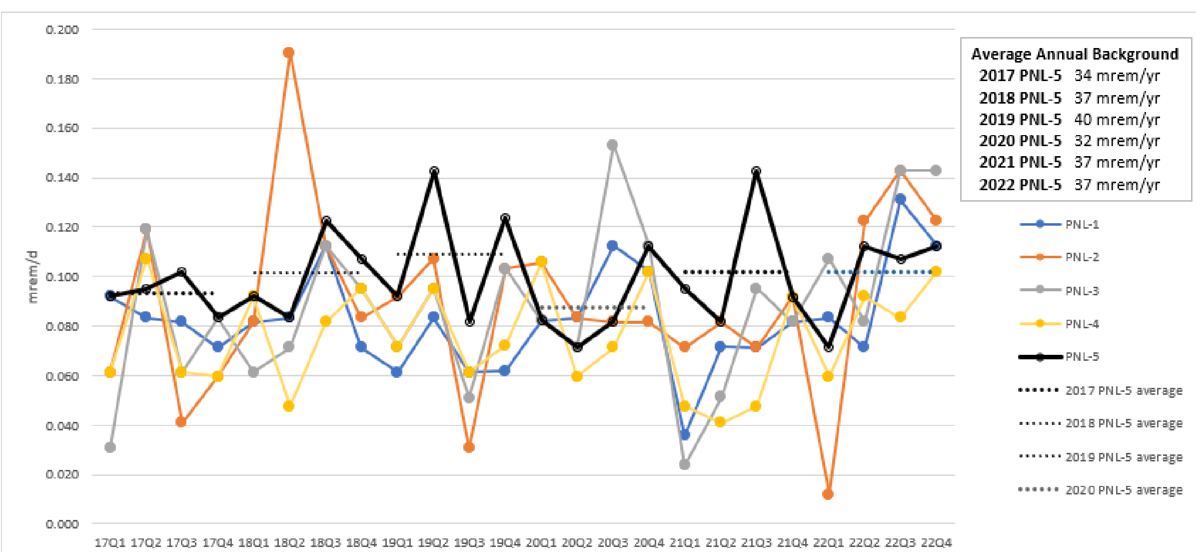

Figure 3.11. OSL External Ambient Dose Results (2017–2022)

3.10 Existing Monitoring Locations

For historical context, originally two interim stations were located on the Hanford Site to the N and NNW of the PSF at locations where power was readily accessible. The Barnett et al. (2010) conclusions resulted in relocation of these two northern monitoring stations (PNL-1 and PNL-2) to onsite Campus locations and added a third station (PNL-3) to monitor in the vicinity of the presumed PNNL-Richland Campus MEI receptor. The relocated stations remain solar-powered, whereas PNL-3 is AC-powered. Barnett et al. (2012) also concluded that a fourth monitoring station would be necessary (PNL-4) for RTL Building and south Campus surveillance. In October 2016, a background monitoring station was added as PNL-5 in Benton City, Washington. Environmental dosimeters were also added to each of the five monitoring stations for x-ray, beta-, and gamma-radiation supplemental monitoring to acquire site-specific data, with the first full calendar year of such surveillance conducted in 2017.

To show how the new modeling, meteorology, and modified fence line impact resulting X/Q values at the fence line and current monitoring station locations, Figure 3.12 and Figure 3.13 are provided for the facilities of interest (PSF buildings 3410, 3420, 3430). Figure 3.12 indicates the Revision 2 X/Q values at the fence line for each building, along with indications of the monitoring station X/Qs (reproduced from Figure 3.14 of Snyder et al. 2017). Figure 3.13 indicates the current revision's X/Q values at the fence line for each building, along with indications of the monitoring station X/Qs.

The X/Q values indicated for the monitoring stations use the different source configurations, dispersion model versions, and meteorology appropriate at the time of evaluation. The recent increased effluent flow rates for 3420 and 3430 are evident from the lower X/Q values in Figure 3.13, compared to Figure 3.12.

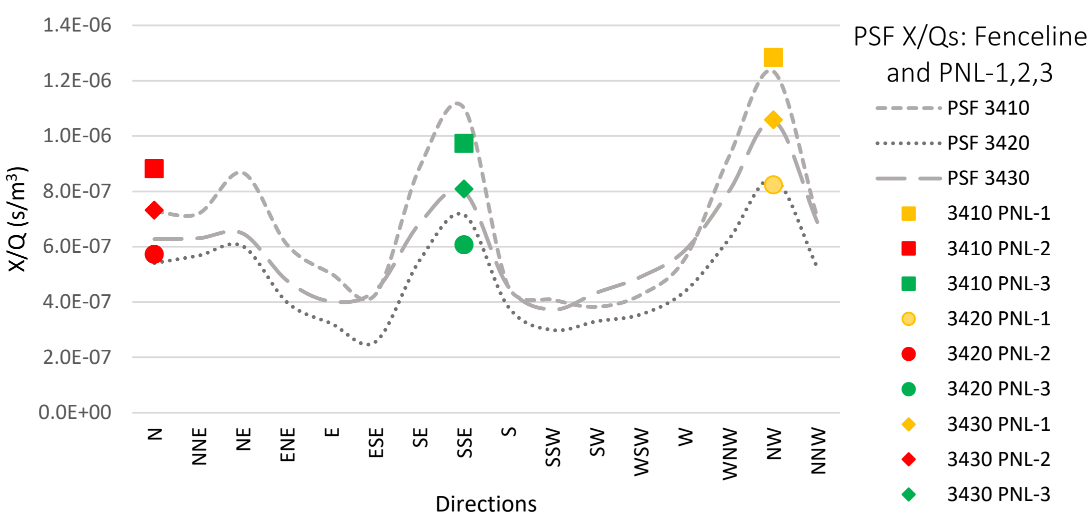

Figure 3.12. Revision 2 X/Q Values for All PSF Major Emission Unit Sources (Snyder et al. 2017)

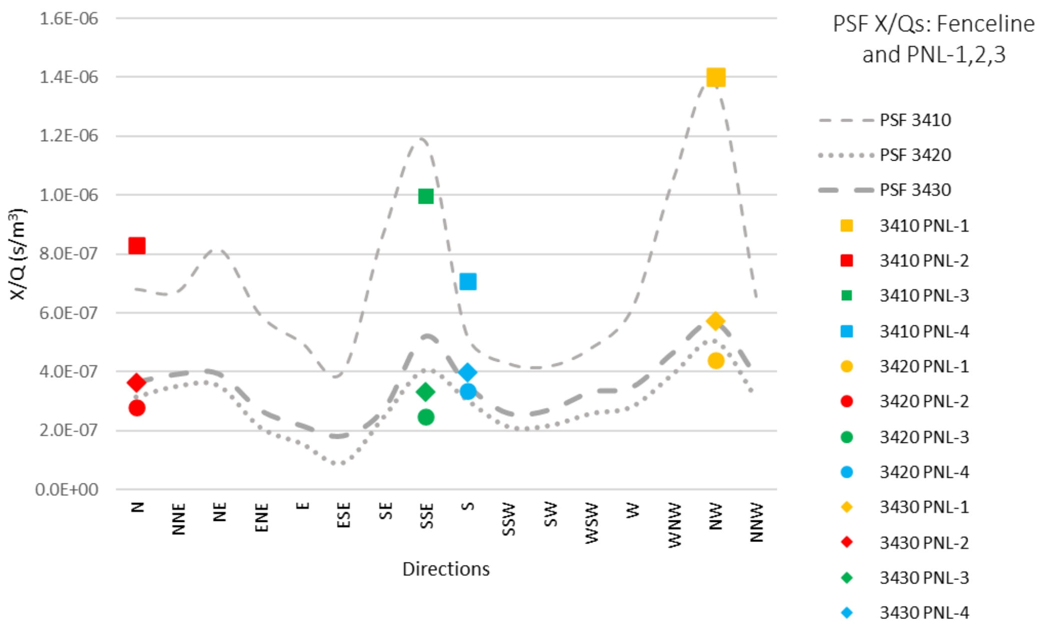

Figure 3.13. X/Q Values for All PSF Major Emission Unit Sources with Updated Modeling

Table 3.7 provides maximum X/Q values for each facility, which are all in the NW direction. Figure 3.13 and Table 3.7 values for each facility (physical locations indicated in Figure 3.8), indicate that PNL-1 continues to provide an excellent sampling location for the major emission units' effluent.

Table 3.7. Current Maximum CAP88-PC X/Q Values for Major Emission Units

Emission Unit	Maximum X/Q value (sec/m^3)
3410-01-S	1.4E-6
3420-01-S	5.5E-7
3430-01-S	6.5E-7

As an additional historical note, the DQO Revision 2 was completed prior to a stack upgrade, which increased the flow of the 3420 Building emission unit. Figure 3.14 indicates how this was expected to impact fence line X/Q values from a 3420 emission (Snyder et al. 2017). Figure 3.13 was created using actual stack operating conditions at 3420 for 2020 and 2021, indicates the upgrade was accomplished according to plans.

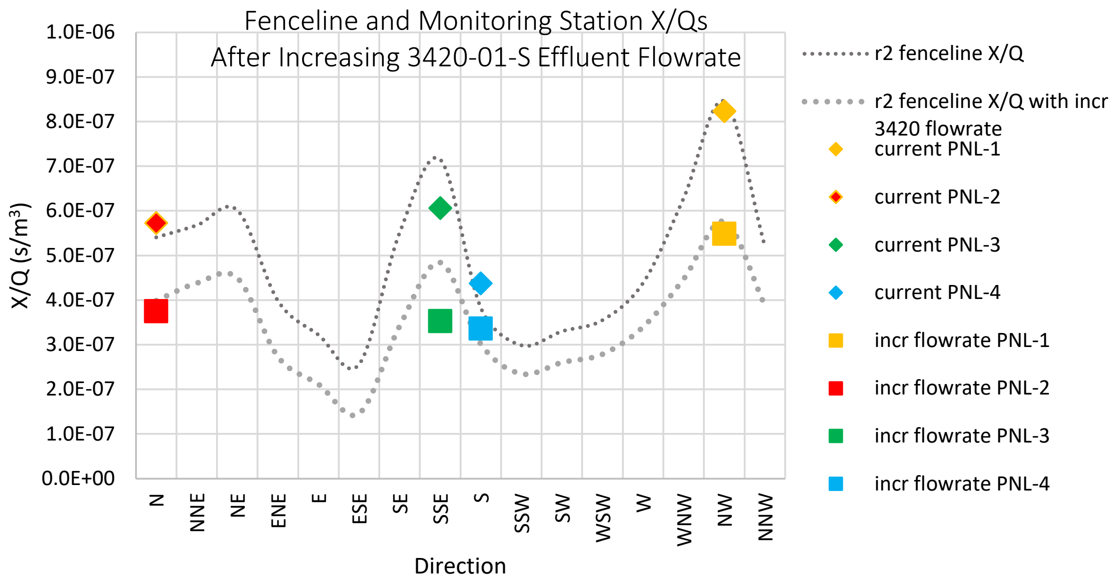

Figure 3.14. Per DQO Revision 2, Anticipated X/Q Reductions from an Increased 3420 Building Major Emission Unit Flow Rate

In the same vein, Figure 3.15 is provided to demonstrate the change in fence line and surveillance station X/Q values resulting from the 3430-01-S remodel. Once the remodel with its increased stack flow rate is accomplished, the 3430-01-S emissions will be more dilute at ground level.

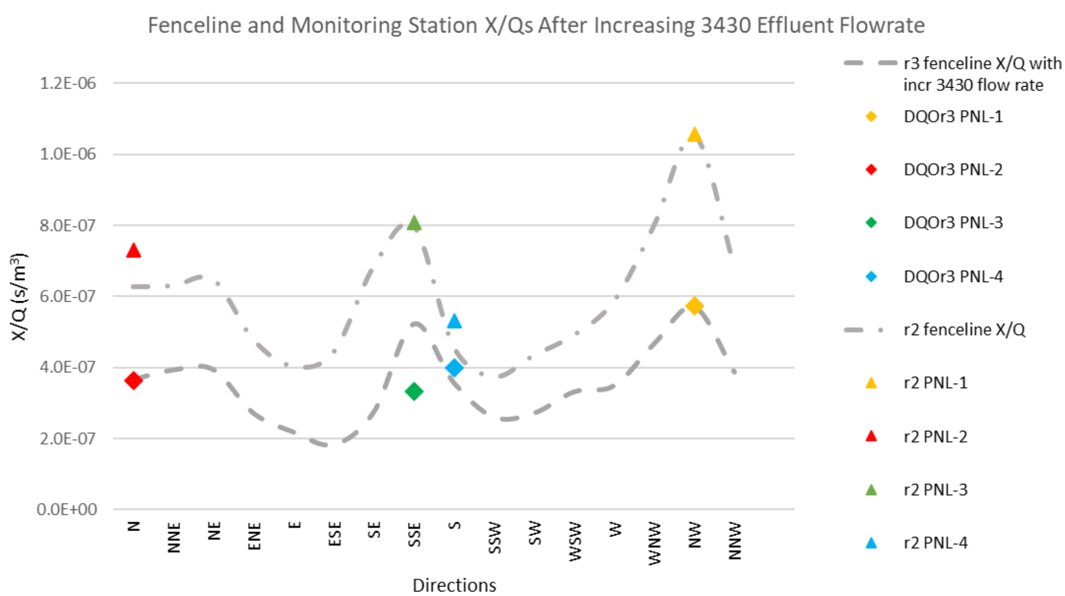

Figure 3.15. X/Q Reductions from an Increased 3430 Building Major Emission Unit Flow Rate in 2023

4.0 Boundaries

This section discusses the logistics of implementing the objectives. Here the boundaries are listed as they exist in the geographic limits (spatial) as well as in practical areas such as location, support, and accessibility. To provide a viable solution to the problem, all factors have to be considered.

4.1 Modeling Boundaries

To appropriately locate environmental sampling stations for airborne radionuclides, it is necessary to understand the long-term transport of radioactive effluents from the PNNL-Richland Campus to potential receptor locations. Atmospheric transport for chronic releases is typically estimated with a Gaussian plume model applied to local meteorological data. The CAP88-PC V4.1 software implements such a model and was used as the primary means for calculating the relative atmospheric dispersion of radionuclides released from the PNNL-Richland Campus. The CAP88-PC V4.1 model accounts for stack-specific parameters such as stack height, diameter, flow rate, and temperature to adjust the dispersion calculations relative to a ground-level release. It does not incorporate topographic parameters, but this is a nonissue as the PNNL-Richland Campus is relatively flat. As noted previously, meteorological data collected at the Hanford Site's 300 Area between 2012 and 2021 were selected as the most appropriate dataset to determine long-term atmospheric dispersion of Campus emissions. This timeframe represents the most recent set of long-term meteorological data available and will represent 2023 conditions.

The output of atmospheric dispersion calculations from the CAP88-PC V4.1 software provides tables of X/Q values by distance and direction for each radionuclide listed in the facility effluent stream. The relative atmospheric dispersion is adjusted to account for radioactive decay during transit to the receptor location (negligible for medium- to long-lived isotopes) as well as removal of radionuclides from the plume by deposition onto the ground. In this evaluation, Pu-239 is the representative radionuclide for modeling longer lived, depositing particulates.

Short-lived radionuclides were not evaluated for this purpose because their estimated downwind concentrations would be lower than those that do not undergo significant radioactive decay during transit. Short-lived nuclides also have not been a dose concern in recent NESHAP Assessments or air emissions reporting (e.g., Snyder et al. 2022). Besides the nonreactive particulate, Pu-239, Barnett et al. (2010) previously modeled two other kinds of radioactive materials: longer lived, nondepositing gases (represented by H-3) and longer lived, reactive particulates with a higher deposition rate (represented by I-129). DQO Revision 2 indicated that, at the relevant receptor and fence line distances and directions, the modeled air concentration results for gases were 1% greater at most and results for reactive particulates were 2–20% less than those of the nonreactive particulates. Given the current nonreactive particulate sampling program and the fact that all three classes of materials would yield substantially the same conclusions regarding appropriate locations for environmental sampling, the use of only Pu-239 in modeling is appropriate.

4.2 Spatial Boundaries

Dispersion modeling for the PNNL-Richland Campus consisted of calculating X/Q values in 16 compass directions and 20 distances relative to the three major emission units (3410, 3420, and 3430 Buildings). The distances evaluated ranged from 100 m, which is the near limit imposed by the software, to 10,000 m, which is well beyond the Campus boundary and current near-Campus sampling stations. The PNL-5 background station in Benton City, Washington, is more than 19,000 m from the Campus and was sited to intentionally not capture Campus emissions.

40 CFR 61, Subpart H defines potential receptor locations for demonstrating compliance with the dose standard as “an offsite point where there is a residence, school, business or office.” In WAC 246-247, the MEI is defined as “any member of the public (real or hypothetical) who abides or resides in an unrestricted area, and may receive the highest TEDE from the emission unit(s) under consideration, taking into account all exposure pathways affected by the radioactive air emissions.” WDOH has historically applied this definition to any member of the public that may spend a substantial fraction of a year at a location where access is not controlled by DOE, including non-DOE enterprises that may lie within the physical boundaries of a DOE facility.[4] LSB at 3350 George Washington Way has been occupied by PNNL staff for several years and is considered part of the PNNL-Richland Campus for the purposes of this DQO revision.

4.3 Temporal Boundaries

To identify the most effective sites for environmental sampling of radioactive air emissions, it is desirable to place the station near a location where the expected radionuclide air concentrations are high enough to be detectable. Other constraints include the following:

- Availability of space to house the station
- Availability of power
- Accessibility for sample retrieval
- Consideration of structures or vegetation between the source and sample station that might perturb transport of airborne radionuclides
- Vulnerability to vandalism or other damage (by water, automobiles, etc.)
- Vulnerability to external factors, such as dust generated by traffic, that could reduce sampler efficiency.

40 CFR 61, Subpart H dose standard applies to the calendar year. Ambient air sampling activities should represent average annual air concentrations.

[4] In addition to meeting the 10 mrem/yr requirement as stated, WAC 173-480-070(2) also requires calculating the dose to members of the public at the point of maximum annual air concentration in an unrestricted area where any member of the public may be.

5.0 Goal of the DQO

This section breaks down the principal study question outlined in Section 2.3 into individual questions that must be answered to meet the goal. There is a recommended action to be taken in answering these questions, and the decision made based on the action is also discussed. Finally, there is an assessment of potential errors with each decision and associated possible consequences. For DQOs that include sampling data, these decision error assessments are normally done statistically. For the purpose of this DQO, to select the appropriate air monitoring stations, the decision error assessment is done in an essay style format.

Questions are presented in a revised order from Revision 2 in this DQO. Question #7 is slightly revised from Revision 2. Questions #8 through #10 are new to this revision.

5.1 Question #1: What radionuclides of concern are expected in the air effluent stream on the PNNL-Richland Campus?

a. State the basis for determining the radionuclides expected to be found.
b. List the method used to determine the radionuclides of concern for ambient air sampling.
c. List the primary radionuclides of concern and their form (e.g., particulate, vapor, gas).

Action #1: Use the available isotope information from RAEL-005 and permitting applications (the NOCs) and building inventory knowledge to establish a list of radionuclides of concern, their particular form, and the method for determining annual release rates. Then determine the radionuclides that should be sampled in ambient air.

