PNNL-19427, Rev. 2

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

Rev. 2, Northern Boundary Change

December 2017

SF Snyder
DGL Moleta
KM Meier
JM Barnett

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 99352

Summary

This is the second revision of the Data Quality Objectives (DQO) Supporting Radiological Air Emissions Monitoring for the Pacific Northwest National Laboratory (PNNL) Richland Campus. In January 2017, the PNNL Richland Campus expanded to the north by 0.35 km^2 (85.6 acres). Under the requirements of Washington State Department of Health (WDOH) Radioactive Air Emissions License (RAEL)-005, the PNNL Campus must operate and maintain a radiological air monitoring program. This revision documents and evaluates the newly acquired acreage while also removing recreational land at the southwest, and also re-examines all active radioactive emission units on the PNNL Campus. No buildings are located on this new Campus land, which was transferred from the U.S. Department of Energy (DOE) Hanford Site. Additionally, this revision includes information regarding the background monitoring station PNL-5 in Benton City, Washington, which became active in October 2016, thereby eliminating the use of the Hanford Site's Yakima Station for background data. The key purpose of this revision is to determine the adequacy of the existing environmental surveillance stations to monitor radiological air emissions in light of this northern boundary change.

In 2012, DOE operations at the PNNL Campus expanded as a result of contractual changes that commit radiological operations in several facilities south of the documented PNNL Campus fenceline to DOE, 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 fenceline 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 AC power, at these more remote locations.

The initial DQO, Revision 0, considered radiological emissions at the PNNL Site resulting from the Physical Sciences Facility (PSF) 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. For this second revision, a team was re-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 is an updated program that monitors the impact to the public from the 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 amended 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 revision history.

Considering any constraints as a result of location, occupancy, or the availability of existing monitoring stations, the team retained the existing sampling stations PNL-1, PNL-2, PNL-3, PNL-4, and incorporated the background station PNL-5 and optically stimulated luminescence dosimeters. This revision of the DQO also updates the discussion of the Environmental Monitoring Plan for the PNNL Richland Campus air samples and how existing external monitoring program results could be used. It was

prepared based on the U.S. Environmental Protection Agency (EPA) *Guidance on Systematic Planning Using the Data Quality Objectives Process*, EPA QA/G4, 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) is 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 current revision has been updated. This revision carries forward pertinent data and expands on that information with the new boundary. While some background material is repeated, references to material in former revisions are used judiciously. In this revision, each study question, decision, and error analysis are 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 are proposed in this revision. Additionally, no location changes to existing air monitoring are proposed.

(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

ALARA	As Low As Reasonably Achievable
CAP-88	Clean Air Act Assessment Package–1988
CAP88-PC	Clean Air Act Assessment Package 1988–Personal Computer
CFR	Code of Federal Regulations
CRD	Contractor Requirements Document
DOE	U.S. Department of Energy
DOE O	U.S. Department of Energy Order
DQO	Data Quality Objectives
EMP	Environmental Monitoring Plan
EMSL	Environmental Molecular Sciences Laboratory
EPA	U.S. Environmental Protection Agency
HEIS	Hanford Environmental Information System
LSB	Laboratory Support Building
LSLII	Life Sciences Laboratory-II
MDA	minimum detectable activity
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	(U.S. Department of Energy) Pacific Northwest Site Office
PSF	Physical Sciences Facility
PSRP	Public Safety and Resource Protection (formerly SESP)
PTE	potential-to-emit
QA	quality assurance
RAEL	Radioactive Air Emissions License
RDL	required detection limit
RTL	Research Technology Laboratory
SESP	Surface Environmental Surveillance Project
TED	total effective dose
TEDE	total effective dose equivalent
WAC	Washington Administrative Code
WDOH	Washington State Department of Health
X/Q	Chi-over-Q

Definitions

Acute Release	A short-duration release of a radioactive air pollutant with a potentially significant dose consequence.
Chi-over-Q (X/Q)	Concentration of a radioactive material in air at a downwind location, normalized by the release rate of the material from the source facility; expressed in units of sec/m^3 (radioactivity per cubic meter per radioactivity released per second).
Chronic Release	The nearly continuous release of small quantities of radioactive air pollutants from an emission unit over a period of at least 3 months.
Diffuse Source (nonpoint source)	As applied in *Washington Administrative Code* (WAC) 246-247 (18): "a location at which radioactive air emissions originate from an area, such as contaminated ground above a near-surface waste disposal unit, whose extent may or may not be well-defined."
Emission Unit	As applied in WAC 246-247-030[10]: "any single location that emits or has the potential to emit airborne radioactive material. This may be a point source, nonpoint source, or source of fugitive emissions."
Fugitive Emissions	As applied in WAC 246-247-030[12]: "radioactive air emissions which do not and could not reasonably pass through a stack, vent, or other functionally equivalent structure, and which are not feasible to directly measure and quantify."
Major Emission Unit	A unit having the potential to emit radionuclides that could result in a dose to the maximally exposed individual exceeding 1% of the 10 mrem/year dose standard in 40 *Code of Federal Regulations* (CFR) Part 61, Subpart H. Major sources are subject to the continuous monitoring requirements of 40 CFR Section 61.93.
Maximally Exposed Individual (MEI)	For the purpose of this DQO report, a maximally exposed individual is a hypothetical member of the public residing near the PNNL Richland Campus who, by virtue of location and living habits, could receive the highest potential radiation dose from radioactive effluents released from the PNNL Richland Campus during a calendar year. The MEI dose calculation can be either prospective or retrospective in nature. A prospective MEI location is based on maximum potential radionuclide emissions (the "potential-to-emit") and long-term meteorological data. The retrospective MEI location uses actual emissions and meteorological data

	applicable to the year for which the evaluation is performed. Emissions affecting the MEI may originate from point sources (i.e., actively ventilated stacks and vents) as well as from fugitive and diffuse sources (such as contaminated soil areas or other facilities that are not actively ventilated). Compliance with federal and state dose standards is determined by the retrospective MEI dose for a specific calendar year.
Millirem (mrem)	A unit of radiation total effective dose equivalent (TEDE) based on the potential for impact on human cells.
Minor Emission Unit	A unit having the potential to emit radionuclides that would not result in a dose exceeding 1% of the 10 mrem/yr dose standard in 40 CFR Part 61, Subpart H. (i.e., less than 0.1 mrem/year) to a maximally exposed individual. Minor sources are subject to the periodic confirmatory measurement requirements of 40 CFR Section 61.93.
Notice of Construction (NOC)	As defined in WAC 246-247-030[19]: "an application submitted to the [the Washington Department of Health {WDOH}] by an applicant that contains information required by WAC 246-247-060 for proposed construction or modification of a registered emission unit(s), or for modification of an existing, unregistered emission unit(s)."
Potential-to-Emit (PTE)	Radionuclide emissions estimated for purposes of permitting a new or modified emission unit. As defined in WAC 246-247-030(21): "the rate of release of radionuclides from an emission unit based on the actual or potential discharge of the effluent stream that would result if all abatement control equipment did not exist, but operations are otherwise normal."
Total Effective Dose Equivalent (TEDE)	The sum of the dose equivalent (for external exposures) and committed effective dose equivalent (for internal exposures); expressed in units of mrem.

Contents

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1.0 Introduction

This revision to the Data Quality Objectives (DQO) addresses the radiological air quality requirements and environmental monitoring needs for the Pacific Northwest National Laboratory (PNNL) Richland Campus, which is a research facility under the oversight of the U.S. Department of Energy's Office of Science, Pacific Northwest Site Office (PNSO). The northern boundary of the Campus was changed in early 2017, and this DQO revision evaluates the need to relocate current ambient monitoring stations in this northern area and the need for additional stations. In the initial DQO (Rev. 0), three ambient monitoring locations were established (Barnett et al. 2010), and in Revision 1 a fourth ambient monitoring location was added (Barnett et al. 2012). Additionally, the background monitoring station PNL-5 for the PNNL Richland Campus began operations in October 2016 (Fritz et al. 2014; Snyder et al. 2017). Ambient monitoring data from the Hanford Site Yakima background station were previously used to define Campus background levels.

Radiological air emissions sources at the approximately 670-acre PNNL Richland Campus do not differ substantially from those of the prior revisions of this DQO (Barnett et al. 2010, 2012) and consist of the Physical Sciences Facility (PSF), Life Sciences Laboratory-II (LSLII), and Research Technology Laboratory complex (RTL) facilities. The PSF is a complex of research laboratories (see Figure 1.1). Particulate ambient air sampling is conducted at the existing air monitoring stations, PNL-1, -2, -3, and -4. Past revisions of this DQO indicated no need to sample for gaseous or iodine emissions.

Figure 1.2 is an aerial view of the PNNL Richland Campus including the expanded boundary (dotted orange line). The current boundary, compared to the Campus boundary of Revision 1, excludes public areas in the southwest region and adds the northern land transferred from the Hanford Site. Revision 1 boundaries are indicated in blue in Figure 1.2. For the purposes of this report, the Laboratory Support Building (LSB) is considered a contiguous part of the PNNL Richland Campus.

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.

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." Additional 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 time).