5.1.1 Decision #1

The list of radionuclides required to be sampled in each major stack is based on the building inventories and stack parameters (see Section 3.4.1). Environmental surveillance sampling blends all stack lists and requires ambient air monitoring for those that would meet detectability and potential dose criteria. All ambient air sampling stations are analyzed for the same set of isotopes. The emission unit RAEL-005 or more recent NOC applications are used to determine the ambient air sampling list (i.e., isotopes that are identified with a PTE greater than 0.1 mrem or 10% of the offsite dose or 25% after controls).

The list of ambient air sample analytes from the original DQO (Am-241, Am-243, Cm-244, Co-60, Pu-238, Pu-239, and U-233), are still measured. These nuclides are all included in the analytical contract that is reviewed annually (typically starting in October and finalizing by December). In addition, the analytical contract includes Cm-243, Pu-240, U-234, U-235, and U-238; these are analyzed because they are measured with other required nuclides for technical reasons: Cm-243 with Cm-244, Pu-240 with Pu-239, and all the uranium isotopes come as an analysis set.

Table 5.1 indicates the crosswalk between calendar year 2022 analyte sampling in stacks and ambient air. While RAEL-005 identifies expected major dose contributors, the annual NESHAP Assessment assures that all emission unit major dose contributors are recognized, based on current research activities. Table 3.4 indicates the RAEL-005/NOC radionuclides of concern and the 2022 NESHAP Assessment radionuclides of interest for the Campus PIC-2 emission units. The NESHAP Assessment may identify additional nuclides contributing 10% or more of the PTE, but because these nuclides are below the 0.1 mrem/yr threshold, a permit modification is not required, and these nuclides are excluded from the list of nuclides required for ambient air sampling. The required ambient air analytes were determined from the current RAEL-005/NOC and 2022 NESHAP Assessment. Some but not all remain applicable when assessed against the current research activities.

RAEL-005 specifies that environmental sampling be done for major contributors to the public receptor dose. A review of the 2021 and 2022 40 CFR 61, Subpart H compliance reporting indicates that gross alpha, gross beta, and U-233/234 contributes the majority of the dose. These analytes are currently sampled in ambient air.

Table 5.1. Radionuclides Sampled in Stack Air and Ambient Air

Stack-air Sampling – 2022	Ambient Air Sampling
Gross Alpha	Gross Alpha
Gross Beta	Gross Beta
Al-26	-
Co-60	Co-60[(a)]
Cs-137	Cs-137[(a)]
Th-229	-
U-233 (as U-233/234)	U-233/234
Pu-238	Pu-238
Pu-239 (as Pu239/240)	Pu-239/240
-	Am-241
-	Am-243
Cm-244 (as Cm-243/244)	Cm-243/244

(a) Co-60 and Cs-137 are part of the Gamma Spectroscopy suite of nuclides reported by the analytical laboratory.

Ambient air contains more diluted radionuclide concentrations than stack air. New stack-sampled radionuclides are to be assessed to determine if the analytical lab can detect the nuclide in ambient air and distinguish it from background, using current analytical methods.

The method of determining impacts from gaseous emission is conservative, as all emissions from gaseous material are assumed to be released, with no capture in research processes nor retention in source containers. Ambient air sampling of gases currently released would not meet the criteria for being readily detectable and distinguishable from background.

The following indicates why emissions from major emission units are of foremost concern and minor and fugitive emission unit air effluent is not considered further. The major (PIC-1 and -2) emission units are expected to produce unabated particulate-emission impacts to the MEI that are three orders of magnitude greater than the three Campus minor and fugitive (PIC-4) emission units and abated impacts about 500 times greater than minor/fugitive emission units, at maximum licensed release rates. Therefore, the radionuclides of concern for the major emission units are determined to be of interest for ambient sampling. The radionuclides that have been identified as major contributors to the potential offsite dose from PNNL-Richland Campus airborne effluents based on the RAEL-005 (e.g., those that meet the release criteria identified in Section 3.4) are Am-241, Am-243, Cm-244, Co-60, Pu-238, Pu-239, and U-233.

Upon review of the radionuclides potentially emitted from the major and minor emission units, there are no radioactive gases or vapors that contribute substantially to the potential offsite dose from any emission unit that would require monitoring. Therefore, only particulate radionuclides are addressed with respect to the environmental sampling program. The inclusion of minor emission units has no effect on this decision because the impacts of these smaller potential emitters are bounded by the permit limits of the major emission units.

Decision #1. The radionuclides of concern in ambient air are based on potential release criteria identified in RAEL-005 and on potential dose (see Table 5.1). Operations resulting in other radionuclides sampled at the stack (i.e., point of emission to the environment) are not included because they are deemed to be below the regulatory requirement for permitting.

5.1.2 Error Assessment #1

The radionuclides of concern for ambient air sampling were originally established based on the inventory mix (i.e., the annual possession quantities) of radionuclides identified in RAEL-005. Normal operations at these research laboratories may result in a different mix of actual radionuclide inventories monitored at their point source (see Table 3.4); however, these would have to be less than the 0.1 mrem/yr PTE criteria, even though they may be in actual inventory at greater than 10% dose or even possibly emitted at greater than 25% with controls. This is a result of managing the emissions at a total PTE dose that is less than the license PTE limit. The action to perform the annual NESHAP Assessment provides a quality check that stack sampling is done for appropriate radionuclides. It also provides a driver for timely updates of the permits in RAEL-005 and subsequently the ambient air sampled nuclide list.

There is a potential for a major permit application revision to contain new radionuclides meeting the requirements identified in Section 3.3, thereby resulting in the need for possible additional and/or different ambient air sampling. A change in the list of radionuclides of concern should not affect the overall emission characteristics (e.g., meteorological data, monitoring location(s), and dispersion modeling). Again, the mechanism is in the permitting process and triggers a change in the sampling and monitoring plan to allow and account for a change to the list of radionuclides of concern.

The consequence of an incorrect list of radionuclides would require a change in the analytical contract so that the correct analytes are included. These changes will be identified through the permitting process of the major emission units. Documentation of the change would be through the annual radioactive air emission report required under both state and federal regulations (WAC 246-247 and 40 CFR 61, Subpart H).

5.2 Question #2: What radionuclide release rates are routinely expected from the PNNL-Richland Campus emission unit(s) of interest?

a. Determine the emission rates of the radionuclides of concern from routine operations.
b. Under currently conceived operating conditions, determine if any releases are anticipated under routine operations that would be inadequately modeled as a chronic release.

Action #2: Given PNNL-Richland Campus emission rates, determine if releases of the radionuclides of concern can be adequately and conservatively modeled by air dispersion codes, assuming a uniform emissions rate under routine operations.

5.2.1 Decision #2

This DQO considers the measurement of routine releases of radioactive materials to the air. The source-release characteristics, whether they are released at a relatively constant rate over time or occur as larger, intermittent releases, can influence the ability to detect the radionuclides. In the case of PSF building releases, the radioactive sources are low level and relatively constant over time. Therefore, they may be characterized as chronic releases and are adequately modeled by the EPA-approved software. Radioactive material inventories and releases are managed within the RMT system and the Radioactive Air Gas Emissions (RaGas) database. If acute releases are anticipated from nonsampled stacks, alternative methods for modeling atmospheric transport may be warranted for the radionuclides involved.

The use and movement of radioactive material is managed within RMT. Radioactive material is proposed for a location, and RMT checks to confirm it is allowed. If allowed, the move can happen. RMT tracks the total throughput for the calendar year and does daily checks to confirm permit limits are not exceeded. The RaGas database is a tool to track the emissions of radioactive gases that are not sampled but are required to be reported. The ERT lead is notified by email for every proposed release. The lead can confirm the release is allowed and emissions tracking for individual gases can be managed on a case-by-case basis.

Decision #2: A chronic release rate of radionuclides of concern is expected and can be used for modeling release and exposure (i.e., dose). Normal facility operations are not expected to result in significant acute releases of radioactive materials. If either planned or unanticipated short-term releases were to occur at the facilities, the need for alternative assessment methods would be evaluated.

5.2.2 Error Assessment #2

A chronic release rate of radionuclides of concern is used for modeling release and exposure (i.e., dose) for regulatory reporting. Normal facility operations do not result in significant acute releases of radioactive materials. If either planned or unanticipated short-term releases were to occur at the facilities, the need for alternative assessment methods would be evaluated.

The radionuclides of concern from both major and minor/diffuse emission units were evaluated for both unabated and abated impacts for this DQO. For this decision, errors would result from problems with inventory and exposure scenario estimates.

With respect to exposure scenario estimate errors: CAP88-PC V4.1 models uniform release and uniform exposure over the entire year. The MEI exposure and intake rates are overestimated in the CAP88-PC V4.1 evaluations. Business locations that models identify as the offsite MEI in recent years are assessed as subsistence residential receptors, in accordance with regulatory requirements. In addition, if it were the case that, in reality, all inventory was released in a short period, during the remainder of the year, the realistic exposure could be zero. Modeling of such acute releases with a chronic model would likely be equivalent or conservative (i.e., overestimated) depending on the realistic exposure factors.

With respect to inventory estimate errors: Under environmental, safety, and health practices at PNNL, there are administrative controls in place to make certain that the annual inventory limits are not exceeded for each emission unit. These include the preparation of an annual Radionuclide NESHAP Assessment and the use of the PNNL RMT system for day-to-day activities.

5.3 Question #3: Where are the potential emission units for radiological air emissions on the PNNL-Richland Campus and which are the most critical for addressing the study question?

a. Identify major emission units and their release characteristics needed for air dispersion modeling (i.e., location, discharge point height and diameter, exit velocity, and temperature).

b. Identify minor emission units, including diffuse/fugitive sites.

Action #3: Determine which PNNL-Richland Campus emission unit(s) generates the greatest offsite impacts, based on qualitative or, if needed, quantitative criteria.

5.3.1 Decision #3

The input data provided in Section 3.4.2 also indicate the estimated impact from emissions, as documented in the RAEL-005 and more recent NOC applications. PSF major stack emissions are the primary concern for this DQO revision because they are closest to the northern boundary change.

Decision #3. No new radioactive air emission facilities are added in this DQO revision. Using only major emission units of PSF, and their current (or planned for 3430-01-S) emission unit characteristics, model the radionuclide releases based on current EPA-approved air dispersion codes. The data will also inform dispersion changes resulting from the update in the meteorological data and the CAP88-PC V4 software.

5.3.2 Error Assessment #3

Considering major and minor emission units on Campus, the major emission units potentially generate the greatest offsite MEI impacts of regulatory concern. The air permitting process requires the applicant to determine the major and minor emission units, which are assessed based on potential offsite impacts. The impact measurement is the dose to the maximally impacted receptor from routine operations. If an error were made in the decision to use the major emission unit releases for guiding the ESP development for the Campus, then the applicability of EPA's system of major and minor emission unit classifications would be called into question. The potential for underreporting offsite impacts would exist only if a major emission unit was not identified. This is unlikely, as building radioactive material inventory is controlled by the RMT system, and major emission unit releases are measured through continuous stack sampling.

5.4 Question #4: Where do the models predict the offsite location(s) of maximum impact from PNNL-Richland Campus emission unit(s) of interest?

a. Use the appropriate atmospheric dispersion model to conservatively estimate the fence line or offsite locations of the maximum nuclide concentrations resulting from Campus' PIC-2 emission units, using historical meteorological data and not taking credit for any engineering devices (such as filtration).

b. Establish the criteria for determining the location of the MEI based on the results of the characteristics of the major emission units.

c. Determine the locations that meet the 65%+ criteria for Campus major emission units and select at least one location to install an air surveillance station that meets the percentage capture requirement. Existing locations may be reassessed, as needed.

d. Determine the impact if the source changes (i.e., a PIC-3 or -4 source becomes a PIC-1 or -2 source).

The location of maximum impact (i.e., maximum dose) to a member of the public from PNNL-Richland Campus air emissions can be an offsite business, school, or residence where particulate air concentrations are modeled to be the greatest. In the prior DQO, land northwest of Campus (west of Stevens Drive) was changed from federal (Hanford Site) to public (Port of Benton) ownership; this land remains undeveloped in 2023. Modeling considers long-term meteorology. Locations of estimated maximum air concentrations are directly proportional to the locations of maximum dose impacts when no previous buildup of atmospheric depositions has occurred.

Action #4: Determine the most desirable locations of ambient air surveillance stations in the offsite (boundary) region surrounding the PNNL-Richland Campus, based on atmospheric dispersion modeling and maximum impact criteria. Determine if any existing air surveillance stations are at any of these locations.

5.4.1 Decision #4

An ambient air surveillance station would ideally be located at a point where it can most successfully capture emissions; in other words, the location where the highest air concentrations from an emission source would be found. CAP88-PC V4.1.1 modeling, through X/Q table output (see Appendix B), indicates locations of highest air concentrations for emissions from each PNNL-Richland Campus major emission unit. The CAP88-PC V4.1.1 model uses the appropriate meteorological data (see Section 3.5) and emission unit characteristics (see Section 3.3).

In the original DQO (Barnett et al. 2010), the criteria for determining the ideal location for the air surveillance station to determine MEI impacts were based on the following:

- "Occupied" offsite location of highest air concentrations from PSF emissions. For the purposes of this evaluation, "occupied" was defined as an offsite location that might be frequented by a single individual. Locations of heavy traffic with no single individual highly impacted were excluded (see Figure 5.1 of DQO Revision 0 [Barnett et al. 2010]).
- Locations where air concentrations were expected to meet the 65%+ Criteria.

5.4.1.1 Historical Decisions Summary

In general, the model presented in the original DQO determined that locations within 500 m and 1,000 m of each PSF source in the S and SSE sectors satisfy the criteria above and would provide data at a point close to the occupied potential MEI locations. The original DQO designated 480 m SSE of the PSF to be suitable for a new sampling location (see Figure 5.2 of Barnett et al. 2010), established as PNL-3. Subsequent changes to the 3410-01-S stack configuration and Campus boundary indicate a more ideal location could be more distant in the

SSE sector. However, DQO Revision 2 determined that PNL-3 remained an adequate location (met the 65%+ Criteria) for ambient air surveillance of 3410 Building emissions.

The PNL-4 sampling station was established based on the DQO Revision 1 evaluation for ambient air sampling for a facility that no longer exists, RTL-520. It was established onsite, 500 m NW of the former RTL-520 Building. While it currently does not surveille a specific source, the sampling station remains in operation, as the sole southern Campus ambient monitoring location (see Figure 2.1). Analyses related to PNL-4, as an operating surveillance station, is provided in graphics and tables where three other critical sampling station information is provided (e.g., Figure 3.13).

5.4.1.2 Current DQO Decisions

Updated meteorology, dispersion software, and current stack configurations were used to evaluate X/Q values for the three PSF facilities with major emission units. Figure 5.1 through Figure 5.7 indicate relevant air concentration ratios for fence line and current station locations, as determined with the updated information. Figure 5.2, Figure 5.4, and Figure 5.6 indicate the adequacy of the existing PNL-1 sampling location. However, PNL-2 has not remained within the original 65%+ Criteria; current average X/Qs are 52–60% of maximum air concentrations. PNL-3 also has remained within the original 65%+ Criteria for only 3410-01-S, with the other emission units about 45% of maximum air concentrations.

Of particular interest was the PNL-2 location information since that station will be most impacted by the north campus construction. Also of interest are data related to 3430 emissions with its increased stack flow rate (anticipated after February 2023+).

Section 7 of EPA (2017) was also reviewed for guidance specific to siting surveillance stations for particulate air monitoring (PM10 and PM2.5). While not exactly relevant to stack particulate monitoring, since significant sources for PM10 and PM2.5 surveillance are roadways rather than stacks, the document provides the following sampling station siting guidance to consider:

- Trees and buildings can alter the air flow, so stations should be placed at a distance from obstructions.
  - Probes should be >10 m (32 ft) from trees and >20m from the dripline of trees.
  - The [horizontal] distance between the sampler probe and the obstacle (e.g., building) should be at least twice the [vertical] distance between the probe height and obstacle height.
  - Unrestricted air flow of 270º around the probe is recommended.
- Particulate samplers should be 5 m (16 ft) from the nearest traffic lane.
- Collocated stations should be 1–4 m apart.

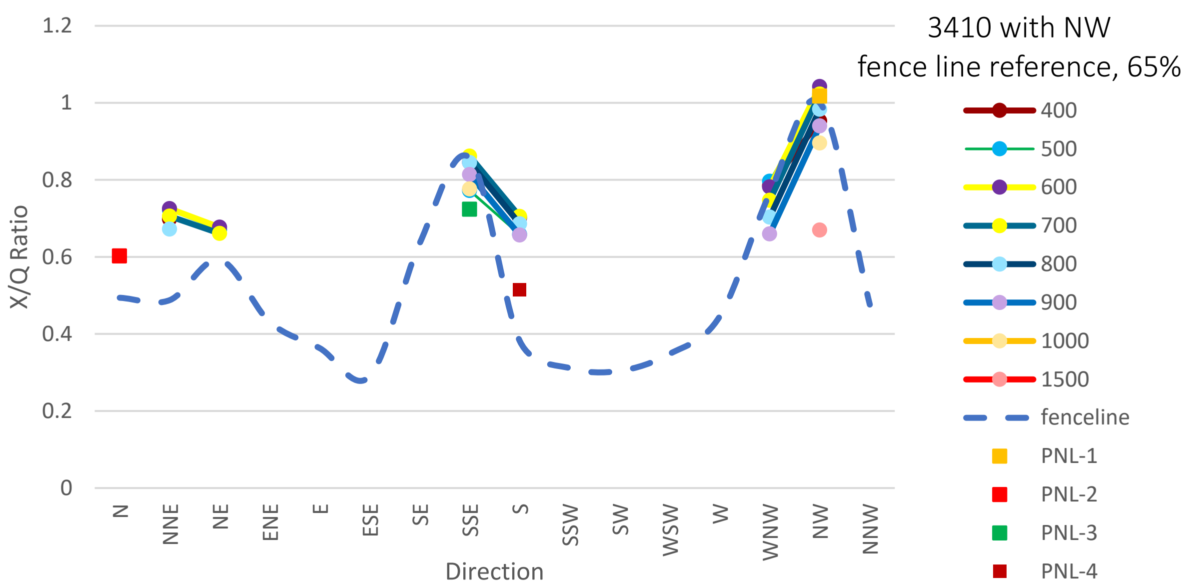

Figure 5.1. Air Concentration Ratios of 3410-01-S Emissions. Location X/Q to Maximum Offsite X/Q (760 m NW of 3410 at fence line) when 65%+ Criteria Met AND at Fence Line or Beyond