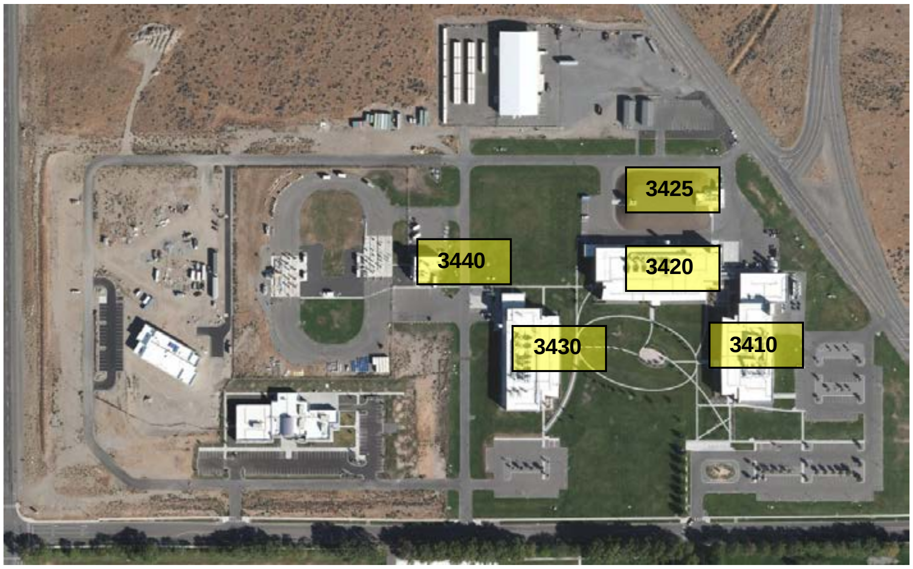

Figure 1.1. PSF Buildings

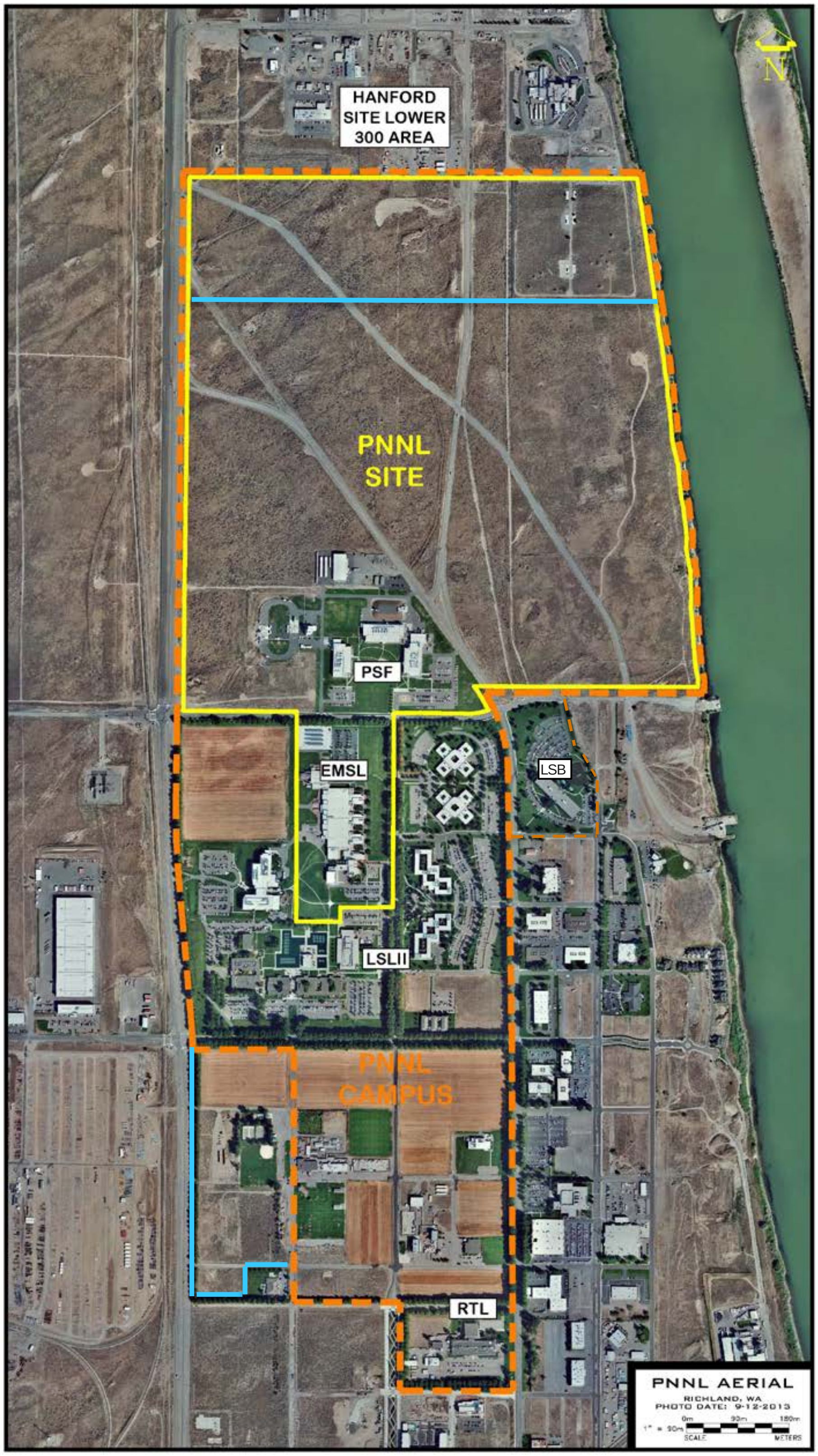

Figure 1.2. Current PNNL Richland Campus Boundary (orange), and the Previous Boundaries of the DQO, Revision 1 (blue)

1.1 Location

PNNL is a DOE research facility operated by Battelle-Pacific Northwest Division in the north part of Richland, Washington. Revision 1 of this DQO considered a 670-acre Campus area. This revision considers an area that includes the addition of 85.6 acres of land along the northern boundary and elimination of recreational land use at the southwest. The 669-acre Campus consists of 434 acres of PNNL Site and an additional 235 acres of Battelle-owned land. As of July 2017, the Richland Campus consists of the following parts:

- Leased facilities on Battelle-owned land
- Other leased facilities
- DOE-owned facilities within the Campus[1]

In addition to the 669-acre Campus, the LSB, 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. 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: Ultra-Trace Laboratory
- LSLII: Life Sciences Laboratory-II
- RTL-520: Research Technology Laboratory 520
- RTL-530: Research Technology Laboratory 530
- Various buildings, including the Environmental Molecular Sciences Laboratory (EMSL; Building 3020), are approved for work with low-level releases of materials under Potential Impact Category (PIC) 5 permits described in Section 3.1.