Figure 5.2. Areas Where 3410-01-S Emission Unit 65%+ Criteria Met

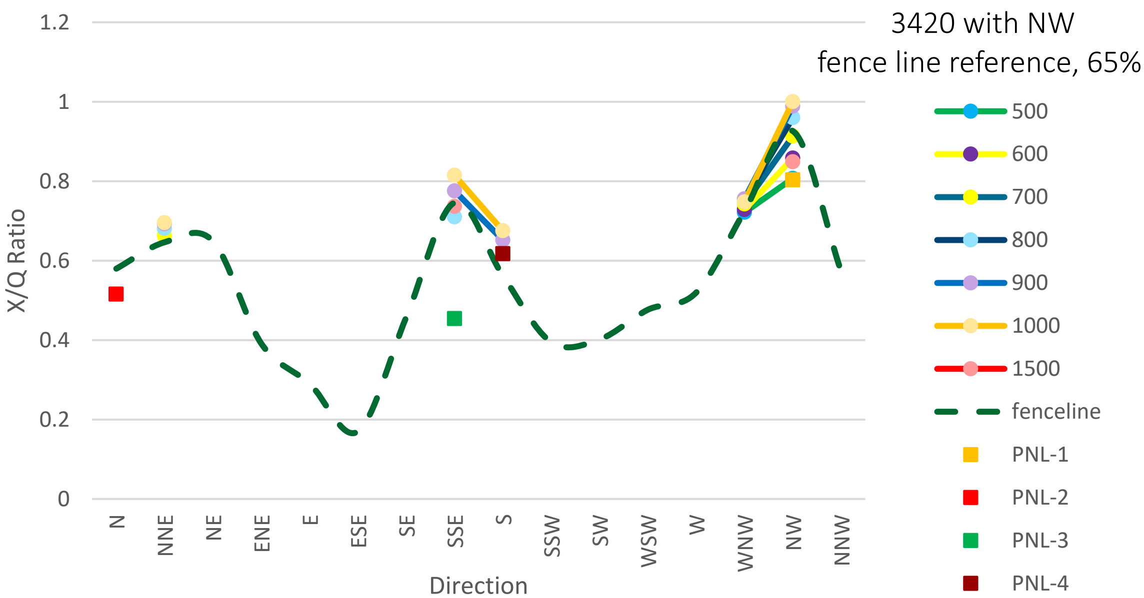

Figure 5.3. Air Concentration Ratios of 3420-01-S Emissions. Location X/Q to Maximum Offsite X/Q (995 m NW of 3420) when 65%+ Criteria Met AND at Fence Line or Beyond

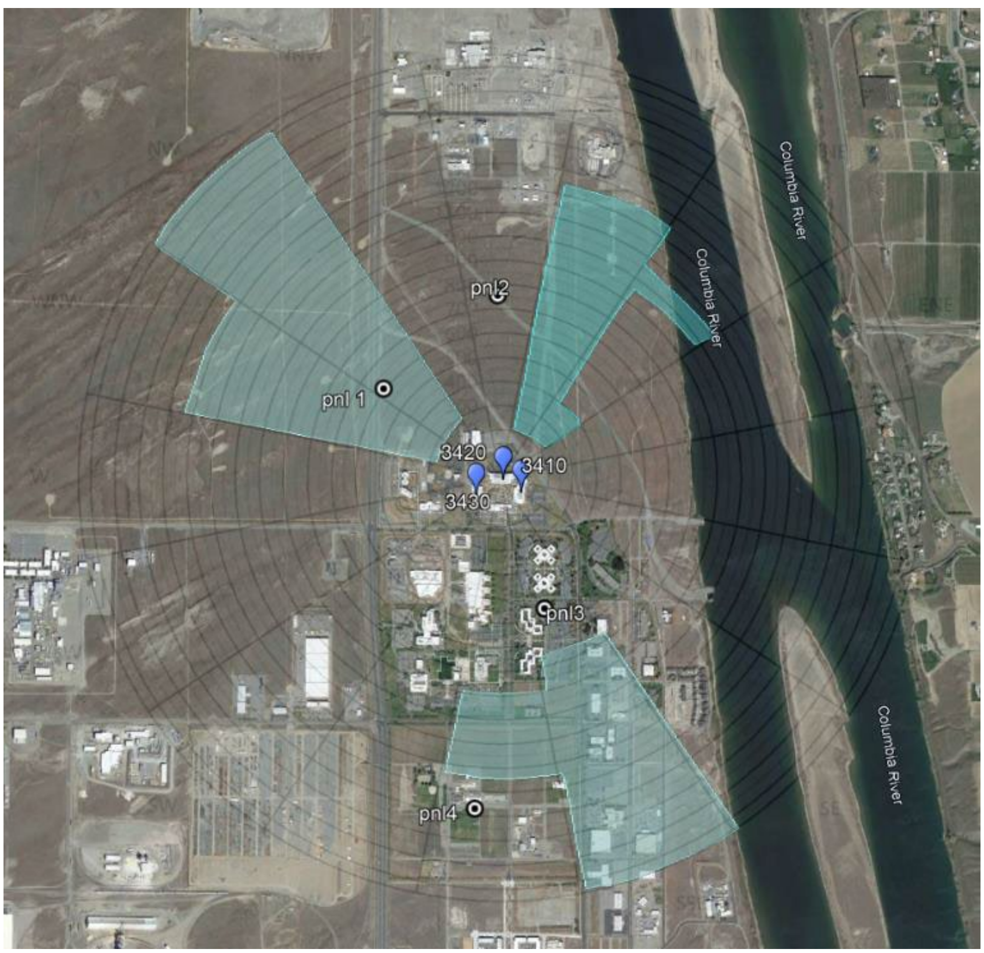

Figure 5.4. Areas where 3420-01-S Emission Unit >65%+ Criteria Met

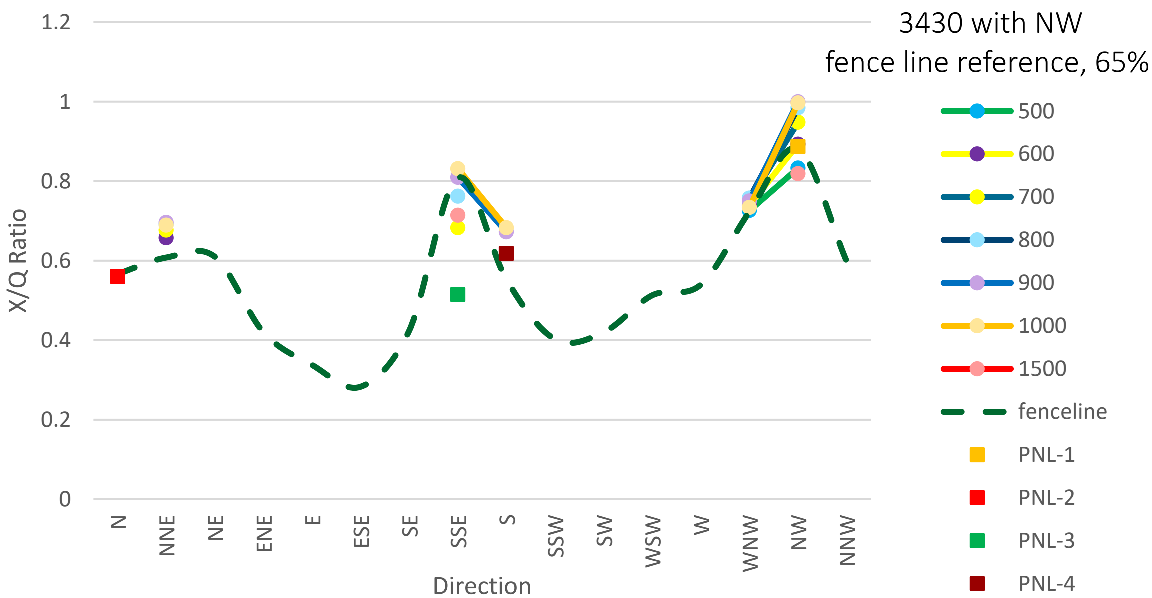

Figure 5.5 Air Concentration Ratios of 3430-01-S Emissions. Location X/Q to Maximum Offsite X/Q (935 m NW of 3430) when 65%+ Criteria Met AND at Fence Line or Beyond

Figure 5.6. Areas Where 3430-01-S Emission Unit 65%+ Criteria Met

Figure 5.7. All-Building Composite Where Individual Major Emission Unit 65%+ Criteria Met

Emissions from all three PSF buildings are best captured to the NW of each facility, as demonstrated by the highest X/Q ratios of the NW sector in Figure 5.1, Figure 5.3, and Figure 5.5. Areas associated with a 65% or greater capture for each facility's emissions are presented in Figure 5.2, Figure 5.4, and Figure 5.6. Several 65%+ Criteria areas have gaps between closer and farther distances where the criterion is not met. In many of these cases, the criterion is almost met. As a composite of the figures, Figure 5.7 indicates the overlapping area meeting the 65%+ Criteria for each of the three facilities.

Figure 5.7 composite areas indicate candidate areas for optimal ambient air sampling of the three Campus major emissions units. North Campus construction will impact PNL-1 and PNL-2. PNL-1 remains strongly within a candidate area. PNL-2 must be moved due to the impending building construction in the north Campus; it is also outside of the candidate areas in Figure 5.7 due to changes in stack configurations and updated meteorology.

5.4.1.3 Focus on PNL-2 Decisions

The DQO team considered options for PNL-2 relocation. The area east of the George Washington Way extension has additional limitations on development (orange area of Figure 5.8). Efforts are underway to relocate PNL-2 within the very limited (green) candidate area remaining, which will be impacted by future realignments of George Washington Way.

Figure 5.8. Development-limited Area (orange) Restricting PNL-2 Relocation Options

The 3410-01-S stack configuration creates the most limits on the total composite area meeting the 65%+ Criteria of Figure 5.8. To expand the candidate area, 3410-01-S stack configuration changes were investigated with the goal of increasing the 3410-01-S effective release height. Increasing the effective release height would allow additional candidate locations to the north of the current 65%+ Criteria area. Increasing the 3410-01-S stack flow rate was not an ideal option because the complex laboratory exhaust routes were recently optimized. Decreasing the stack diameter was also not ideal for the same reason. Increasing the stack height at least 2 m (6 ft) may be a potential option that would permit additional PNL-2 relocation region options (Figure 5.9).

Figure 5.9. PNL-2 Relocation Options (Green) Expanded if 3410-01-S Release Height is Increased

As an additional analysis for this DQO, Hanford Site 300 Area emissions were considered in relation to 3420 Building emissions. One 300 Area facility is responsible for the majority of the radioactive emissions. It would be impossible to capture only Campus emissions and no Hanford Site 300 Area emissions at PNL-1 and PNL-2, and it is desirable to site the stations in a manner that makes it more likely to capture Campus emissions and less likely to capture Hanford Site 300 Area emissions. Using the stack specifications listed in Barnett and Snyder (2021), Figure 5.10 indicates X/Q values at PNL-1 and PNL-2 from the 300 Area, 325 Radiochemical Processing Laboratory (RPL) facility.

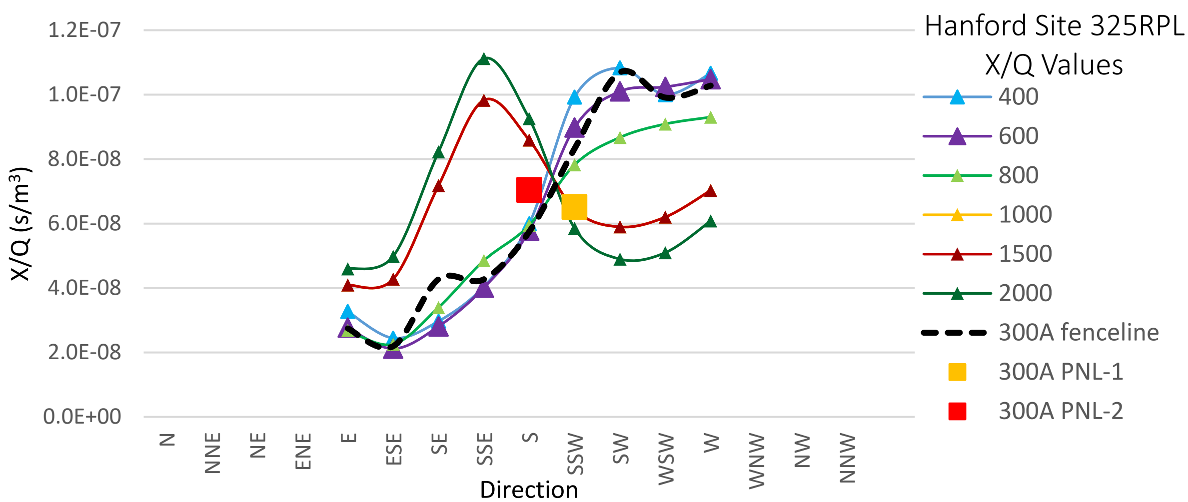

Figure 5.10. The 300 Area (325RPL) X/Qs for the Hanford Site Fence Line, Various Distances, and PNNL Sampling Stations PNL-1 and PNL-2

Figure 5.11 indicates the relative air concentrations for a unit release of a particulate from either the 3420 Building or the Hanford Site 300 Area. The results demonstrate that for a given identical release from each building, CAP88-PC modeling of the respective stack configurations indicates that PNL-1 and PNL-2 stations are currently sited to more likely capture Campus emissions than Hanford Site emissions. The tall stack configuration of the Hanford Site facility results in emissions over-flying the PNNL monitoring stations. While environmental monitoring and modeling results are subject to moderate uncertainties, primarily due to meteorology, the results indicate the propensity for the PNL-1 and PNL-2 stations to be more likely to capture Campus emissions.

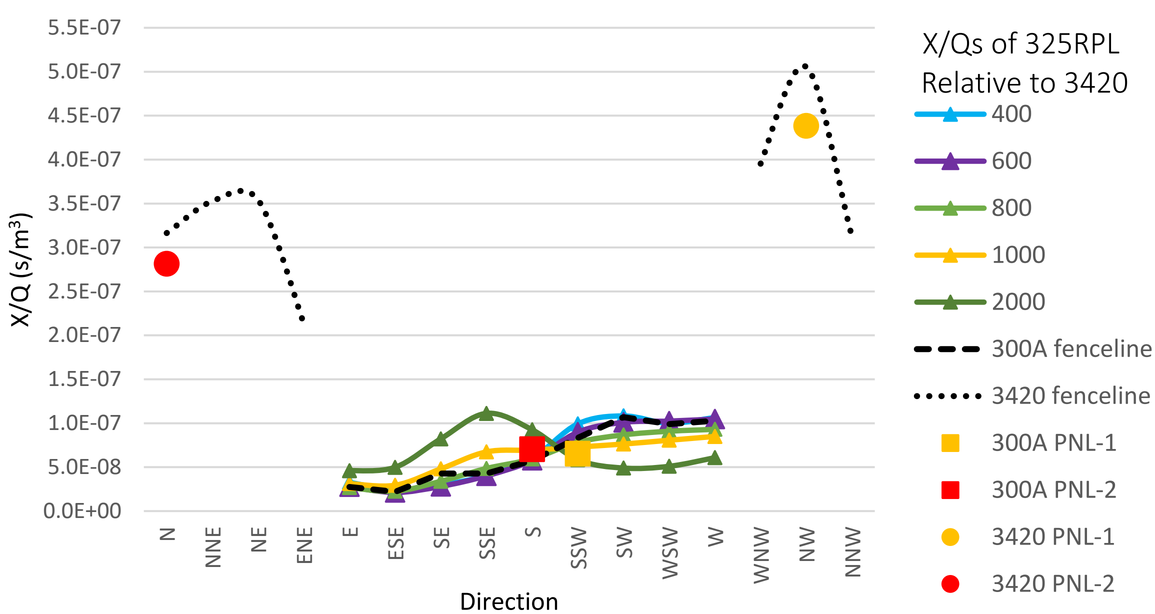

Figure 5.11. Relative to PNL-1 and PNL2, Particulate X/Q Results from 3420 Building Emissions and Hanford Site 300 Area Emissions

The question of the quantities of Hanford Site 300 Area particulate emissions compared to PSF particulate emissions was reviewed. Table 5.2 indicates the trends for total emission rates of currently sampled ambient radionuclides (Am-241, Am-243, Co-60, Co-137, U-233/234, Pu-238, Pu-239/240, and Cm-243/244) from the PNNL-Richland Campus (major emission units) and Hanford Site (300 Area totals) based on each site's air emissions compliance reporting. These reported annual emissions include both measured and calculated particulate releases. Total emissions of this nuclide set are roughly similar, with a relative reduction in Campus emissions noted during the pandemic reduction of site operations in 2020 and 2021. It is believed that the PNL-1 sampling is expected to represent more of the Campus emissions and the current PNL-2 location sampling is not expected to represent Campus emissions due to roughly equivalent capture of equivalent releases from 325RPL and PSF facilities.

Table 5.2. PNNL PSF and Hanford Site 300 Area Radioactive Air Effluent for Campus-sampled Ambient Radionuclides (2018-2022).

Calendar Year	PNNL-Richland Campus Major Emission units (Ci/yr)[(a)]	Hanford Site 300 Area Total (Ci/yr)[(a)]
2018	1.2E-7	3.3E-7
2019	1.1E-7	3.0E-7
2020	5.6E-8	1.9E-7
2021	8.2E-8	3.4E-7
2022	2.0E-7	2.9E-7

(a) Am-241, Am-243, Co-60, Co-137, U-233/234, Pu-238, Pu-239/240, and Cm-243/244 emissions.

5.4.1.4 Decision #4 Conclusions Including Relocation Options

Modeling results were used to determine how the current locations of air surveillance stations would adequately capture the PNNL-Richland Campus emissions and adequately represent the preferred sampling locations of the offsite (boundary) region. Based on the CAP88-PC V4 X/Q estimates and the updated Campus boundary, a review of the capture ratio of each of the three PSF buildings and the construction activity, siting, and operational decisions were made for the siting locations of each sampling station. The current number of sampling stations was determined to be adequate, with no additional stations suggested by the updated modeling results. PNL-1 and PNL-2 were the primary stations impacted by the northern Campus development activities.

PNL-1 will remain at its current location but taken offline during the underground work phase of the 300 Area water line work. PNL-1 operations during this activity are expected to meet the sampling downtime criteria (15% or less) established for the PNNL ambient air sampling program.

PNL-2 will be relocated due to north campus construction. The proposed PNL-2 preferred and alternate relocation options are indicated in Figure 5.12 (preferred is about 540 m and alternate is 900 m NNE of 3420-01-S). The alternate location is contingent on implementing a higher physical release height for 3420-01-S. Figure 5.13 indicates the current flat and open topography of the two options.

Preference decisions were determined based on year-round access issues, need to increase the 3410-01-S stack height (significant expense), distance from power supply, and potential for additional National Environmental Policy Act (NEPA) review (significant expense).

Figure 5.12. Options for PNL-2 Relocation

Figure 5.13. PNL-2 Preferred and Alternate Relocation Options, Looking South

While maintaining solar-powered operations at PNL-1 and PNL-2, AC-powered sampling stations are preferred due to greatly reduced maintenance costs and better sample quality resulting from sampling issues during days with poor air quality (ambient dust, smoke). As the areas around the stations are developed, additional opportunities for AC connections will be available. Relocation of the solar-powered operations would be preferred to guarantee against loss of availability of the preferred location in the future.

PNL-3 location was also reviewed as a result of this DQO assessment. The station, currently 480 m SSE of the 3410 Building at light pole #811, is recommended for relocation. Modeling with current stack configurations (all major stacks) and updated meteorology, indicates the composited area where the 65%+ Criteria is met for all stacks is farther south than the current PNL-3 location. Figure 5.14 indicates the locations recommended for relocation based on the candidate areas. For the preferred option, Table 7-2 of EPA guidance (EPA 2017) was reviewed to establish the offset from the tall sycamore trees that border the Campus. EPA 2017 indicates the recommended distance from tree dripline to the probe inlet (greater than 20 m [65 ft]) for particulate matter monitoring for criteria pollutant sampling. The reference also has guidance (e.g., see Figure 7.5 in EPA 2017) about distance from roadways for the context of particulate matter monitoring; due to the different purposes of sampling, this road-offset information is worth consideration but not directly applicable to radioactive effluent sampling.

Figure 5.14. Options for PNL-3 Relocation

PNL-4 station is no longer a required critical location for PNNL emission unit ambient air sampling since the RTL complex has been demolished. However, it will remain as a sampling location because of its value as a station collocated with both the Department of Health and the Hanford Site.

As a final piece of information, Figure 5.15 provides the CAP88-PC modeled X/Q data for the PNL-2 and PNL-3 relocations (preferred [a] and alternate [b]). Once relocations were commissioned, these data represent the improvements in emission unit plume capture, as a comparison with the existing station X/Qs indicated in Figure 3.13.

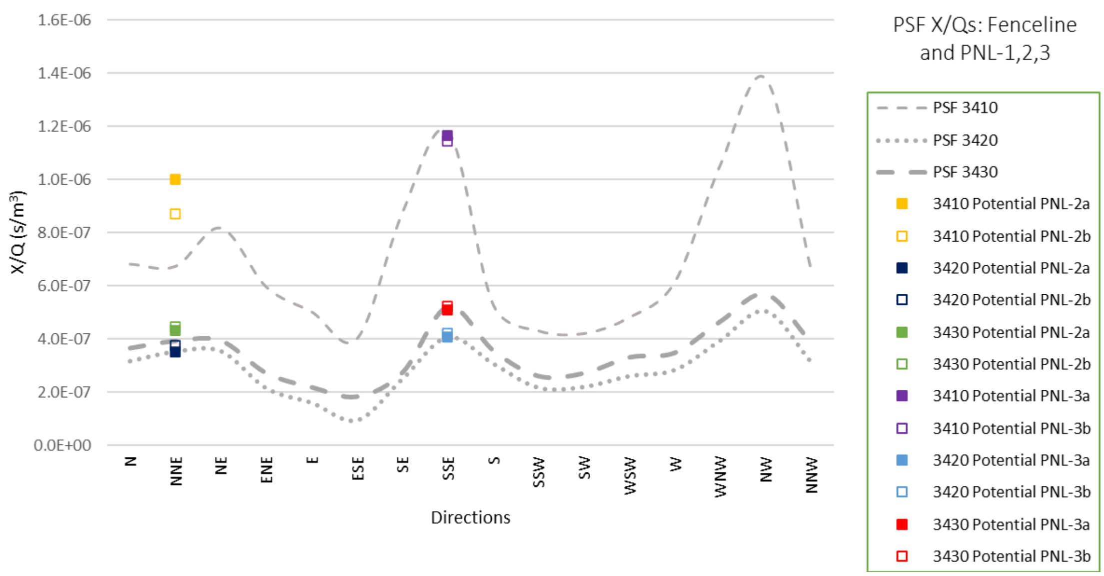

Figure 5.15. X/Q Values for All PSF Major Emission Unit Sources for the Preferred (a) and Alternate (b) Relocated PNL-2 and PNL-3 Stations.

5.4.2 Error Assessment #4

Sampling for PNNL-Richland Campus radioactive material effluent in ambient air is currently conducted at four critical locations and a background station. The sampling results are used to confirm low emissions and provide an indication of a potential elevated result. Results are not used as the basis for compliance against the NESHAP standard but as supportive data confirming low emissions. Updated dispersion modeling indicated two of the four sampling stations should be moved to better capture significant dispersion locations.

Dispersion was based on operational history. Changing research may result in changes in stack configurations, which by the nature of the activity can be variable. The best options for station siting were proposed based on modeling approved for compliance against the NESHAP standard. Proposed new station locations were decided based on locations with as much buffer distance as possible from locations that do not meet the 65%+ Criteria. This provides more confidence that the sampling location will remain appropriate as minor stack configuration changes and uncertainties associated with the meteorology occur.

5.5 Question #5: What environmental media should be monitored for the effects of radioactive air emissions?

a. Consider all potential media (e.g., air, soil, water, food—produce, meat, poultry—vegetation, wildlife, sediment).

b. Consider both gaseous and particulate contamination for the air pathway.

c. Consider radiation emission types: alpha, beta, and gamma.

Action #5: Determine which environmental media should be collected as part of the proposed ESP.

5.5.1 Decision #5

Air is the only pathway that could contribute a significant dose to the hypothetical receptor that necessitates monitoring. Water at a receptor location originates from the Columbia River and is supplied by the City of Richland. If necessary, concentrations of radionuclides in drinking water at the maximally impacted receptor location could be obtained from Public Safety and Resource Protection. PNNL-Richland Campus operations contribute an exceptionally small amount of emissions to the contaminant load of the Columbia River (through atmospheric deposition), and it is impossible to differentiate these from background levels of radionuclides in the river. Campus air effluent releases depositing to water or soil that result in a radiation dose to aquatic and terrestrial biota are conservatively calculated (e.g., Thompson et al. 2023) and consistently below the radiation dose limits prescribed by DOE (2019). For this reason, all liquid pathways (e.g., irrigation, immersion, and ingestion) can be discounted and need not be considered further.

PNNL-Richland Campus radioactive waste generated at PSF is consolidated at an offsite PNNL-managed radiological facility (325RPL Building on the Hanford Site), then shipped offsite for disposal. Radioactive air emissions from such waste are essentially zero.

While apartments have been constructed adjacent to the Campus, they are located at the southern border. Dispersion results indicate that PSF emissions will most significantly impact offsite office locations SE of PSF. Since the maximally impacted PSF receptor location is a work location (not a residence), the ingestion pathway is not realistically a significant contributor to dose. There are currently no onsite garden plots or leased farmland, as both of those opportunities have ceased. If maximum NOC amounts of each radionuclide were released, unabated, only Co-60 would be of concern for ingestion. Co-60 is an easy-to-detect particulate because of its strong gamma energy and relatively short half-life, so air sampling will effectively monitor this radionuclide, and food crop sampling would not be necessary. An environmental OSL dosimeter would also detect gamma emissions from Co-60.

Inhaling resuspended dust containing PNNL-Richland Campus emissions that had deposited on the ground is a potential exposure pathway. However, atmospheric surveillance provides a more realistic means of evaluating this pathway than that associated with soil monitoring. An evaluation of all air pathway dose impacts was performed for the Campus radionuclides of concern. Further, since emissions from Campus are primarily (nearly exclusively) particulates, only particulate monitoring will be necessary. No monitoring of gaseous radionuclides is necessary.

5.5.2 Error Assessment #5

All possible exposure routes (air, water, soil, food, and biota) were reviewed. PNNL-Richland Campus operations do not release any radioactive effluent to the ambient environment other than very low concentrations of airborne effluent. No potential errors can be identified based on anticipated operations described in the RAEL-005 and superseding NOCs. If Campus operations were to change, such that types of radionuclides not currently identified as significant contributors to offsite impacts were potentially emitted from the facilities, the need for changes to the sampling program could be reevaluated and implemented as necessary.

5.6 Question #6: What are the requirements for an adequate radioactive ambient air surveillance program?

a. Requirements for an air surveillance program for radionuclides are documented in DOE Handbook DOE-HDBK-1216-2015 Chg Notice 1, *Environmental Radiological Effluent Monitoring and Environmental Surveillance* (DOE 2022).

b. The use of environmental measurements of radionuclide air concentrations at critical receptor locations is described in 40 CFR Part 61, Subpart H; § 61.93 (5).

c. WDOH may require the operator of any emission unit to conduct ambient air surveillance to demonstrate compliance with the standards as indicated in WAC 246-247-075 (9).

   i. WDOH requires environmental monitoring in the RAEL-005.

   ii. It will consist of sampling at representative locations of the highest anticipated offsite dose to the MEI and the Maximum Air Concentration Location.

   iii. Environmental monitoring will remain in operation during the effective period of the license and additional sampling stations may be established consistent with the implemented program.

d. A QA program is required for the environmental monitoring (air surveillance network) as well as for the analytical requirements.

e. Conduct background sampling. Background measurements specific to the PNNL-Richland Campus commenced in October 2016. Prior to October 2016, background information was obtained from the Yakima Station associated with the Hanford Site.

f. From a sampling perspective, the sampling system and sample collection schedule must collect enough material to be able to measure the radiological releases at levels required to demonstrate compliance with the Table 2 notification levels of 40 CFR Part 61, Appendix E. The Campus EMP is in four documents (Snyder et al. 2020 [main text]; Meier 2011 [EMP Att. 1]; Bisping 2011 [EMP Att. 2]; and Snyder 2021 [EMP Att. 3]).

g. Outages in existing sampling station operations may occur. These can be due to planned maintenance or construction activities or unplanned activities like power bumps. Outages where the sampling station is (temporarily) deenergized may be commensurate with or without sampling covered by other sampling stations. An overall operation factor (e.g., 85%) should be maintained and documented with appropriate justifications for exceeding program established limits.

Action #6: Continue to maintain, and improve as needed, the ambient air ESP for the PNNL-Richland Campus, considering applicable regulatory and government requirements and equipment/sampling specifications.

5.6.1 Decision #6

The PNNL-Richland Campus ESP is mature and has been in operation for more than a decade. Currently, there are four Campus surveillance stations for ambient air and a background surveillance station that have been sited and are operational. Each station also has an environmental OSL dosimeter. Information regarding the ESP is documented in the Campus EMP, data are maintained in a compliant database, and the program meets programmatic and regulatory needs. Sampling collection, analysis, sample results, recordkeeping, and reporting are done in a compliant manner. The DOE-HDBK-1216-2015 environmental surveillance requirements are met with the current program.

An acceptable program must meet the regulatory requirements regarding QA and provide operating coverage (temporal and spatial). To have the ability to detect radionuclides of concern, the operating parameters of the sampling equipment and compositing schemes of samples must be conducted according to the Campus EMP and effluent management QA requirements and procedures.

Additional guidance for program development may be found in National Council on Radiation Protection and Measurements (NCRP) Report No. 169, *Design of Effective Radiological Effluent Monitoring and Environmental Surveillance Programs* (NCRP 2012). It covers monitoring objectives, environmental surveillance program requirements, typical monitoring programs, and systems and applications of environmental surveillance programs.

The Campus air surveillance network is composed of four air surveillance stations and a background station; it also includes external dose monitoring by an environmental dosimeter at each station. The EMP describes the current ambient air surveillance program. The background station (at Kiona-Benton High School) is located approximately 0.8 km (0.5 mi) north of the nearby the Benton City Junior Fair and Rodeo Association Hanford Station (N947). Environmental surveillance is conducted continuously according to the requirements in the effluent management QA plan, site license, and regulatory mandates.

The new evaluations conducted for this DQO revision indicate the Campus air surveillance network of four stations and a background station is still adequate. However, the siting locations of these stations may move based on planned and expected emissions characteristics discussed herein and planned new construction on the north Campus. More specifically, this DQO evaluation indicates that station siting remains within the DQO Revision 2 criteria for the PNL-1 station. The PNL-2 and PNL-3 sampling stations can be improved with relocations driven by emission unit changes and, for PNL-2 the impending north campus construction. Finally, PNL-4 no longer samples an existing radiological source (e.g., the former RTL complex) but provides air quality information in the southern Campus; it is also collocated with both WDOH and Hanford Site stations.

Continuous operation of sampling follows regulatory guidance. Regulatory guidance in WAC 246-247 indicates routine maintenance, routine repair, and replacement-in-kind are excluded from the definition of a modification. “Routine” includes the maintenance, repair, or replacement-in-kind performed on systems, equipment, components, or devices as a planned part of an established program as well as normal day-to-day operations. “Replacement-in-kind” means the substitution of existing systems, equipment components, or devices with equivalent or better performance specifications that will perform the same function(s). In this sense, existing sampling stations may be temporarily shut down, with or without sampling covered by the remaining stations, in order to accommodate planned activities (e.g., maintenance or replacement-in-kind) as well as with relocating a station to a more preferred location. Meeting the programmatic goals for operational availability is desired.

5.6.2 Error Assessment #6

Based on the well documented wind patterns in the Hanford Site 300 Area and the PNNL-Richland Campus, current models indicate the likelihood that four sampling locations are adequate and cover essential operating areas of the Campus. Relocation of a station or temporary station outages are part of planned program operations and considered routine within the context of the regulations. Background measurements provide an additional source of information collaborating overall emissions. The potential for increased risk is further diminished by the presence of the Hanford Site air monitoring and surveillance network. With the present inventory and uses of radiological materials at the Campus, there is a large and significant margin of safety such that the public is not at undue risk, and the design is adequate and can stand alone. As occurred for this DQO revision, changes to Campus operations, stacks, emissions, or the addition of new public areas that encroached on the Campus would require additional evaluation to assess the adequacy of the program.

5.7 Question #7: What regional ambient air surveillance program practices can PNNL staff assess to determine if there are opportunities for improving the PNNL-Richland Campus monitoring program?

a. Identify any non-PNNL surveillance programs at or near the PNNL-Richland Campus.

b. Assess other programs have design/practices that could improve the Campus program.

c. Identify the radionuclides monitored by other programs.

d. Determine if the data from other programs are of sufficient quality to be used in conjunction with or in lieu of data collected by PNNL.

Action #7: Identify some aspects of non-PNNL surveillance programs that might be usable by the PNNL-Richland Campus ESP; consider operating procedures, practices, schedules, and equipment.

5.7.1 Decision #7

PNNL staff reviewed two nearby non-PNNL ambient air surveillance programs. Sample exchanges for particulate monitoring were observed and program documents acquired in the event that additional program details were needed. Hanford Site sampling and WDOH sampling were observed.

5.7.1.1 Hanford Site HMIS Sampling

PNNL staff observed the Hanford Mission Integration Solutions (HMIS) ambient air sampling process for particulate sampling, which included air filter exchange, procedure, and discussions with program staff. HMIS also samples for tritium, which was not observed. The procedure also indicates I-129 and C-14 sampling procedures that will occur in the future for Waste Treatment Plant emissions sampling, also not observed.

Notable differences observed between the HMIS and PNNL program included:

- **Air flow rate** at 2.0 cfm with 20% [1.6–2.0 cfm] acceptable variability (vs. PNNL's 1.6 cfm with 15% [1.4–1.8 cfm] acceptable variability)
  - Increasing flow rates at PNNL sampling stations would lower the minimum detectable activity (MDA) of the biweekly samples, so would be an option if such precision were

needed. The PNNL solar-powered stations as currently configured, however, would have difficulty maintaining this flow over the biweekly sampling period.

- **One item of calibrated** equipment involved in sample collection (i.e., portable rotameter) (vs. PNNL's two pieces of calibrated equipment: high-volume air flow calibrator and gas meter)
  - The number of HMIS sampling stations (about 100) is significantly greater than that of PNNL (5). Not having to calibrate an additional piece of equipment likely results in cost savings. The PNNL system provides greater assurance in the total volume of air sampled because changes in flow rate over the sample period are reflected in actual flow volume results rather than averaged over the sample period (start and end flow rates). PNNL has criteria for total volume of air sampled that may not be able to be accurately assessed if the HMIS (on/off flow rate * time) results were used for sample acceptance.
- **Sampling station equipment** includes an hourly timer for measuring sample duration for determining total volume of air sampled when multiplied by the presumed constant air flow rate (vs. PNNL's AC samplers using calibrated gas meters that provide total volume of air sampled)
  - The HMIS sampling equipment does not provide totalized flow or totalized volume. The HMIS procedure records on/off flow rates and elapsed time, with the timer halting operations when the air pump fails. The PNNL station equipment indicates either total sample flow (ft^3; solar) or total volume of air sampled (m^3; AC).
- Field data **entered electronically,** for sample data and station bar-code identification (vs. PNNL's paper forms)
  - Were PNNL to decide to develop tools for electronic entry, it would save some data entry time, though may be more prone to data entry errors. Again, there are great advantages in using such a system for a large sampling program. Additionally, paperwork is also prone to weather damage in the field. An electronic system would be a nice investment.
- In-field **survey of filter** for beta/gamma and for alpha (vs. PNNL lack of field contamination survey)
  - The greater inventories potentially released from Hanford Site locations create a greater need for such in-field surveys. Surveys may be useful for PNNL stations closest to the Hanford Site 300 Area.

5.7.1.2 Washington State Department of Health Sampling

PNNL staff observed the WDOH ambient air sampling process for particulate sampling of ambient air. This included air filter exchange observation, documentation (procedure and 2021 Summary Report [also available at: https://doh.wa.gov/community-and-environment/radiation/publications/environmental-sciences]), and discussions with program staff. WDOH also samples charcoal cartridges for Iodine-131 analysis and environmental dosimeters (OSLs read by Landauer, same as PNNL), which was not observed.

Notable differences observed between the PNNL and WDOH program included:

- **Air flow rate** similar at 1.5 cfm (vs. PNNL's 1.6 cfm)
- **Filter paper** is 3µm 47mm Versapor (vs. PNNLs 2-inch LB-5211)
  - WDOH loads and unloads their own filter-head assemblies (vs. PNNL where this service is performed by the contracted analytical services laboratory).
- **Sampling station equipment** used by WDOH resembles that used by PNNL (i.e., sampling hutch, gas meter, vacuum pump) with a few exceptions:
  - Sampling hutch is shorter at approximately 3 ft in height.
  - Vacuum pump has an in-line flow meter attached.
  - The in-line flow meter and gas meter receive an initial vendor calibration at the time of procurement; thereafter, the equipment is not calibrated. However, the portable air flow rotameter, used at the time of air filter collection, is routinely calibrated.
  - Particulate air filter housing is more exposed than PNNL's rainhat assembly (see Figure 5.16).
- **Field data** is handwritten on a blank sample collection log (Air Sample Worksheet) and blank sample label(s); there is no pre-generated information printed on the sample collection log or label (e.g., sample ID, date). Information is transferred to a database upon returning to the office in order to generate chain of custody (COC) documents for the analytical laboratory, which is QA checked prior to sample shipment (vs. PNNL's pre-generated COCs and sample collection record forms, which also require limited handwritten entries, but do include pre-generated sample information (e.g., sample ID, location, start date/volume, analyses)**.**
  - Paper field data log records could get lost, crumpled, wet, or stained, making them ineligible for transcription to a database or prone to transcription error.