Evaluations in Revision 1 emphasized emissions with the greatest potential to impact the offsite public. This results in emphasis of major and minor emission units with the potential for impacts of significance relative to major emission units. Boundary changes at the north end of the Campus will focus the attention of this revision on PSF emission units in the northern Campus. However, due to updated input data, RTL and LSLII emission points will also be considered, but to a limited extent.

[1] The PNNL facilities are managed under the DOE Office of Science PNSO.

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.

2.1 Background and Scope

The following text was largely excerpted from Revisions 0 and 1 (Barnett et al. 2010, 2012) of the DQO, and updated as appropriate. At the PNSO-WDOH interface meeting of November 12, 2008, WDOH indicated that the PNNL would need to establish an environmental monitoring program 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 radioactive air emissions license. 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 hutches) would be sufficient to demonstrate low emissions. The two interim stations were located on the Hanford Site to the N and NNW of the PSF at locations where power was readily accessible (Figure 2.1).

The conclusions of the initial DQO resulted in the relocation of the two northern interim monitoring locations to more optimized positions onsite 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 2.2). The initial Hanford Site monitoring stations were called Solar North and Solar South, but have been relocated and renamed PNL-2 and PNL-1, respectively; they are solar-powered, an innovative option in 2010.

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 station monitored RTL emissions and the southern Campus area. The current four ambient air environmental surveillance station locations, based on Revision 1 of the DQO, as well as the newly added background monitoring station PNL-5, are shown in Figure 2.3. 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. Inaugural Monitoring Stations North of the PNNL Site and MEI (red star) Site of WDOH Agreement

Figure 2.2. Inaugural and Relocated Stations of Barnett et al. 2010

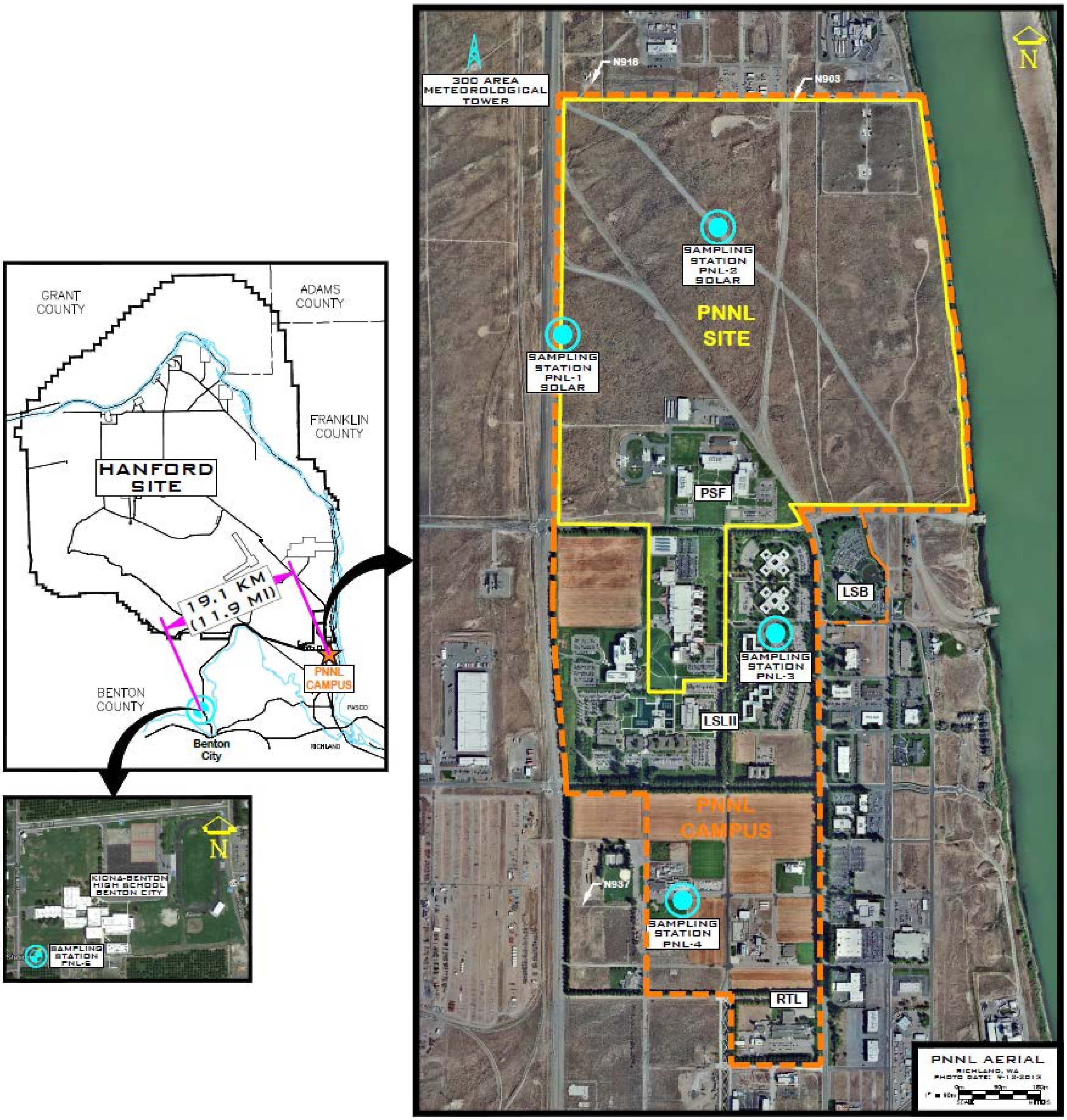

Figure 2.3. PNNL Richland Campus Radiological Air Monitoring Stations as of November 2017