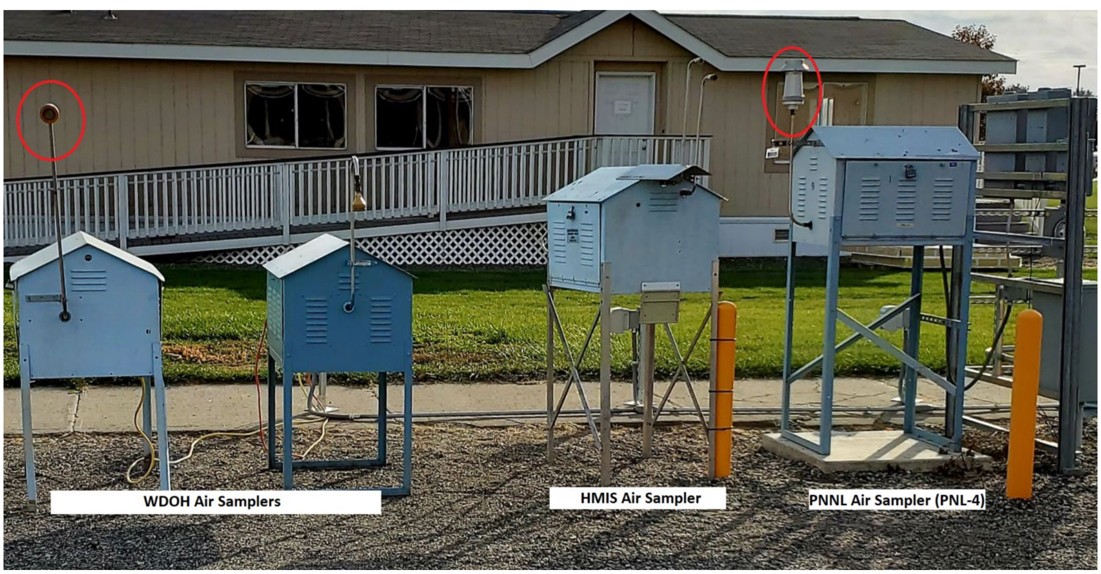

Figure 5.16. WDOH, HMIS, and PNNL Air Surveillance Stations

5.7.2 Error Assessment #7

Following the observation of two similar ambient air surveillance programs, the PNNL-Richland Campus ESP, as it pertains to sampling equipment, collection, and data management, is operating successfully. However, opportunities for improvement related to modernizing field sampling equipment and automating data entry while in the field could be beneficial. After considering the initial investment costs for equipment and software needs, operating costs, reliability of systems and ease of operation, such improvements may be a significant investment and not cost effective for the site's smaller scale ambient air surveillance program.

5.8 Question #8. What do construction staff need to know about working in the vicinity of sampling stations?

a. Who are the PNNL staff involved in architectural plans of hazards on the worksite so that sampling station locations and their hazards are represented on the plans?

b. What critical sampling operations/needs/limitations must be communicated to the construction project manager to ensure continuous and adequate ambient air samples (particulate and external dose)? Who is the ERT point of contact for the project manager?

c. For a temporary fence around existing sampling stations during the active construction phase, is an extended buffer region required between the station footprint and fence? What criteria need to be considered for the type of fence used?

d. What dust control measures will be required to maintain adequate air samples (consider particulate filter loading, dosimeter packet dustiness, solar energy collection, and panel surface longevity)? What other potential hazards exist to the ambient air sampling equipment and samples that might damage equipment or reduce the quality of the sample results?

e. If major, short-term, dust-generating events are anticipated, can construction staff request that particulate sampling equipment be turned off? If yes, how would such a process be implemented?

f. If field spraying (e.g., herbicide, water spray, hydroseeding) applications occur, how is the applicator informed to avoid spraying sampling equipment?

Action #8. Identify the planning, documents, and training needed to safely proceed with construction in the vicinity of the AC- and solar-powered sampling stations and the general process for construction workers to be informed of the hazards and limitations of work around sampling station locations.

5.8.1 Decision #8

This section is written to address the infrastructure installation phase of the north campus construction. It is presumed that the same or similar information would apply during the later building and road construction phases. Generally stated, if construction activities impact required ambient air surveillance activities, reporting or alternative/corrective actions will be necessary, as indicated in procedures or the EMP Attachment 1 (Meier 2011).

Protecting the air sampling equipment from construction activities will be addressed through the General Contractors submittals (e.g., drawings, documents, mock-ups created by the contractor). These may include applying water to control dust when disturbing soils near stations, maintaining clearances, and/or requiring spotters when operating equipment near the air stations.

Existing sampling equipment must be represented on project maps. During the planning and active construction phases, a point of communications must be established between the construction project manager and an ERT lead. The project manager must make sure the existing sampling locations are indicated on construction maps used onsite. The project manager must maintain clear and timely communications regarding schedule for dust-generating and heavy-machine activity in the vicinity of the stations, involving the construction manager and construction contractor staff, as needed. “Vicinity” for the purpose of this DQO will be considered 5-10 ft (1.5-3 m). Typical WDOH-approved dust mitigation controls applied to the likes of soils, debris, and stockpiles include water/wetting, fixatives, covers, containment enclosure, clean soil, and windscreens, as needed (e.g., WDOH 2018). Mitigation controls are applied as necessary to control airborne releases during the work evolution and at the end of daily work activities; work activities resulting in dust should be limited or ceased when sustained or predicted winds are >20 mph.

Dust generation can impact the collection of solar energy, and vigorous dirt-moving activities may damage the equipment or degrade the particulate sample results. In addition, care must be taken with soil stabilization applications (e.g., water, chemicals for dust suppression) so that sample collection equipment is not inundated.

When heavy dust or overspray onto equipment is likely, sampling may be suspended for short periods of time. The construction manager must communicate the start and end of such activities to the ERT lead. This allows scheduling of Radiation Protection Technologist (RPT) time for existing sample collection and time to deenergize sample fans or take other protective measure, as well as permitting equipment checks and maintenance prior to the timely resumption of sampling.

Ground motion by construction equipment was also considered. No vendor information is available that speaks to this. Construction vibration may adversely impact sensitive sampling equipment, especially solar units. Damage may be hidden to casual view and may only become apparent later when failure takes place. Vibrations may also cause cracks in concrete pads, degrading the longevity of the station foundation, but not be of immediate concern. Operation of compaction equipment is likely the greatest concern.

The ERT lead must assure that materials used for sampling station fencing are securely anchored so that wind damage to sampling equipment is not a concern.

Goals:

- Prevent equipment damage.
- Prevent dust suppression inundation onto sampling equipment.
- Prevent sample degradation.
- Allow for sampling equipment maintenance (e.g., dusting solar arrays, checking for damage/operations).
- Prevent excessive vehicle traffic impacting dust control in the vicinity of active sampling activities.

- Prevent excessive ground vibrations in the immediate vicinity of stations.
- Allow continuous or near-continuous quality sampling operations.

The area of excavation around the air sampling station(s) needs to be appropriately barricaded/fenced to protect sampling equipment and sampling staff. When sampling staff are required to cross any excavated areas, there must be means to do so safely.

An understanding of the time to dismantle solar-powered stations and establishing AC-powered stations is useful. Relocating solar equipment will require, among other actions, lifting and rigging support to offload. Once a service request (SR) to dismantle and relocate the solar-powered station equipment to a laydown area is approved, the time estimate to dismantle and relocate the equipment to the laydown area is approximately 1-4 weeks. Finding a secure storage area large enough to accommodate the dismantled panels, skids, and batteries may be a challenge resolved with a Building Manager or Cognizant Space Manager.

The lead time for purchasing and receiving new AC equipment is approximately 4-6 weeks. Once an SR for establishing a new pad for the AC equipment with associated cultural review and electrical planning is approved, the time estimated to set up a new AC-operated station is approximately 4-6 weeks.

5.8.2 Error Assessment #8

Clear schedule and activity communications are key. Ambient air sampling is a permit requirement for radiological operations on the PNNL-Richland Campus. Failure of communications for activities that impact sampling locations may result in impacts ranging from unacceptable particulate air sample quality to, in the most extreme case, cessation of radiological activities on Campus.

Ambient air sampling equipment must be maintained at a minimum number of locations to comply with permit requirements. The ability to perform quality sampling must be maintained. Any damage to equipment that impacts the quality of the sample must be corrected in a timely manner.

5.9 Question #9. What do sampling staff need to know about working in the vicinity of active construction?

a. Will RPTs/ERT staff need to sign in and out of the construction zone or otherwise contact construction staff to cross barricades/barriers in order to access PNL-1 or PNL-2 air sampling stations? If yes, who is to be contacted and how much advanced notice is necessary? What is the best way for ERT staff to communicate this information to RPTs?

b. What potential on-location hazards (health and safety) exist (e.g., hard hats, noise protection) to RPTs/ERT staff performing ambient air sampling activities during the construction in the north Campus? Will vehicle access to sampling sites change?

c. What preventative measures can be taken to mitigate the potential hazards to both staff and ambient air sampling equipment? Will there be personal protective equipment (use of hardhats, safety glasses, hearing protection, etc.) or other postings staff will need to follow?

d. Will PNNL staff need any additional training (such as working near heavy equipment) to access the active construction area (PNNL or non-PNNL training)?

e. What potential signs of construction-generated impacts to the sampling equipment/samples should the RPTs/ERT staff note, which might indicate damage to the equipment or reduce the quality of the sample results? What measures should RPTs/ERT staff take to rectify construction-generated impacts to sampling equipment?

Action #9: Identify the planning, documents, and training needed to continue to safely sample during construction and the general process for RPTs to be informed of the hazards and limitations of work around the construction activities.

5.9.1 Decision #9

RPTs normally would be in the north Campus twice a month. More frequent visits could be required if issues arise (e.g., dust-generating activities); alternatively, less frequent sampling might be done if the sampling station is temporarily shut down.

Ideally, RPTs should have a single point of contact to discuss access, atypical sampling issues or site conditions, and any off-normal conditions noted at the time of sample collection. The ERT sample collection coordinator will be the single point of contact for the RPTs. RPTs would not be expected to be in direct communications with construction staff. For construction-driven issues, information would ideally flow from the construction point of contact to the ERT lead, who would flow the information down to the ERT sample collection coordinator. A request to access the area shall be provided to the construction manager at least one day in advance.

RPTs are expected to review and sign the General Contractors Job Safety Analysis and obey all site access and safety postings, which may include use of reflective vests, hard hats, safety glasses, etc. No additional training is anticipated unless required by the general contractor. Site access will be coordinated through the ERT sample collection coordinator and project/construction manager at least one day in advance. On sampling days, the sampling coordinator will communicate any alterations to normal vehicle access to the RPTs. If RPTs note any equipment or sample issues outside of what may typically be found, they should call the ERT sample collection coordinator and note the issue on the COC paperwork, as appropriate.

5.9.2 Error Assessment #9

Staff responsible for ambient air sample collection are the RPTs and the ERT sample collection coordinator. Collection is done under procedure EPRP-AIR-029. Communication between the RPTs and ERT sample collection coordinator is key. During the construction period, measures already in place for maintaining communication during routine sample collection (i.e., cell phone access) will remain in practice; however, additional coordination for safe collection and effective sampling may be required (e.g., pre-job briefings).

Construction sites are busy places where heavy machinery is often used. Traffic plans and barriers separating operations from other important works are key to site safety. Uneven ground and materials lying around can present risks of trips, slips, and fall. Repetitive sounds from machinery/tools can affect hearing and may prevent workers from communicating efficiently, it is important to always be aware of your surroundings.

Sample collection occurs during normal business hours. If a failure to communicate access issues during a particular day were to occur, the RPTs would contact the sample coordinator for further direction. The RPTs may be readily able to ascertain a solution at the time, but they are routinely instructed to contact the sample coordinator to resolve issues.

5.10 Question #10. When an existing sampling location no longer meets the original acceptance criteria or is otherwise limited/impacted in its operations, what actions are necessary to address adequate surveillance?

a. Does regulatory ambient air sampling need to be accommodated during the transition to a new sampling location? For example, as a result of above and belowground construction activity at the north Campus.

b. Is any amount of downtime acceptable when transitioning from old to new sampling location? Are there circumstances that would require a sampling location to run two stations simultaneously during transition?

c. How will the type of continuous air sampling system (24-volt direct current [DC] or 120-volt AC) and design needs be determined for the new sampling location? Will the sampling equipment from the existing location be installed at the new location or will new equipment be procured, retrofitted, calibrated, etc. (consider storage of unused field equipment)?

d. Will ambient external dose monitoring (i.e., environmental dosimeters) occur at the new sampling location? Will additional dosimeters need to be procured?

Action #10a: Given the impending redesign of the north Campus, identify if sampling must continue at the existing sampling location or if sampling can be temporarily or permanently discontinued (equipment removed/repurposed elsewhere).

Action #10b: If continuous air sampling in the area is required, determine the most desirable location based on atmospheric dispersion modeling and desired criteria (e.g., available infrastructure, minimized obstructions, ease of access, secure). Identify the type of air sampling system (24 or 120 volt) best suited for the newly appointed ambient monitoring location(s) and the necessary resources, including equipment needs and list of key staff, needed for implementation.

5.10.1 Decision #10

Ambient air surveillance requires a quality sample (e.g., continuity of sampling collection, minimal construction-generated particulates in sample, minimize risk to operability of sampling equipment). Based on principals in 40 CFR Part 61, Appendix B, Method 114 for usable result completeness (Method 114, Section 4.4), the acceptance criteria established at PNNL is when the sampling system collects a sample 85% or more of the time (Meier 2011). Reestablishment of a sampling station location may be necessitated by loss of a station (e.g., vehicle collision), extended/permanent loss of access to station, or extended loss of station power. Reestablishing a station at a new location is best preplanned but may be driven by unforeseen circumstances. Preplanning allows for early coordination with facility staff in identifying any siting or construction needs as well as ability to preorder supplies and obtain calibrated equipment. If the time it took to reestablish a sampling system is no more than 15% of the overall 12-month operational frequency, sampling quality impacts likely would be minimal. Extended outages would require additional coordination. A discussion with WDOH staff indicated that a longer planned outage may be acceptable, if necessary or unavoidable, but such an event would have to be appropriately coordinated among WDOH, PNSO, and PNNL.

PNL-1 is expected to be taken offline temporarily while construction work is occurring in the immediate vicinity of this sampling station. The similar temporary interruption of service is expected in the event this station is converted to AC power when it becomes available near this location.

Relocation options for sampling stations PNL-2 and PNL-3 are discussed in Section 5.4.1.4. Continuous sampling is expected at the existing stations until the new stations are established. Current configurations indicate that the PNL-2 relocated station will initially be solar powered, with eventual transition to AC power when it becomes available nearby, when the George Washington Way realignment construction activity occurs. The relocated PNL-3 station is anticipated to be AC powered and would not be moved until such a power supply would be available at the relocated site.

Additional supplies for sampling stations (e.g., hutches, pumps) are ordered when budget and station setup timelines dictate. A temporary storage location for standby supplies has been established. New AC station configurations should ensure that enough electrical circuits are installed to power an additional sampling setup (e.g., subsequent collocated WDOH sampling). Surplus solar stations may be relocated to the PNNL-Sequim Campus.

The Environmental Information Management database configuration was considered for station identification for relocated stations. The database manages sampling Location ID (PNL-1, PNL-2, etc.) and spatial information (i.e., latitude and longitude). The team decided that for a relocated sampling station surveilling the same general sector as the location it was moved from, the Location ID will remain the same and the location record in the database will be notated with the relevant change(s) made to the sampling location. In the PNNL case, the 65% criteria are met in three "sectors:" NW (for PNL-1), N/NE (for PNL-2), and S/SSE (for PNL-3). Location IDs will be retained for relocated PNL-2 and PNL-3 stations.

5.10.2 Error Assessment #10

Particulate air sampling of Campus emissions is performed at four critical and one background locations. The established ambient air surveillance program produces quality samples from station locations. Equipment is maintained in good order and sample COC is maintained per procedure. No recommended changes are anticipated to impact these outcomes.

Current RAEL-005 permitted emissions are low enough that operational emissions would be below detection even if the sampling stations were located where CAP88-PC indicates is the most ideal site. As indicated by the CAP88-PC v4.1 X/Q values PNL-1 best samples all three PSF PIC-2 emission unit effluents for routine emissions. Based on this, extended outages of PNL-1 would most greatly impact the ambient air sampling program. PNL-2 and PNL-3 are both recommended for relocation; PNL-1 and PNL-4 will remain at their current locations.

CAP88-PC model verification for dispersion results was performed with AERMOD. Results are consistent between the two models as indicated in Appendix C. While CAP88-PC is approved for 40 CFR Part 61, Subpart H compliance determination, it uses compact meteorological data. AERMOD dispersion results use a more detailed annual meteorological dataset and are considered a more robust result in this aspect. The AEROMOD data in Appendix C corroborates the CAP88-PC results for the relocations of PNL-2 and PNL-3 in the sites proposed.

Per routine, the ERT typically maintains a pool of available equipment if equipment fails. There are processes in place to appropriately capture and report such instances (EPRP-AIR-029). The availability of spare equipment for relocated or damaged stations may impact sampling completeness. Funding availability for station relocations and power supply changes depends on resource allocations and communication to management, facilities, and construction project staff. The north campus construction schedule is fluid and extended; however, based on the proposed order of activities, sampling at PNL-1 will be impacted first and relocation of PNL-2 and PNL-3 is not deemed urgent.

5.11 Summary of DQO Conclusions

The objective of this document is to consider how north campus construction may impact successful ambient air surveillance of Campus radioactive material emissions in air effluent, and determine necessary modifications to the program from updated dispersion modeling and programmatic constraints. The PSF radiological facilities and two ambient sampling stations (PNL-1 and PNL-2) are the primary focus of this document due to proximity to the north campus construction. However, this updated assessment of all PNNL-Richland Campus continuous ambient air monitoring stations is a result of updated Campus-wide dispersion modeling.

North campus construction includes three major construction activities: 300 Area water line and north-central infrastructure installation, as well as north Campus building construction. The first of the construction activities are scheduled to occur in 2024, with some ground preparations occurring in 2023.

The DQO team recommends no relocation for PNL-1 with limited sampling operation impacts during 300 Area water line activities. Communications and coordination with construction staff are important to maintaining compliant sampling at PNL-1. Additionally, a change from solar to AC power for PNL-1 is strongly recommended as north campus development proceeds, as a measure to improve the reliability and quality of the sampling.

Relocation of both PNL-2 and PNL-3 sampling stations were determined by the DQO team to be necessary. The relocations are driven by updated dispersion modeling of current PIC-2 stack configurations and necessitated for PNL-2 only by the future building construction.

- The preferred and alternate options for a PNL-2 relocation are presented (see Section 5.4.1), with the alternate option depending on a 3410-01-S stack remodel. Using the same rationale indicated for PNL-1, a change from solar to AC power is strongly recommended for a relocated PNL-2. Communications and coordination with construction staff are important to maintaining PNL-2 compliant sampling during north campus construction and during the sampling station relocation.
- The preferred and alternate options for a PNL-3 relocation are presented (see Section 5.4.1). AC power availability would have to be created for both locations. While a relocated PNL-3 could be solar powered, AC power is strongly recommended. Communications and coordination with construction staff are important to maintaining PNL-3 compliant sampling during the sampling station relocation.

Ambient air sampling stations PNL-4 and PNL-5 (see Figure 2.1) are not impacted by construction activities or modeling results presented in this DQO.

6.0 Optimization Guidelines

PNNL currently operates five ambient air sampling stations: four on Campus and one background station (see Figure 2.1). This section briefly reviews optimizing the collection of quality ambient air sample data.

6.1 Sampling Equipment

Ambient sampling is performed for radioactive particulates and for external dose from air and soil radioactivity. Particulate sampling is conducted with 2-inch glass-fiber filter paper. The filters are routinely analyzed for gross alpha and beta activity and periodically composited for a variety of radionuclides of interest. The environmental dosimeters are changed out quarterly for routine analysis for x-ray, beta-, and gamma-radiation monitoring (Bisping 2023).

PNNL uses two types of particulate ambient air samplers: 1) a 24-V direct current solar operated system (Figure 6.1); and 2) a 120-V AC operated system (Figure 6.2). The 120-V systems have an air volume meter, flow controller, and a ¼ HP vacuum pump contained in the sampling hutch. The 24-V solar-powered system has a built-in flow controller providing automatic set point and flow control along with a digital display showing instantaneous flow rate, total sample volume, and elapsed time. For ambient air samples, flow rates through the filter head are set to collect a minimum of 856 m^3 of ambient air over a 2-week period. Sample volumes below this threshold are evaluated to determine the acceptability of the sample and whether or not to conduct any analysis on the sample. The 2-week samples are analyzed for gross alpha and gross beta and then combined into semiannual composite samples. Radionuclide analyses are performed on composite samples for each location. This is done to meet analytical detection limits and the performance requirements of the permit.

While maintaining solar-powered operations at two of the five sampling locations, AC-powered sampling stations are preferred due to greatly reduced maintenance costs and better sample quality resulting from sampling issues during days with poor air quality (e.g., ambient dust, and smoke).

Figure 6.1. Example of 24-V Solar-Powered Particulate Sampling System (PNL-2)

Figure 6.2. Example of 120-V AC-Powered Particulate Sampling System (PNL-4)

6.2 Analytical Detection Limits

Particulate ambient air samples are submitted to the analytical laboratory under contract to PNNL for all radiological analyses. Two air concentration criteria are important for compliance determination: the required detection level (RDL) and the MDA. For the purposes of this report, the RDL is the calculated detection level from idealized sampling. The minimum detectable concentration (MDC) of activity in an air sample depends on the analytical method and detector efficiency, counting time, and collected volume which may be impacted by filter loading and airflow rate control. The sample MDC is the sample-specific MDA divided by the sampled volume.

The EPA expects a site to detect the nuclide at levels where a receptor at the sampling station would be expected to incur a 1 mrem/yr dose above background (40 CFR 61.93.b.5.iii). The levels can be regulated based on air concentrations, with Table 2 of 40 CFR Part 61, Appendix E, providing a set of air concentrations that regulators indicate would result in exceeding the Subpart H limit of 10 mrem/yr dose. Therefore, a 1 mrem/yr dose would result from 10% of these Table 2 air concentrations (Table 6.1).

The Appendix E Table 2 values were based on older modeling and dosimetry. To determine the air concentrations that would result from the latest modeling and dosimetry and the use of PNNL regional modeling (e.g., precipitation rates; 100-year buildup; dose includes ingrowth of progeny), the CAP88-PC V4.1 model was used to estimate the air concentration that would result a 1 mrem/yr receptor dose (Table 6.1). Under CAP88-PC v4.1 modeling with its more current dosimetry, higher air concentrations would be permitted prior to notifications to regulators for all PNNL sampled radionuclides. As a conservative measure, PNNL will notify the state regulator when the annual average station air concentration for a radionuclide is at the lower, more health conservative level of 10% of the Appendix E Table 2 values. However, reported dose for annual compliance reporting will be based on CAP88-PC modeling with more current dosimetry and site-specific considerations.

In order to determine if the notification value is exceeded, the reported sample result must meet an MDA for the sampled volume. To determine the MDA (i.e., the minimum activity detectable in the sample) for Campus composite air samples, the Appendix E Table 2 and the CAP88-PC V4.1 “1 mrem air concentrations” were multiplied by the nominal sampled volume of 10,400 m^3. This sample volume is 85% of the ideal biweekly sample volume (1.6 ft^3/min ideal sampler flow rate* 60 min/hr * 0.0283 m^3/ft^3 * 24 hr/d * 14 d/biweekly sample * 0.85 = 776 m3/biweek), which is rounded up to one significant digit (800 m^3/biweek); then 800 m^3 is multiplied by the 13 biweekly samples in a composited semiannual sample for radionuclide-specific analyses. An 85% collection efficiency is deemed acceptable for the sampling period. While current CAP88-PC V4.1 modeling indicates the sample MDA can be greater than Appendix E Table 2-based values, the Appendix E Table 2-based values are conservative (based on older modeling).

The RDL for 1 mrem levels is identified a priori; the actual sample MDC is calculated after a sample is analyzed based on actual sampled volume. The sampled volume can vary due to filter plugging, equipment issues, power supply issues, and exact collection times. The average and maximum MDCs, for 2022 sampling at all PNNL sample stations, are indicated in Table 6.1. The maximum 2022 MDCs are all below the Appendix E Table 2 notification values (i.e., Appendix E Table 2-based 1 mrem dose value).

Table 6.1. Ambient Air Radionuclide-specific Sampling Analysis Criteria with 2022 Results.

Basis:	Regulations (RDL)	Modeled (RDL)	Analytical Results	Analytical Results	Calculated Based on Regulations and Sample Volume	Calculated Based on Modeling and Sample Volume
Analyte	Annual Average Notification Value - 10% Table 2[(a)] (pCi/m^3)	CAP88-PC V4.1 Air Concentration for a 1 mrem/yr Annual Dose (pCi/m^3)	Average Sample MDCs, 2022 (pCi/m^3)	Maximum Sample MDCs, 2022 (pCi/m^3)	Nominal MDA 10% Appendix E, Table 2-Based (pCi)	Nominal MDA CAP88-PC V4.1- Based (pCi)
Al-26	4.8E-04	2.4E-03	n/a	n/a	4.9	24
Am-241	1.9E-04	1.2E-03	2.0E-05	3.1E-05	2.0	12
Am-243	1.8E-04	1.2E-03	1.2E-05	2.1E-05	1.9	12
Cm-244[(b)]	2.6E-04[(c)]	1.6E-03[(c)]	1.3E-05	4.6E-05	2.7	17
Co-60	1.7E-03	1.6E-02	1.4E-04	1.6E-04	18	161
Cs-137	1.9E-03	1.0E-02	1.3E-04	1.7E-04	20	101
Pu-238	2.1E-04	1.1E-03	1.2E-05	2.1E-05	2.2	11
Pu-239/240[(d)]	2.0E-04	1.0E-03	1.2E-05	1.9E-05	2.1	10
Th-229	5.3E-05	6.9E-04	n/a	n/a	0.54	7.0
U-233[(e)]	7.1E-04[(c)]	1.6E-02[(c)]	2.0E-05	3.4E-05	7.4	161

(a) Table 2 of 40 CFR Part 61, Appendix E
(b) Analytical laboratory provides combined Cm-243/244 results.
(c) Cm-243/244 combined sample conservatively based on lower Cm-243 value; U-233/234 combined sample conservatively based on lower U-233 value.
(d) Analytical laboratory provides combined Pu-239/240 results.
(e) Analytical laboratory provides combined U-233/234 results.
RDL = required detection level
MDC = minimum detectable concentration (air concentration in pCi/m3)
MDA = minimum detectable activity (radioactivity level in analyzed sample in pCi)

The analytical laboratory should meet a contractual MDC to assure that samples can be detected at concentrations of regulatory significance. The contract-required RDLs (CRDLs) are based on the same level of risk (dose). The laboratory CRDL is designated as 1% of Appendix E Table 2 air concentration values (Table 6.2). These values would nominally correspond to a 0.1 mrem dose to a hypothetical sampling station receptor from the isotope, based on older dosimetry and modeling assumptions. If all sample results were at these values, CAP88-PC V4.1 modeling indicates each radionuclide-specific dose would be no more than 0.02 mrem. For reference, the nominal MDA corresponding to CRDL and nominal 10,100 m^3 sample volume (assuming 85% sampling during the sampling period) is also indicated in Table 6.2.

Table 6.2. Richland Campus Contract-RDLs for Ambient Air Samples.

Analyte	Current Semiannual CRDL (pCi/m^3)	Annual Average 40 CFR Part 61, Appendix E, Table 2 (1% Table 2)[a] (pCi/m^3)	Nominal MDA 1% Appendix E, Table 2-Based (pCi)
Am-241	1.9E-05	1.9E-05	0.20
Am-243	1.8E-05	1.8E-05	0.19
Cm-244[b]	2.6E-05	2.6E-05	0.27
Co-60	1.7E-04	1.7E-04	1.8
Cs-137	1.9E-04	1.9E-04	2.0
Pu-238	2.1E-05	2.1E-05	0.22
Pu-239/240[c]	2.0E-05	2.0E-05	0.21
U-233[d]	7.1E-05	7.1E-05	0.72

(a) Table 2 of 40 CFR Part 61, Appendix E.
(b) Analytical laboratory provides combined Cm-243/244 results. Cm-243/244 combined sample conservatively based on lower Cm-243 value.
(c) Analytical laboratory provides combined Pu-239/240 results.
(d) Analytical laboratory provides combined U-233/234 results. U-233/234 combined sample conservatively based on lower U-233 value.
CRDL = contract required detection level
MDA = minimum detectable activity

Gross alpha and gross beta/gamma samples are collected biweekly for compliance reporting. Values reported as “gross beta” are actually gross beta and gamma results but abbreviated as gross beta. The gross sampling is used as a rapid, inexpensive potential indicator of when an unknown release may have taken place. The sample result is not nuclide specific. Typically, the sample result predominantly contains natural background radionuclides rather than site-specific emissions; however, data trends can be used to screen air samples on a biweekly basis. There is no regulated MDA or MDC for gross alpha and gross beta sampling. Of relevant consideration, gross alpha and gross beta/gamma in air filters is routinely part of the analytical laboratory’s intercomparison performance testing protocol.

CRDLs are specified for gross alpha and gross beta analyses. The values in the current contract are listed in Table 6.3; these values are based on CAP88-PC V4.0 modeling in the prior DQO. All CRDLs may be revised as necessary as a result of DQO revisions or during annual contract renewals, with the basis for the updates documented. The nominal MDA resulting from these values and the biweekly nominal sample volume of 800 m^3 is indicated in Table 6.3, as well as the range of reported MDCs from 2022 Campus air samples.

In order to provide a uniform technical basis for the gross alpha and gross beta CRDLs, the following technical approach is adopted.

a. The site-specific alpha emitter with the lowest air concentration limit using current modeling (i.e., CAP88-PC V4.1) is determined. From Table 6.1, this would be 239/240Pu. 239Pu is commonly used as the nuclide to represent a generic alpha emitter (e.g., see Snyder et al. 2023).

b. The annual air concentration for this limiting nuclide that results in a 1 mrem annual dose is determined. From Table 6.1, this would be 1.0E-3 pCi/m^3. In order to meet this detection level, the analytical laboratory would evaluate samples (e.g., consider counting time) so that a lower MDC would be expected. In fact, currently, routine MDCs are in the range of 3E-04 pCi/m^3 (Table 6.3).

c. Gross alpha samples are 2-week samples of a nominal 800 m^3. Gross alpha samples contain site-specific and natural radioactive particulates. Considering that dose limits are regulated on an annual basis, slightly elevated emissions could occur for a portion of the year (multiple 2-week periods) if lower emissions occur for the majority of the year. In addition, there is a delay time from sample collection to the receipt of sample results. Therefore, the 1 mrem air concentration level for CRDLs in biweekly gross alpha samples would be acceptable. In addition, gross alpha results at this CRDL over a 10 biweek period (40% of the year) may drive the need for an early composite analysis, if no other cause for the elevated results is known (e.g., an offsite gross alpha release event).

A similar technical basis is applied for the gross beta CRDL.

a. The site-specific beta/gamma emitter with the lowest air concentration limit using current modeling (i.e., CAP88-PC V4.1) is determined. From Table 6.1, this would be Co-60, the only beta/gamma emitter currently requiring ambient sampling. However, Cs-137 is commonly used as the nuclide to represent a generic gross beta emitter because it has a greater dose impact from CAP88-PC V4 modeling (e.g., see Snyder et al. 2023).

b. The annual air concentration for Cs-137 that results in a 1 mrem annual dose from CAP88-PC V4.1 modeling is determined (1.0E-2 pCi/m3). This value updates the 1.1E-2 pCi/m^3 value from the prior DQO (see Table 6.1 of DQO Rev2). This Cs-137 value is more limiting than the Co-60 value from Table 6.1 (1.6E-2 pCi/m^3). In order to meet the Cs-137 detection level, the analytical laboratory would evaluate samples (e.g., consider counting time) so a lower MDC would be expected. In fact, currently, routine MDCs are in the range of 5E-04 pCi/m^3 (Table 6.3). During the next contract update, an update to the CRDL for gross beta is recommended.

c. Gross beta samples are 2-week samples of a nominal 800 m^3. Gross beta samples contain site-specific and predominantly natural radioactive particulates. Current gross beta results average 1.6E-2 pCi/m^3 in Campus and background samples, which is above the 1.1E-2 pCi/m^3 CRDL that is based on a nuclide-specific 1 mrem/yr Cs-137-based level. Radionuclide-specific analyses cover a full suite of beta and gamma emitters[5] beyond the RAEL-required Co-60. Due to the large contributions of non-Campus emissions to gross beta/gamma results, gross beta analyses would not be particularly informative for Campus emissions monitoring at current operational levels but could be indicative of offsite sources.

[5] Beryllium-7, cobalt-60, cesium-134, cesium-137, europium-152, europium-154, europium-155, potassium-40, ruthenium-106, and antimony-125.

Table 6.3. PNNL-Richland Campus Gross Alpha and Gross Beta Biweekly Sampling.

Analyte	2023 CRDL[(a)] (pCi/m^3)	2022 Laboratory Reported MDCs for Biweekly sampling (min-max pCi/m^3)	Nominal MDA[(b)] Proposed Contract-required RDL (pCi)
Gross alpha	1.0E-03	1.2E-04 – 9.8E-04	0.8
Gross beta	1.1E-02	2.1E-04 – 7.6E-04	8.8

(a) CY2023 contract with the analytical laboratory.
(b) Based on nominal 800 m^3 biweekly sample volume.
CRDL = contract-required detection level
MDC = minimum detectable concentration
MDA = minimum detectable activity

7.0 References

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Appendix A – Meteorological Data

The tables below contain Joint Frequency Distributions of atmospheric stability, wind speed, and transport direction for the 300 Area at 9.1 m (30 ft) above ground level, Hanford Site, Washington. The first table is based on 1983-2006 data from the 300 Area instrumented tower (Duncan (ed.) et al. 2007) and was used in the original and Revision 1 DQO reports (Barnett et al. 2010, 2012). The second table is data from 2004-2013 used in DQO revision 2 (Snyder et al. 2017). The final table is the most recent data from 2012-2021 used in this DQO revision.

Table A.1. 1983-2006 Meteorology

Average Wind Speed	Atmospheric Stability Class	1983-2006 – Percentage of Time Wind Blows in the 300 Area toward the Direction Indicated															
	9.1 m	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s (2 mph)	A	0.07	0.07	0.09	0.11	0.11	0.11	0.12	0.10	0.07	0.05	0.05	0.04	0.04	0.04	0.06	0.07
	B	0.05	0.04	0.04	0.04	0.05	0.05	0.06	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.05
	C	0.04	0.03	0.04	0.04	0.04	0.05	0.06	0.05	0.04	0.04	0.02	0.02	0.03	0.02	0.03	0.05
	D	0.33	0.20	0.17	0.18	0.21	0.34	0.38	0.37	0.34	0.32	0.29	0.26	0.28	0.28	0.40	0.45
	E	0.35	0.20	0.14	0.13	0.20	0.35	0.50	0.54	0.55	0.46	0.43	0.39	0.42	0.46	0.54	0.49
	F	0.28	0.17	0.12	0.09	0.16	0.28	0.49	0.53	0.49	0.37	0.35	0.30	0.31	0.38	0.50	0.46
	G	0.16	0.08	0.05	0.05	0.07	0.11	0.19	0.21	0.20	0.14	0.15	0.12	0.13	0.17	0.24	0.22
2.65 m/s (6 mph)	A	0.24	0.32	0.41	0.50	0.67	0.67	0.62	0.30	0.27	0.34	0.29	0.15	0.08	0.05	0.08	0.17
	B	0.13	0.14	0.12	0.14	0.19	0.21	0.27	0.15	0.11	0.13	0.12	0.06	0.03	0.02	0.04	0.12
	C	0.12	0.11	0.10	0.11	0.14	0.18	0.21	0.11	0.10	0.11	0.09	0.04	0.02	0.02	0.06	0.11
	D	0.96	0.49	0.31	0.31	0.51	0.96	1.31	0.69	0.63	0.64	0.51	0.33	0.22	0.23	0.57	1.10
	E	1.09	0.34	0.08	0.09	0.23	1.13	1.81	1.07	1.01	0.75	0.59	0.42	0.35	0.39	0.69	1.23
	F	0.66	0.16	0.03	0.02	0.09	1.01	1.98	1.02	0.69	0.43	0.24	0.13	0.13	0.17	0.43	0.82
	G	0.27	0.06	0.01	0.01	0.03	0.33	0.79	0.38	0.21	0.11	0.06	0.03	0.03	0.05	0.19	0.36
4.7 m/s (10.5 mph)	A	0.28	0.57	0.42	0.11	0.15	0.30	0.34	0.15	0.25	0.62	0.66	0.29	0.08	0.06	0.09	0.15
	B	0.12	0.16	0.08	0.03	0.03	0.08	0.10	0.05	0.09	0.21	0.22	0.11	0.04	0.02	0.04	0.09
	C	0.11	0.11	0.06	0.03	0.02	0.05	0.08	0.04	0.07	0.16	0.18	0.08	0.02	0.01	0.04	0.08
	D	0.74	0.41	0.20	0.07	0.09	0.22	0.39	0.24	0.42	0.88	0.88	0.48	0.18	0.14	0.44	0.87
	E	1.07	0.34	0.05	0.03	0.04	0.25	0.34	0.24	0.51	0.85	0.91	0.48	0.21	0.17	0.38	0.79
	F	0.74	0.22	0.02	0.02	0.02	0.26	0.30	0.11	0.25	0.38	0.34	0.14	0.03	0.02	0.07	0.40
	G	0.36	0.10	0	0	0.01	0.14	0.18	0.04	0.07	0.10	0.08	0.03	0.01	0	0.02	0.16
7.2 m/s (16 mph)	A	0.12	0.19	0.05	0	0	0	0.02	0.01	0.06	0.34	0.56	0.41	0.11	0.05	0.10	0.08
	B	0.04	0.04	0.01	0	0	0	0.01	0	0.02	0.11	0.16	0.10	0.03	0.01	0.03	0.05
	C	0.03	0.02	0.01	0	0	0	0.01	0	0.02	0.09	0.14	0.08	0.02	0.01	0.03	0.04
	D	0.16	0.10	0.03	0.01	0	0.01	0.04	0.04	0.14	0.49	0.69	0.38	0.15	0.08	0.39	0.42
	E	0.13	0.07	0.03	0.02	0.01	0.01	0.04	0.04	0.10	0.36	0.64	0.26	0.09	0.05	0.29	0.29
	F	0.06	0.03	0.02	0.02	0	0	0	0.01	0.02	0.08	0.17	0.05	0.01	0	0.01	0.05
	G	0.03	0.02	0	0	0	0	0	0	0.01	0.04	0.05	0.01	0	0	0	0.01
9.8 m/s (22 mph)	A	0.01	0.02	0	0	0	0	0	0	0.01	0.09	0.16	0.17	0.07	0.02	0.04	0.02
	B	0.01	0.01	0	0	0	0	0	0	0	0.02	0.05	0.04	0.02	0	0.01	0.01
	C	0	0	0	0	0	0	0	0	0	0.02	0.04	0.04	0.01	0	0.02	0.01
	D	0.02	0.02	0.01	0	0	0	0	0.01	0.03	0.15	0.29	0.14	0.07	0.02	0.16	0.08
	E	0.01	0.04	0.02	0.01	0	0	0	0.01	0.02	0.11	0.28	0.06	0.02	0.01	0.08	0.04
	F	0	0	0	0	0	0	0	0	0	0.01	0.04	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0.01	0.02	0	0	0	0	0

Table A.1 (cont.)