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 changes to these regulatory requirements have occurred since 2012. Portions of DOE Order (O) 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 maximally exposed individual 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 environmental ambient air sampling program in response to a WDOH requirement to confirm low emissions from all significant radioactive air emission units; however, the environmental monitoring program 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 environmental monitoring program nor the methods approved by regulations for estimating atmospheric dispersion and dose consequences were intended to be applied to high-level or 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 determine the environmental monitoring needs for routine radioactive air emissions to the atmosphere from the PNNL Richland Campus in north Richland, Washington, in response to the expanded footprint resulting from the addition of land at the northern end of the Campus. The PSF area is the primary focus of this document because it is closest to the modified northern boundary, with special attention paid to the 3420 Building since it is the northernmost of the facilities.

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 the Notices of Construction (NOCs) submitted to WDOH. 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 and the Public Safety and Resource Protection (PSRP) programs operated by Mission Support Alliance in Richland. These programs and their predecessors have collected data on and around the Hanford Site for several decades. In earlier DQO revisions, PSRP was referred to by its prior name: Surface Environmental Surveillance Project (SESP). Meteorological data are available in a form usable by the atmospheric dispersion software.

Current environmental monitoring program information and emission point characteristics are available from PNNL Richland Campus staff. The atmospheric dispersion software is available from the federal internet website[1] and is accepted for use on desktop devices.

The information required to achieve the objective of northern boundary assessment 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 northern boundary change. The more northward boundary location brings the PNNL Campus even closer to major emission units on the Hanford Site. Therefore, these Hanford Site emissions are also evaluated to provide confidence that Campus emissions would more likely be captured at the Campus monitoring location.

2.4 Participants

For Revision 2 of the DQO, the planning team includes the following members:

[1] Available at: https://www.epa.gov/radiation/cap-88-cap-88-pc. Last accessed 22 August 2017.

- A radioactive air task lead with background in regulatory compliance, environmental monitoring, and low-level radiation detection. This member is a final decision maker.
- 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. This member is the DQO facilitator.
- A quality assurance engineer with experience in the DQO process and environmental issues.
- An environmental engineer (technical intern level 4) with the ability to perform atmospheric dispersion calculations appropriate to the 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/G4, 2/2006 (EPA 2006).
- *Systematic Planning: A Case Study of Particulate Matter Ambient Air Monitoring,* EPA QA/CS-2, 3/2007 (EPA 2007)
- *100-NR-2 Groundwater Operable Unit Ecological Risk Assessment Data Quality Objectives Summary Report, Fluor Hanford,* WMP-23141, Rev. 0, 6/2005 (Bauer et al. 2005)
- *Regulatory Data Quality Objectives Supporting Tank Waste Remediation System Privatization Project, PNNL,* PNNL-12040, Rev. 0, 12/1998 (Weimers et al. 1999)

The DQO process was facilitated by a modeling subject matter expert with directed support from the environmental science intern. Team members are experienced in using and evaluating 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.

This revision commenced in June 2017 and maintained key members of the Revision 1 team, with the addition of an environmental engineer here as an intern.

3.0 Inputs

This section lists and describes the sources used to ultimately answer the objective listed 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 2015), *Environmental Radiological Effluent Monitoring and Environmental Surveillance,* was published in 2015 and provides guidance for meeting the requirements of DOE O 458.1. This 2015 Handbook updated DOE/EH-0173T (DOE 1991), referenced in earlier DQO revisions. It includes guidance for airborne effluent monitoring and environmental surveillance. Team members referred to the 2015 Handbook to make certain that critical items were not omitted or overlooked.

In July 2011, Battelle's 1830 contract, DOE-Battelle Prime Contract for the Management and Operation of Pacific Northwest National Laboratory DE-AC05-76RL01830 with DOE, was updated to change the standard for radiation protection of the public and the environment from DOE 5400.5 to DOE O 458.1. The contract requirement[1] 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 December 2017

3.1 Emission Units

The PNNL Richland Campus has several buildings with potential radioactive material emission units. In accordance with laboratory practice (Ballinger et al. 2012), 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 Radioactive Air Emissions License (RAEL)-005 permit (WDOH 2015) includes PIC 2 and PIC 4 emission units; and PIC 5 permits. Table 3.1 lists the currently registered emission units: 3 major, 11 minor, and 3 fugitive emission units under permit, and 4 campus-wide PIC 5 permits for radioactive releases. Any onsite particulate radioactive emissions occurring under the PIC 5 permits could

[1] Current as of modification M1110, June 23, 2017.

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.

Except for fugitive emissions, the NOC applications and air emission registrations otherwise indicate the potential dose to the MEI, which is used to categorize stacks as major or minor emission units. The radionuclides of concern, i.e., those nuclides that most impact the categorization as major or minor emission units, are discussed in Section 3.2. Radionuclide release rates for the radionuclides of concern are discussed in Section 3.3. The emission unit operating characteristics are discussed in Section 3.4.