Average Wind Speed	Atmospheric Stability Class 9.1 m	1983-2006 – Percentage of Time Wind Blows in the 300 Area toward the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
12.7 m/s (29 mph)	A	0	0	0	0	0	0	0	0	0	0.01	0.05	0.04	0.02	0	0.01	0
	B	0	0	0	0	0	0	0	0	0	0	0.02	0.01	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0.02	0.01	0	0	0	0
	D	0.01	0.01	0	0	0	0	0	0	0	0.05	0.17	0.04	0.02	0.01	0.03	0.01
	E	0	0.01	0	0	0	0	0	0	0	0.04	0.11	0.01	0.01	0	0.02	0
	F	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
15.6 m/s (35 mph)	A	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0	0.01	0.04	0.01	0.01	0	0	0
	E	0	0	0	0	0	0	0	0	0	0.01	0.02	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 m/s (43 mph)	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.2. 2004-2013 Meteorology

Average Wind Speed	Atmospheric Stability Class 9.1 m	2004-2013 – Percentage of Time Wind Blows in the 300 Area Toward the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s (2 mph)	A	0.04	0.04	0.05	0.04	0.04	0.05	0.05	0.05	0.03	0.04	0.02	0.03	0.03	0.03	0.03	0.02
	B	0.01	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.01
	C	0.05	0.05	0.07	0.07	0.07	0.08	0.07	0.08	0.04	0.03	0.03	0.02	0.02	0.02	0.03	0.04
	D	0.26	0.20	0.18	0.19	0.20	0.29	0.37	0.31	0.28	0.27	0.21	0.20	0.24	0.28	0.34	0.39
	E	0.37	0.22	0.18	0.17	0.22	0.41	0.58	0.59	0.61	0.49	0.44	0.41	0.42	0.51	0.62	0.54
	F	0.35	0.19	0.14	0.12	0.17	0.31	0.56	0.55	0.49	0.36	0.34	0.34	0.35	0.52	0.62	0.54
	G	0.16	0.08	0.06	0.06	0.09	0.13	0.21	0.21	0.19	0.13	0.11	0.10	0.12	0.17	0.24	0.24
2.65 m/s (6 mph)	A	0.13	0.15	0.30	0.44	0.51	0.61	0.50	0.27	0.24	0.32	0.25	0.10	0.07	0.04	0.06	0.09
	B	0.08	0.10	0.20	0.30	0.34	0.34	0.31	0.17	0.13	0.17	0.13	0.05	0.02	0.02	0.03	0.05
	C	0.12	0.14	0.19	0.16	0.20	0.27	0.34	0.19	0.15	0.19	0.14	0.05	0.03	0.02	0.05	0.09
	D	0.68	0.39	0.26	0.19	0.32	0.77	1.26	0.61	0.57	0.56	0.42	0.22	0.16	0.20	0.63	0.92
	E	0.94	0.29	0.08	0.07	0.18	1.06	1.94	1.10	1.00	0.81	0.60	0.46	0.37	0.41	0.90	1.39
	F	0.59	0.15	0.04	0.02	0.07	0.99	2.49	1.17	0.78	0.45	0.25	0.16	0.12	0.21	0.59	0.95
	G	0.22	0.05	0.01	0	0.03	0.31	0.92	0.41	0.22	0.11	0.05	0.03	0.03	0.06	0.21	0.39
4.7 m/s (10.5 mph)	A	0.15	0.30	0.48	0.13	0.15	0.35	0.41	0.15	0.27	0.60	0.60	0.19	0.07	0.07	0.06	0.11
	B	0.11	0.17	0.15	0.06	0.07	0.12	0.18	0.07	0.13	0.31	0.25	0.07	0.02	0.02	0.02	0.05
	C	0.13	0.14	0.07	0.03	0.04	0.06	0.11	0.07	0.13	0.30	0.28	0.10	0.02	0.02	0.03	0.10
	D	0.46	0.26	0.10	0.03	0.06	0.19	0.36	0.18	0.40	0.82	0.81	0.37	0.16	0.13	0.38	0.69
	E	1.02	0.24	0.03	0.02	0.02	0.21	0.41	0.27	0.57	0.96	1.05	0.52	0.22	0.22	0.45	1.00
	F	0.65	0.16	0.01	0.01	0.02	0.28	0.41	0.12	0.30	0.44	0.38	0.15	0.03	0.02	0.10	0.49
	G	0.29	0.07	0	0	0	0.13	0.25	0.03	0.07	0.11	0.09	0.01	0	0	0.03	0.20

Table A.2 (cont.)

Average Wind Speed	Atmospheric Stability Class 9.1 m	2004-2013 – Percentage of Time Wind Blows in the 300 Area Toward the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
7.2 m/s (16 mph)	A	0.09	0.14	0.08	0	0.01	0.01	0.02	0.01	0.08	0.28	0.54	0.30	0.07	0.08	0.10	0.04
	B	0.03	0.04	0.01	0	0	0.01	0.01	0	0.02	0.10	0.19	0.09	0.02	0.01	0.04	0.02
	C	0.05	0.02	0.01	0	0	0	0.01	0	0.03	0.14	0.19	0.09	0.03	0.02	0.02	0.05
	D	0.13	0.06	0.01	0	0	0.01	0.03	0.03	0.11	0.47	0.62	0.32	0.14	0.08	0.32	0.34
	E	0.13	0.05	0.02	0.02	0	0.01	0.06	0.07	0.15	0.53	0.72	0.28	0.11	0.08	0.37	0.28
	F	0.04	0.01	0.02	0.02	0	0	0	0	0.03	0.11	0.21	0.04	0.01	0	0.03	0.06
	G	0.02	0	0.01	0	0	0	0	0	0.01	0.04	0.05	0.01	0	0	0	0.01
9.8 m/s (22 mph)	A	0.01	0.02	0.01	0	0	0	0	0	0.01	0.08	0.14	0.15	0.04	0.04	0.05	0.01
	B	0	0	0	0	0	0	0	0	0	0.02	0.07	0.04	0.01	0	0.01	0.01
	C	0	0.01	0	0	0	0	0	0	0	0.03	0.09	0.05	0.02	0.01	0.02	0.01
	D	0.02	0.02	0.01	0	0	0	0	0	0.03	0.14	0.30	0.14	0.06	0.03	0.16	0.07
	E	0.02	0.03	0.03	0.01	0	0	0	0.03	0.03	0.21	0.38	0.07	0.03	0.02	0.10	0.03
	F	0	0	0.01	0	0	0	0	0	0	0.01	0.05	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0.01	0.02	0	0	0	0	0
12.7 m/s (29 mph)	A	0	0	0	0	0	0	0	0	0	0.01	0.03	0.05	0.01	0	0.01	0
	B	0	0	0	0	0	0	0	0	0	0	0.03	0.01	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0.01	0.02	0.01	0.01	0	0	0
	D	0	0.01	0	0	0	0	0	0	0	0.04	0.15	0.04	0.02	0.01	0.04	0
	E	0	0.02	0.02	0	0	0	0	0	0.01	0.07	0.15	0.03	0	0	0.03	0
	F	0	0	0	0	0	0	0	0	0	0.01	0.01	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.6 m/s (35 mph)	A	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0.01	0	0	0	0	0	0	0	0	0.03	0.01	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0.01	0.02	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 m/s (43 mph)	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.3. 2012-2021 Meteorology

Average Wind Speed	Atmospheric Stability Class 9.1 m	2012-2021 – Percentage of Time Wind Blows in the 300 Area Toward the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s (2 mph)	A	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.03
	B	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
	C	0.03	0.04	0.07	0.08	0.07	0.07	0.08	0.06	0.04	0.03	0.03	0.02	0.01	0.01	0.02	0.03
	D	0.33	0.23	0.20	0.21	0.28	0.37	0.47	0.34	0.29	0.23	0.19	0.21	0.25	0.29	0.39	0.43
	E	0.40	0.22	0.17	0.17	0.23	0.39	0.59	0.56	0.54	0.45	0.43	0.40	0.43	0.52	0.59	0.62
	F	0.37	0.22	0.20	0.14	0.18	0.32	0.53	0.52	0.46	0.32	0.28	0.29	0.34	0.44	0.60	0.55
	G	0.18	0.09	0.07	0.06	0.10	0.15	0.22	0.21	0.15	0.11	0.09	0.09	0.12	0.16	0.25	0.24

Table A.3 (cont.)

Average Wind Speed	Atmospheric Stability Class 9.1 m	2012-2021 – Percentage of Time Wind Blows in the 300 Area Toward the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
2.65 m/s (6 mph)	A	0.08	0.12	0.19	0.26	0.28	0.30	0.29	0.14	0.14	0.19	0.15	0.06	0.05	0.03	0.03	0.05
	B	0.06	0.09	0.19	0.34	0.33	0.36	0.30	0.15	0.12	0.16	0.14	0.05	0.02	0.01	0.02	0.04
	C	0.12	0.15	0.24	0.31	0.30	0.45	0.51	0.22	0.20	0.23	0.15	0.05	0.03	0.03	0.04	0.07
	D	0.89	0.44	0.31	0.28	0.41	1.05	1.44	0.62	0.54	0.49	0.38	0.24	0.16	0.19	0.65	1.10
	E	1.14	0.30	0.09	0.08	0.19	1.19	2.02	0.97	0.96	0.80	0.62	0.41	0.38	0.44	0.84	1.38
	F	0.70	0.14	0.03	0.02	0.09	1.06	2.35	1.03	0.66	0.37	0.23	0.13	0.12	0.18	0.50	0.93
	G	0.26	0.05	0.01	0.01	0.02	0.28	0.81	0.37	0.19	0.09	0.04	0.03	0.03	0.07	0.18	0.34
4.7 m/s (10.5 mph)	A	0.13	0.29	0.33	0.08	0.09	0.23	0.27	0.12	0.14	0.39	0.42	0.16	0.05	0.04	0.04	0.06
	B	0.10	0.28	0.22	0.09	0.09	0.25	0.23	0.11	0.15	0.36	0.27	0.09	0.02	0.02	0.02	0.05
	C	0.15	0.21	0.12	0.08	0.07	0.15	0.22	0.10	0.13	0.41	0.34	0.11	0.03	0.02	0.03	0.06
	D	0.61	0.28	0.06	0.05	0.05	0.24	0.40	0.18	0.41	0.78	0.75	0.34	0.15	0.14	0.38	0.77
	E	1.12	0.21	0.04	0.03	0.01	0.25	0.40	0.25	0.55	0.93	1.00	0.48	0.21	0.23	0.48	0.84
	F	0.70	0.11	0.01	0.01	0.01	0.34	0.42	0.09	0.24	0.45	0.33	0.16	0.04	0.03	0.09	0.36
	G	0.34	0.05	0	0	0	0.16	0.24	0.04	0.08	0.12	0.09	0.02	0	0	0.02	0.14
7.2 m/s (16 mph)	A	0.11	0.22	0.08	0.01	0	0	0.01	0.01	0.04	0.23	0.50	0.26	0.05	0.04	0.08	0.06
	B	0.07	0.06	0.01	0	0	0	0.01	0.01	0.04	0.16	0.24	0.10	0.03	0.01	0.02	0.03
	C	0.06	0.04	0.01	0	0	0	0.01	0	0.03	0.19	0.24	0.11	0.03	0.02	0.03	0.05
	D	0.23	0.08	0.01	0	0	0.01	0.03	0.02	0.11	0.50	0.60	0.31	0.15	0.10	0.36	0.39
	E	0.24	0.06	0.04	0.02	0	0.01	0.04	0.05	0.13	0.55	0.75	0.26	0.10	0.05	0.35	0.38
	F	0.07	0.01	0.02	0.01	0	0	0	0.01	0.03	0.12	0.18	0.04	0	0	0.02	0.07
	G	0.02	0	0.01	0	0	0	0	0	0.01	0.04	0.06	0.01	0	0	0	0
9.8 m/s (22 mph)	A	0.02	0.03	0.01	0	0	0	0	0	0.01	0.07	0.15	0.14	0.04	0.02	0.05	0.01
	B	0.01	0.01	0	0	0	0	0	0	0	0.04	0.07	0.07	0.03	0	0.01	0.01
	C	0.01	0	0	0	0	0	0	0	0	0.04	0.08	0.04	0.02	0.01	0.02	0.01
	D	0.05	0.03	0.01	0	0	0	0	0	0.02	0.14	0.25	0.14	0.07	0.03	0.19	0.13
	E	0.03	0.04	0.02	0	0	0	0.01	0.03	0.04	0.21	0.36	0.08	0.02	0.01	0.12	0.07
	F	0	0	0	0	0	0	0	0	0	0.02	0.04	0.01	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0.01	0.02	0	0	0	0	0
12.7 m/s (29 mph)	A	0	0	0	0	0	0	0	0	0	0.01	0.04	0.04	0.02	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0.03	0.01	0.01	0	0.01	0
	C	0	0	0	0	0	0	0	0	0	0.01	0.03	0.01	0.01	0	0.01	0
	D	0.01	0.01	0	0	0	0	0	0	0	0.04	0.12	0.04	0.01	0.01	0.05	0.03
	E	0.01	0.02	0.01	0	0	0	0	0.01	0.01	0.05	0.17	0.02	0	0	0.02	0.01
	F	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
15.6 m/s (35 mph)	A	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0.01	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0.01
	E	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 m/s (43 mph)	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix B – Chi-over-Q Tables

The X/Q tables listed here use 2012-2021 average meteorology, current stack configurations, and are modeled using CAP88-PC V4.1.1. Values reflect a unit emission of the representative particulate, Pu-239.

Table B.1. Chi/Q (sec/m^3) for 3410 Building Stack Parameters—Effective Stack Height with Buoyant and Momentum Plume Rise

Direction	100	200	300	400	500	600	700	800	900	1000	1500	2000	5000	10000
N	3.80E-07	5.49E-07	6.18E-07	7.15E-07	8.04E-07	8.49E-07	8.53E-07	8.32E-07	8.00E-07	7.63E-07	5.66E-07	4.35E-07	1.51E-07	6.33E-08
NNE	7.29E-07	9.64E-07	9.43E-07	9.62E-07	9.95E-07	9.99E-07	9.72E-07	9.26E-07	8.73E-07	8.19E-07	5.76E-07	4.29E-07	1.42E-07	5.86E-08
NE	7.93E-07	9.41E-07	8.82E-07	8.91E-07	9.24E-07	9.33E-07	9.11E-07	8.69E-07	8.19E-07	7.67E-07	5.36E-07	3.96E-07	1.29E-07	5.30E-08
ENE	3.94E-07	4.47E-07	4.56E-07	5.14E-07	5.72E-07	6.00E-07	5.99E-07	5.81E-07	5.54E-07	5.24E-07	3.75E-07	2.82E-07	9.37E-08	3.82E-08
E	2.06E-07	2.26E-07	2.76E-07	3.66E-07	4.44E-07	4.88E-07	5.01E-07	4.93E-07	4.77E-07	4.56E-07	3.37E-07	2.57E-07	8.72E-08	3.55E-08
ESE	1.57E-07	1.76E-07	2.54E-07	3.72E-07	4.73E-07	5.32E-07	5.53E-07	5.51E-07	5.37E-07	5.17E-07	3.90E-07	3.01E-07	1.05E-07	4.30E-08
SE	1.83E-07	2.37E-07	4.13E-07	6.25E-07	7.83E-07	8.64E-07	8.86E-07	8.73E-07	8.45E-07	8.10E-07	6.05E-07	4.65E-07	1.63E-07	6.83E-08
SSE	2.39E-07	3.34E-07	5.78E-07	8.60E-07	1.06E-06	1.17E-06	1.19E-06	1.16E-06	1.12E-06	1.07E-06	7.89E-07	6.02E-07	2.09E-07	8.83E-08
S	3.51E-07	4.60E-07	6.04E-07	7.78E-07	9.07E-07	9.67E-07	9.71E-07	9.45E-07	9.05E-07	8.61E-07	6.30E-07	4.80E-07	1.67E-07	7.15E-08
SSW	5.73E-07	6.96E-07	6.58E-07	6.44E-07	6.27E-07	5.98E-07	5.58E-07	5.16E-07	4.76E-07	4.40E-07	2.99E-07	2.20E-07	7.11E-08	2.91E-08
SW	6.12E-07	7.71E-07	6.89E-07	6.13E-07	5.51E-07	4.94E-07	4.43E-07	3.97E-07	3.59E-07	3.26E-07	2.15E-07	1.55E-07	4.86E-08	1.94E-08
WSW	4.98E-07	7.67E-07	7.19E-07	6.43E-07	5.74E-07	5.12E-07	4.56E-07	4.06E-07	3.64E-07	3.27E-07	2.08E-07	1.47E-07	4.35E-08	1.70E-08
W	5.57E-07	7.95E-07	7.61E-07	7.15E-07	6.67E-07	6.14E-07	5.60E-07	5.07E-07	4.60E-07	4.19E-07	2.73E-07	1.96E-07	5.99E-08	2.39E-08
WNW	6.81E-07	1.01E-06	1.05E-06	1.08E-06	1.10E-06	1.08E-06	1.03E-06	9.69E-07	9.09E-07	8.52E-07	6.06E-07	4.57E-07	1.56E-07	6.57E-08
NW	6.87E-07	1.04E-06	1.18E-06	1.31E-06	1.41E-06	1.44E-06	1.41E-06	1.36E-06	1.30E-06	1.23E-06	9.23E-07	7.17E-07	2.58E-07	1.12E-07
NNW	3.86E-07	5.71E-07	6.50E-07	7.44E-07	8.24E-07	8.61E-07	8.60E-07	8.37E-07	8.06E-07	7.73E-07	5.84E-07	4.55E-07	1.64E-07	6.99E-08

Table B.2. Chi/Q (sec/m3) for 3420 Building Stack Parameters—Effective Stack Height with Buoyant and Momentum Plume Rise