Table 3.1. PNNL Richland Campus 2017 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.
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.
	EP-3430-1606P-S	PIC 4. Minor emission unit. Room 1606 perchloric acid hood.
	EP-3430-1608P-S	PIC 4. Minor emission unit. Room 1608 perchloric acid hood.
	EP-3430-1610P-S	PIC 4. Minor emission unit. Room 1610 perchloric acid hood.
	EP-3430-1612P-S	PIC 4. Minor emission unit. Room 1612 perchloric acid hood.
	EP-3430-1614P-S	PIC 4. Minor emission unit. Room 1614 perchloric acid hood.
LSLII	EP-LSLII-01-V	PIC 4. Minor emission unit.
	EP-LSLII-02-V	PIC 4. Minor emission unit.
RTL	EP-RTL-10-V	PIC 4. RTL-520 minor emission unit.
	EP-RTL-11-V	PIC 4. RTL-520 minor emission unit.
	J-RTL530	PIC 4. Fugitive emissions. Activities limited to waste management and storage.
	J-RTL Complex	PIC 4. Fugitive emissions. Activities limited to demolition and removal of the RTL Complex.
Campus	J-VRRM	PIC 5. Volumetrically released radioactive material.
	J-NDRM	PIC 5. Non-dispersible radioactive material.
	J-Facilities Restoration	PIC 5. Facilities restoration.
	J-LLS	PIC 5. Low-level sources.

3.2 List of Radionuclides of Concern

The following text was excerpted from Revision 1 (Barnett et al. 2012), and updated as appropriate. An NOC application needs to contain the following information (WAC 246-247):

1. The indicated annual possession quantity for each radionuclide.
2. The physical form of each radionuclide (solid, particulate solid, liquid, or gas).

3. Release rates (potential-to-emit [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).

In submitting an NOC application, radionuclides are required to be identified by the applicant if their PTE meets one of the following release criteria (WAC 246-247):

1. Radionuclides that could contribute >10% of PTE total effective dose equivalent (TEDE) to the MEI.
2. Radionuclides that could contribute >0.1 mrem/yr PTE TEDE to the MEI.
3. Radionuclides that could contribute >25% of the PTE TEDE to the MEI with effluent controls in place.

Potential releases from the PNNL Richland Campus to which the MEI might be exposed consist of airborne radioactive effluents from laboratory facilities. For a radionuclide meeting one of the above conditions, the applicant is required to describe the method for monitoring or calculating those radionuclide emissions in sufficient detail to demonstrate compliance with the applicable state requirements.

In determining the PTE, PNNL uses the EPA-approved CAP88-PC Version 4 (Rosnick 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.

Inputs to developing the list of radionuclides of concern are obtained from NOC applications submitted in September 2009 for major emission units and from the 2012 Revision 1 for the 3410 Building.[1] There were no radionuclides identified that could contribute >25% of the PTE TEDE to the MEI with effluent controls in place, and none are shown in the tables below identifying nuclides of interest. The 2009 NOC applications were based on dose-per-unit release factors based on older dose-per-unit release factor documentation. Table 3.2 provides the results of a review to determine which nuclides remain potentially >0.1 mrem/yr contributors using the NOC application release rates and current dose-per-unit release factor documentation data.

As of July 2017, PNNL administrative levels for minor, non-sampled emission units are limited to <0.001 mrem/yr PTE to the MEI. The PNNL Richland Campus does not 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 from the

[1] DOE. 2009. *Transmittal of the Pacific Northwest National Laboratory Site Radioactive Air Emissions Notice of Construction Applications for the Operation of the Physical Sciences Facility*. Letter from MJ Weis, PNSO, to PJ Martell, WDOH, dated September 14, 2009, letter number 09-PNSO-0590. U.S. Department of Energy, Pacific Northwest Site Office, Richland, Washington; and DOE. 2012. *Contract No. DE-AC05-76Rl01830-Radioactive Air Pollutants Notice of Construction Application for the Materials Science And Technology Laboratory (3410 Building), Revision 1, PNNL Site, Richland, Washington*. Letter from RE Snyder, PNSO, to PJ Martell, WDOH, dated May 16, 2012, letter number 12-PNSO-0224.

major emission units are considered herein to be candidate radionuclides of concern (40 CFR 61; ANSI 1999; Ballinger et al. 2012).

Table 3.2 through Table 3.4 indicate the radionuclides of concern for each major emission unit on the PNNL Richland Campus.

Table 3.2. Campus Radionuclides of Interest for Major Emission Units

Radioisotope	Current NOCs >10% PTE TED to the MEI without controls in place[(a)] PSF	Current NOCs > 0.1 mrem/yr PTE TED to the MEI PSF	2017 RAEL-005 and NESHAP Assessment >10% PTE TED to the MEI without controls in place[(b)] (Buildings 3410/3420/3430)
^{241}Am	-	X	X/-/-
^{243}Am	-	X	-/-/-
^{244}Cm	X	X	X/X/X
^{60}Co	-	X	X/X/X
^{238}Pu	X	X	X/X/X
^{239}Pu	X	X	X/X/X
^{240}Pu[(c)]	X	X	X/-/-
^{233}U[(c)]	X	X	na/na/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 or 2016 NESHAP Assessment.
(c) ^{240}Pu only applicable to the 3410 major emission unit and ^{233}U only applicable to the 3430 major emission unit.
"-" = Criteria not met.
na = not applicable in RAEL-005 nor 2016 NESHAP Assessment.

3.3 Radionuclide Release Quantities

The RAEL-005 provides information regarding expected releases of the radionuclides of concern from the major emission units. The PSF 3425 Building NOC application was also reviewed for consideration of diffuse releases. The air emission registrations of LSLII and RTL were also reviewed. The facility inventories are based on annual possession quantities.

The unabated releases of radionuclides from the major stacks are indicated in Table 3.3. The NOC application conservatively estimates abatement by effluent control devices to reduce the releases to 1% of the indicated unabated release. The tabulated ^{233}U inventory is conservative, considering that it is only pertinent to the 3430 Building. The 3420 and 3410 Building inventories for this nuclide (0.0098 Ci) are less than 1% of that indicated for the 3430 Building. In 2017, the major emission units of 3410, 3420, and 3430 do not have potential emissions above 0.1 mrem/yr.

Table 3.3. Unabated Release Estimates for PNNL Richland Campus Major Emission Units

Radioisotope	Emission Type	Annual Possession Inventory (Ci/yr)[(a)]	Release Fraction[(b)]	Unabated Release Estimate (Ci/yr)
^{241}Am	Alpha	0.5	1E-03	5.0E-04
^{243}Am	Alpha	0.5	1E-03	5.0E-04
^{244}Cm	Alpha	1.2	1E-03	1.2E-03
^{60}Co	Gamma	30	1E-03	3.0E-02
^{238}Pu	Alpha	1.4	1E-03	1.4E-03
^{239}Pu	Alpha	1.2	1E-03	1.2E-03
^{240}Pu	Alpha	0.2	1E-03	2.0E-04[(c)]
^{233}U	Alpha	9	1E-03	9.0E-03[(c)]

(a) Maximum possession limit for any PSF facility per NOC applications and RAEL-005.
(b) Release form is particulate/liquid as identified in 40 CFR 61, Appendix D.
(c) ^{240}Pu release estimates only applicable to the 3410 Building, and ^{233}U release estimates only applicable to the 3430 Building.

Estimates of RTL unabated release impact have decreased significantly since Revision 1 of the DQO (Barnett et al. 2012). All radioactive sources have been removed from the facility, so only residual materials remain. The other minor sources on Campus have PTEs below 1.0 E-03 mrem/yr, which is well below the major emission unit classification of greater than 0.1 mrem/yr. Therefore, the primary focus will be the PSF and the modified northern boundary.

3.4 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 modeling are tabulated (Table 3.4). The characteristics indicated are those based on present operations (Barnett et al. 2015). Additionally, LSLII and RTL-520 currently have no active radiological laboratories; therefore, the pairs of stacks at these buildings comprising the emission units for these facilities were each assumed to be a single stack. The RTL Complex also has a new fugitive emissions authorization for near-term demolition activities. These assumptions would result in conservative, overestimated air concentration results. The LSLII stack was assumed to have an effective discharge height of 23.1 m with a diameter of 1.49 m. The RTL-520 stack was assumed to have an effective discharge height of 20.5 m with a diameter of 0.81 m. An increase in the flow rate of the 3420 Building major emission unit is anticipated. This change is discussed in Section 3.10.

Table 3.4. Major Emission Unit Operation Parameters

Unit Type/ Emission Point ID	Average Flow Rate	Total Flow	Average Temper-ature	Physical Discharge Height	Physical Discharge Diameter	Effective Discharge Height
EP-3410-01-S	21,700 ft^3/min (10.2 m^3/s)	1.14E+10 ft^3 (3.24E+08 m^3)	72 °F (22.2 °C)	44 ft (13.4 m)	3.3 ft (1.0 m)	103 ft (31.3 m)
EP-3420-01-S	47,200 ft^3/min (22.3 m^3/s)	2.49E+10 ft^3 (7.04E+08 m^3)	69 °F (20.6 °C)	45 ft (13.8 m)	4.3 ft (1.3 m)	125 ft (38.2 m)
EP-3430-01-S	32,588 ft^3/min (15.4 m^3/s)	1.72E+10 ft^3 (4.86E+08 m^3)	70 °F (21.1 °C)	44 ft (13.4 m)	3.7 ft (1.1 m)	113 ft (34.4 m)

3.5 Meteorological Data

The 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 help plan weather-dependent activities and as a resource to assess the environmental effects of site operations. The Hanford Meteorology Station relies on data provided by the Hanford Meteorological Monitoring Network. This network consists of 30 remote monitoring stations that transmit data to the Hanford Meteorology Station via radio telemetry every 15 minutes. There are twenty-seven 9-meter (30-foot) towers and three 61-meter (200-foot) 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 calculations were performed using historical meteorological data for the 300 Area (station 11) averaged from 2004–2013 (see Appendix A). This is updated information from the 1983–2006 dataset used in the earlier DQOs. Because the 300 Area is located about 1 km north of the PSF complex, 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., the 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 and 2004–2013 datasets is shown in Figure 3.1. 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 and the average temperature was 12.01 °C. Mixing height and humidity parameters were set to default values as a conservative assumption (overestimating results) for the PNNL Richland Campus region.