Direction	100	200	300	400	500	600	700	800	900	1000	1500	2000	5000	10000
N	5.64E-08	1.96E-07	2.18E-07	2.20E-07	2.30E-07	2.50E-07	2.74E-07	2.97E-07	3.14E-07	3.24E-07	2.85E-07	2.42E-07	1.07E-07	4.91E-08
NNE	1.10E-07	3.68E-07	3.90E-07	3.68E-07	3.54E-07	3.53E-07	3.62E-07	3.72E-07	3.78E-07	3.79E-07	3.14E-07	2.58E-07	1.05E-07	4.69E-08
NE	1.23E-07	3.87E-07	3.84E-07	3.50E-07	3.30E-07	3.27E-07	3.35E-07	3.45E-07	3.52E-07	3.54E-07	2.95E-07	2.42E-07	9.72E-08	4.31E-08
ENE	6.21E-08	1.88E-07	1.81E-07	1.68E-07	1.69E-07	1.80E-07	1.96E-07	2.11E-07	2.22E-07	2.28E-07	1.99E-07	1.66E-07	6.94E-08	3.09E-08
E	3.29E-08	9.62E-08	8.93E-08	8.79E-08	1.00E-07	1.20E-07	1.42E-07	1.62E-07	1.77E-07	1.86E-07	1.70E-07	1.45E-07	6.33E-08	2.83E-08
ESE	2.53E-08	7.23E-08	6.78E-08	7.24E-08	9.16E-08	1.18E-07	1.47E-07	1.72E-07	1.91E-07	2.04E-07	1.90E-07	1.65E-07	7.44E-08	3.37E-08
SE	2.93E-08	8.62E-08	8.74E-08	1.06E-07	1.48E-07	1.98E-07	2.45E-07	2.85E-07	3.13E-07	3.30E-07	3.02E-07	2.59E-07	1.15E-07	5.26E-08
SSE	3.77E-08	1.15E-07	1.23E-07	1.51E-07	2.08E-07	2.74E-07	3.37E-07	3.87E-07	4.23E-07	4.45E-07	4.02E-07	3.42E-07	1.49E-07	6.79E-08
S	5.49E-08	1.70E-07	1.78E-07	1.90E-07	2.21E-07	2.61E-07	3.00E-07	3.33E-07	3.56E-07	3.69E-07	3.25E-07	2.74E-07	1.19E-07	5.43E-08
SSW	8.82E-08	2.82E-07	2.83E-07	2.60E-07	2.46E-07	2.40E-07	2.38E-07	2.36E-07	2.32E-07	2.26E-07	1.74E-07	1.37E-07	5.29E-08	2.32E-08
SW	9.36E-08	3.04E-07	3.15E-07	2.87E-07	2.60E-07	2.40E-07	2.24E-07	2.10E-07	1.98E-07	1.86E-07	1.32E-07	1.00E-07	3.66E-08	1.57E-08
WSW	7.10E-08	2.68E-07	3.11E-07	2.97E-07	2.73E-07	2.52E-07	2.35E-07	2.20E-07	2.06E-07	1.93E-07	1.35E-07	1.00E-07	3.42E-08	1.41E-08
W	8.16E-08	2.91E-07	3.22E-07	3.05E-07	2.87E-07	2.73E-07	2.63E-07	2.53E-07	2.43E-07	2.32E-07	1.70E-07	1.30E-07	4.62E-08	1.94E-08
WNW	9.92E-08	3.58E-07	4.05E-07	3.98E-07	3.94E-07	3.98E-07	4.05E-07	4.11E-07	4.12E-07	4.08E-07	3.29E-07	2.67E-07	1.11E-07	5.04E-08
NW	1.02E-07	3.56E-07	4.10E-07	4.22E-07	4.40E-07	4.68E-07	4.98E-07	5.24E-07	5.40E-07	5.46E-07	4.63E-07	3.91E-07	1.76E-07	8.25E-08
NNW	5.76E-08	1.99E-07	2.26E-07	2.31E-07	2.42E-07	2.62E-07	2.84E-07	3.05E-07	3.20E-07	3.28E-07	2.87E-07	2.45E-07	1.12E-07	5.22E-08

Table B.3. Chi/Q (sec/m3) for 3430 Building Stack Parameters—Effective Stack Height with Buoyant and Momentum Plume Rise

Direction	100	200	300	400	500	600	700	800	900	1000	1500	2000	5000	10000
N	8.71E-08	2.37E-07	2.57E-07	2.64E-07	2.84E-07	3.13E-07	3.44E-07	3.68E-07	3.82E-07	3.87E-07	3.27E-07	2.73E-07	1.16E-07	5.17E-08
NNE	1.70E-07	4.43E-07	4.52E-07	4.28E-07	4.19E-07	4.25E-07	4.37E-07	4.47E-07	4.50E-07	4.46E-07	3.56E-07	2.86E-07	1.12E-07	4.91E-08
NE	1.90E-07	4.59E-07	4.40E-07	4.03E-07	3.89E-07	3.93E-07	4.05E-07	4.16E-07	4.20E-07	4.17E-07	3.34E-07	2.68E-07	1.03E-07	4.50E-08
ENE	9.56E-08	2.22E-07	2.07E-07	1.98E-07	2.06E-07	2.25E-07	2.45E-07	2.61E-07	2.70E-07	2.73E-07	2.27E-07	1.85E-07	7.41E-08	3.23E-08
E	5.07E-08	1.12E-07	1.03E-07	1.09E-07	1.30E-07	1.58E-07	1.85E-07	2.06E-07	2.19E-07	2.26E-07	1.96E-07	1.64E-07	6.79E-08	2.97E-08
ESE	3.89E-08	8.43E-08	7.96E-08	9.35E-08	1.24E-07	1.60E-07	1.94E-07	2.21E-07	2.39E-07	2.49E-07	2.20E-07	1.87E-07	8.01E-08	3.54E-08
SE	4.51E-08	1.02E-07	1.06E-07	1.44E-07	2.04E-07	2.68E-07	3.23E-07	3.64E-07	3.88E-07	4.00E-07	3.48E-07	2.92E-07	1.24E-07	5.54E-08
SSE	5.81E-08	1.37E-07	1.51E-07	2.03E-07	2.86E-07	3.70E-07	4.41E-07	4.93E-07	5.23E-07	5.37E-07	4.62E-07	3.84E-07	1.60E-07	7.15E-08
S	8.45E-08	2.03E-07	2.12E-07	2.38E-07	2.85E-07	3.38E-07	3.83E-07	4.16E-07	4.35E-07	4.41E-07	3.72E-07	3.08E-07	1.28E-07	5.72E-08
SSW	1.36E-07	3.35E-07	3.25E-07	3.00E-07	2.89E-07	2.84E-07	2.82E-07	2.77E-07	2.69E-07	2.59E-07	1.94E-07	1.51E-07	5.63E-08	2.42E-08
SW	1.44E-07	3.64E-07	3.62E-07	3.27E-07	2.97E-07	2.74E-07	2.55E-07	2.38E-07	2.23E-07	2.08E-07	1.45E-07	1.09E-07	3.88E-08	1.64E-08
WSW	1.10E-07	3.29E-07	3.63E-07	3.40E-07	3.12E-07	2.88E-07	2.67E-07	2.48E-07	2.31E-07	2.15E-07	1.47E-07	1.08E-07	3.59E-08	1.46E-08
W	1.26E-07	3.54E-07	3.74E-07	3.52E-07	3.32E-07	3.18E-07	3.05E-07	2.91E-07	2.77E-07	2.62E-07	1.87E-07	1.41E-07	4.88E-08	2.01E-08
WNW	1.53E-07	4.37E-07	4.75E-07	4.68E-07	4.69E-07	4.78E-07	4.87E-07	4.89E-07	4.85E-07	4.74E-07	3.71E-07	2.98E-07	1.20E-07	5.31E-08
NW	1.58E-07	4.33E-07	4.86E-07	5.07E-07	5.38E-07	5.77E-07	6.13E-07	6.36E-07	6.46E-07	6.44E-07	5.29E-07	4.41E-07	1.91E-07	8.75E-08
NNW	8.89E-08	2.42E-07	2.67E-07	2.78E-07	2.98E-07	3.26E-07	3.54E-07	3.75E-07	3.87E-07	3.91E-07	3.30E-07	2.78E-07	1.22E-07	5.53E-08

Appendix C – AERMOD

AERMOD version 22112 (AERMIC 2022)[6] was used to corroborate the CAP88-PC V 4.1.1 dispersion modeling for preferred relocation areas of ambient air surveillance stations PNL-2 and PNL-3. Models were considered to be corroborated if the resulting concentration contour maps had considerable overlap and followed a similar trajectory. AERMOD Concentration contour maps were produced using BREEZE 3D Analyst version 4.1.0.12 (Trinity Consultants 2023).

Both AERMOD and CAP88-PC are steady-state Gaussian plume models; however, there are some key differences between the algorithms and software that make AERMOD a more robust modeling application and an excellent validation tool for this revision of the DQO. First, AERMOD calculates true hourly concentration for receptors using unique dispersion coefficients derived from the site's meteorological vertical profiles of temperature, wind, and turbulence, whereas CAP-88 calculates concentration for receptors by aggregating the site's meteorological vertical profiles into Pasquill-Gifford-Turner stability classes that have predetermined dispersion coefficients based on general empirical observations in rural environments. The former method allows for a turbulence profile that more accurately reflects the site's meteorological traits as the dispersion coefficients are unique to the site's hourly meteorological data at the planet boundary layer. Second, AERMOD has the ability to calculate a concentration for receptors affixed to a Cartesian grid (a feature that was used in the AERMOD model run for this revision of the DQO), as opposed to CAP88-PC's limitations to calculating a concentration for receptors affixed to a polar grid with 16 radials. Using a Cartesian receptor grid allows for a denser receptor network with more discrete points where concentration can be calculated. Third, AERMOD's algorithm allows for incorporation of turbulence caused by building downwash and can model multiple point sources in a model run without collocating, which are features not available in CAP-88 and can be significant when modeling plume dispersion for short distances.

For the AERMOD dispersion modeling, meteorological data from 2005-2009 from station 11 at the 300 Area of the Hanford Site was used. While this date range is different than what was used for the CAP-88 dispersion modeling (2012-2021), it was determined to be sufficient for corroboration purposes given the meteorological consistency observed in the 300 Area (see Section 3.5 of this DQO revision for a detailed comparison of atmospheric conditions of the 300 Area over a span of 38 years). The same major emission unit operation parameters (see Table 3.3 of this DQO revision) that were used in CAP88-PC were used in AERMOD. A one gram per second emission rate was assumed for all stacks.

Figures C.1 to C.3 show a side-by-side comparison of the CAP88-PC dispersion model results (left and center) and AERMOD dispersion model results (right) for each individual PSF building with a stack. Figure C.4 shows an all-building emission dispersion composite from CAP88-PC (left) and AERMOD (right), in addition to a 300 Area wind rose from 2007 (Rokkan et al., 2008) (center). As expected, the dispersion pathways follow the prevailing winds of the 300 Area that predominantly blow from the SW, NW, and NE (see Figure C.4).

X/Q values from two dispersion models commonly differ because of distinct calculational approaches, and dispersion differences are evident between CAP88-PC and AERMOD. For example, the building wake modeling of AERMOD produces higher concentrations at close-in distances, whereas CAP88-PC has plume overflight for the elevated stack releases. To obtain

[6] A refined consumer interface for the AERMOD software, BREEZE AERMOD version 11.0.0.10 (Trinity Consultants 2022) was used to run the AERMOD EPA Executable 22112.

X/Q units from AERMOD output in the figures, divide the concentration results by the effluent release rate of 1 g/s.

In general, the concentration contour maps produced through the dispersion modeling performed by AERMOD are consistent with those of CAP88-PC. The preferred relocation areas for ambient air surveillance stations PNL-2 and PNL-3 as determined by CAP88-PC are encapsulated within the two highest concentration levels generated by AERMOD; corroborating the results.

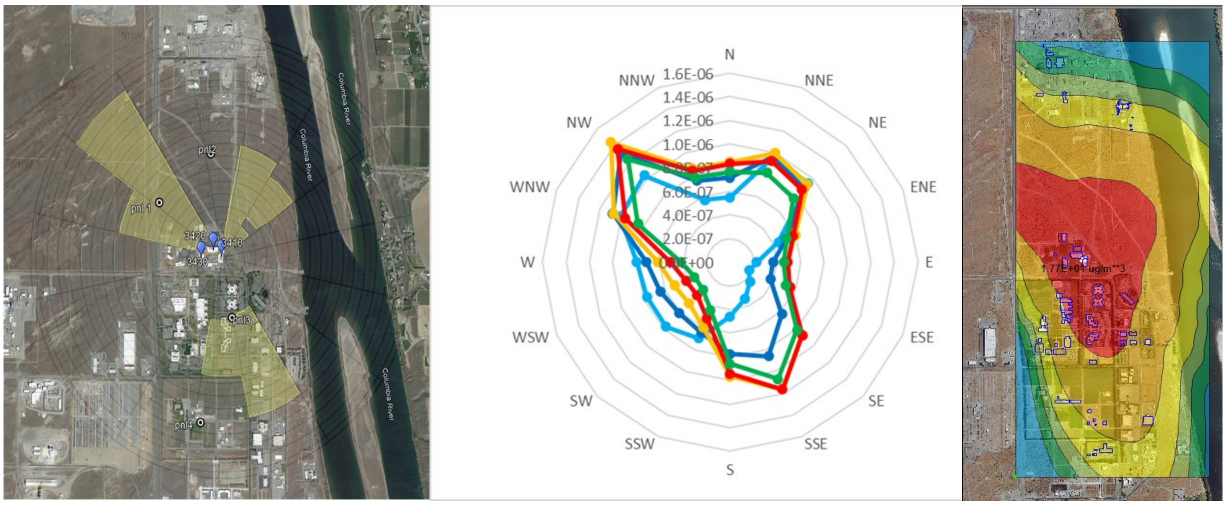

Figure C.1. 3410-01-S Emission Unit X/Q Distribution from CAP-88 (left and center) and Concentration Dispersion from AERMOD (right)

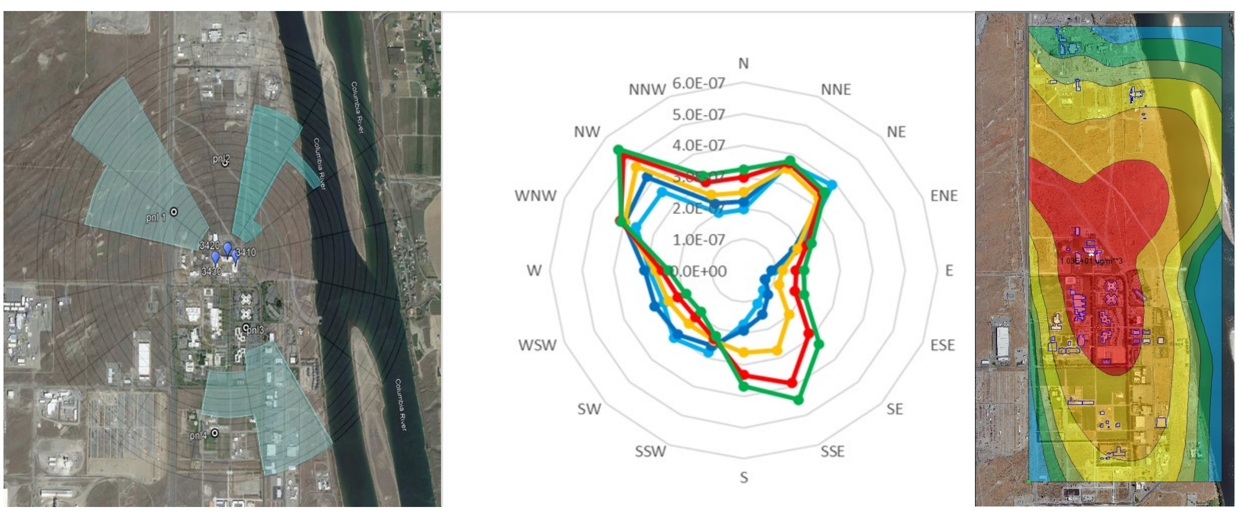

Figure C.2. 3420-01-S Emission Unit X/Q Distribution from CAP-88 (left and center) and Concentration Dispersion from AERMOD (right)

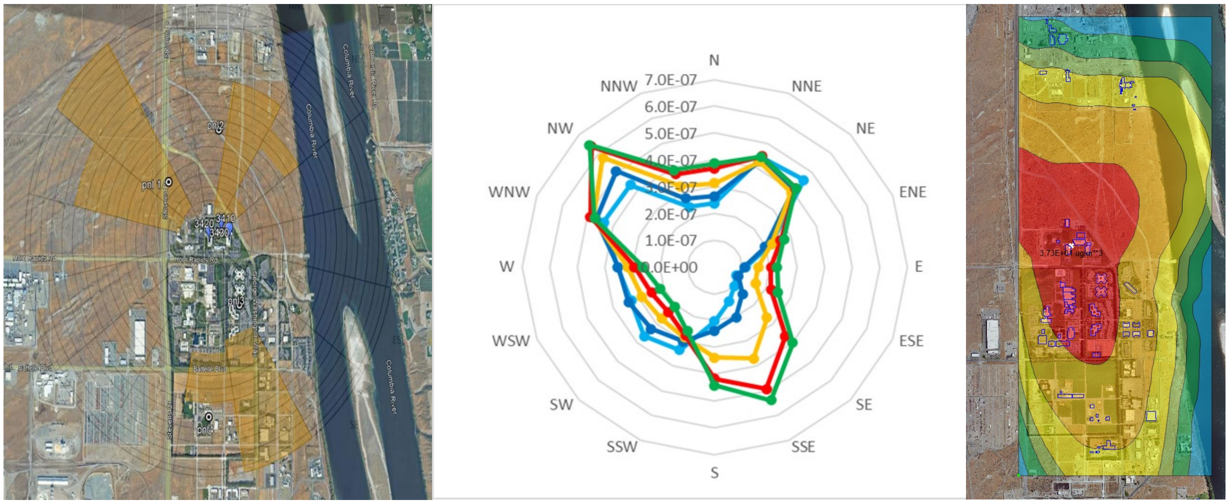

Figure C.3. 3430-01-S Emission Unit X/Q Distribution from CAP-88 (left and center) and Concentration Dispersion from AERMOD (right)

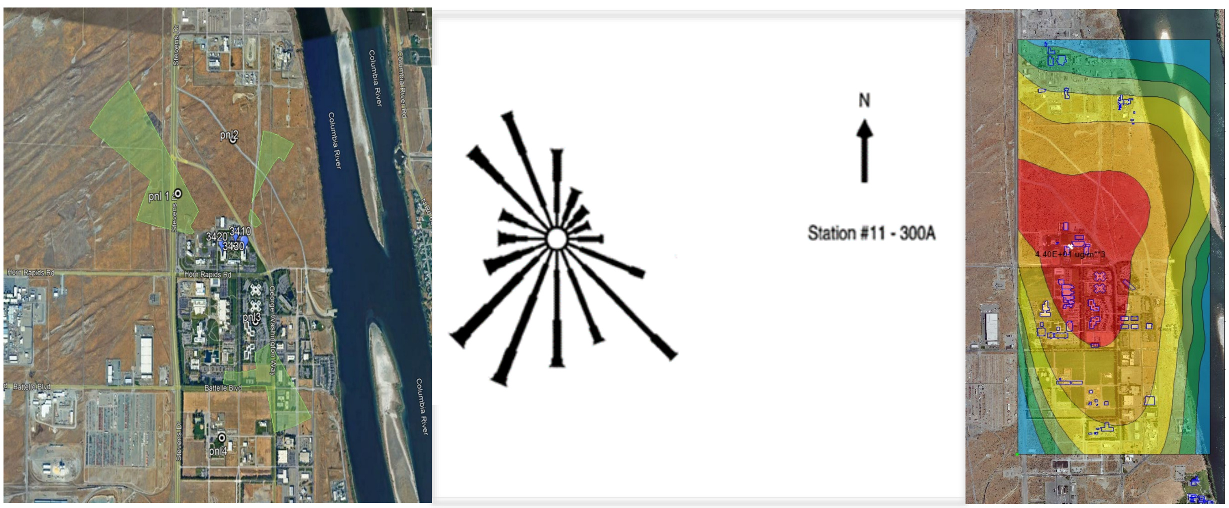

Figure C.4. All-Building Composite Emission Unit X/Q Distribution from CAP-88 (left), 300 Area 2007 Wind Rose (Rokkan et al. 2008) (center), and All-Building Concentration Dispersion from AERMOD (right)

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