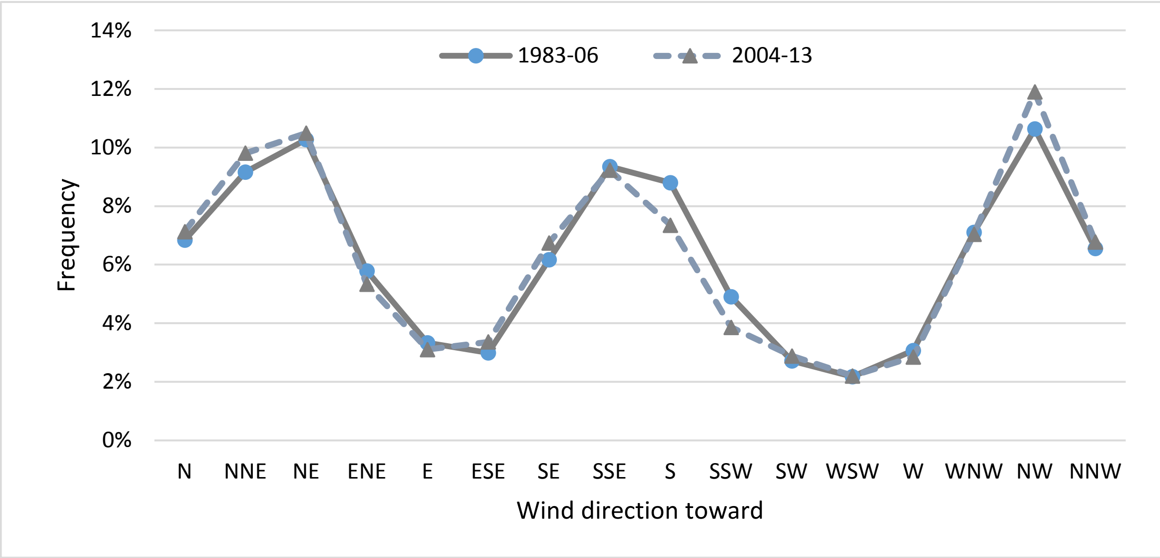

Figure 3.1. Average Frequency of Wind Direction for the 300 Area Station, Previous DQOs (1983–2006 data [circles]) and Current Report (2004–2013 data [triangles])

3.6 Air Dispersion Modeling, CAP88-PC Model

The CAP88-PC V4 computer code (Rosnick 2015) is an EPA-approved model that is used to determine 40 CFR 61 Subpart H compliance at the PNNL Richland Campus (e.g., see Snyder et al. 2017). 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
  - Build-up 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 calculations were performed to consider the expanded northern fenceline. Entering stack release characteristics and the long-term average meteorological dataset from the 300 Area into a CAP88-PC V4 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/m^3) 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. The fenceline locations were determined for each of the three major PSF emission units as well as for the minor emission units of LSLII and RTL-520, even though the latter two are not specifically needed for the main objective of this assessment.

3.7 MEI Exposure Characteristics

This information is excerpted from Barnett et al. 2012 and updated as needed. The MEI dose is determined from the radionuclide releases, the environmental dispersion of the release, and the MEI pathways of exposure. The exposure pathways considered for the MEI are inhalation, ingestion, and external exposure. Businesses and schools are located offsite. Since the previous revision, additional resident locations (apartments and townhomes) have been built in proximity to the Campus, near RTL. A daycare facility is adjacent to a portion of the southern boundary.

The inhalation and external pathways are the most likely routes of exposure for the likely 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 the nearby office and apartment facilities. There are crops grown by a farmer for commercial sale in small farm fields onsite (e.g., see Figure 1.2). This crop growth will be discontinued at the end of the 2017 growing season, when all lands will be transferred to federal management.

3.8 Relevant Maximum Air Concentration Location(s)

The stack operating characteristics (Table 3.4) and meteorological data (Section 3.5 and Appendix A) were used in the CAP88-PC V4 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 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 PSF 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. The 3410 Building emission unit may create the greatest offsite air concentrations at potential MEI locations, but dispersion data from the 3420 Building are presented as the example of dispersion data output in this document due to its closer proximity to the updated northern Campus boundary. As the greatest potential contributor, dispersion data from that unit are presented as an example of dispersion data output.

Figure 3.2 was reproduced from Barnett et al. 2010. Figure 3.3 is presented to demonstrate the impact to the X/Q results from the use of updated stack parameters, updated CAP88-PC V4 model, and updated meteorology. The figures graphically present the X/Q values (s/m^3) at the indicated location for several distances from the indicated PSF building. The higher effective release height used for the 3420 Building emission in Figure 3.3 resulted in maximum air concentrations farther from the facility than those of the 3410 Building in Figure 3.2. This also resulted in lower X/Q values in all directions. Particulate concentrations remain highest in the NW and SSE directions in the older and newer analyses. Figure 3.4 shows the location that CAP88-PC modeling indicates to be the maximum air concentration location for each PSF facility.

To provide a convenient reference, graphics are provided to show where a building emission reaches the boundary in each of 16 compass directions (Figure 3.5 through Figure 3.7). Figure 3.5 originates from a central PSF location rather than providing similar graphics for each of the three PSF facilities.

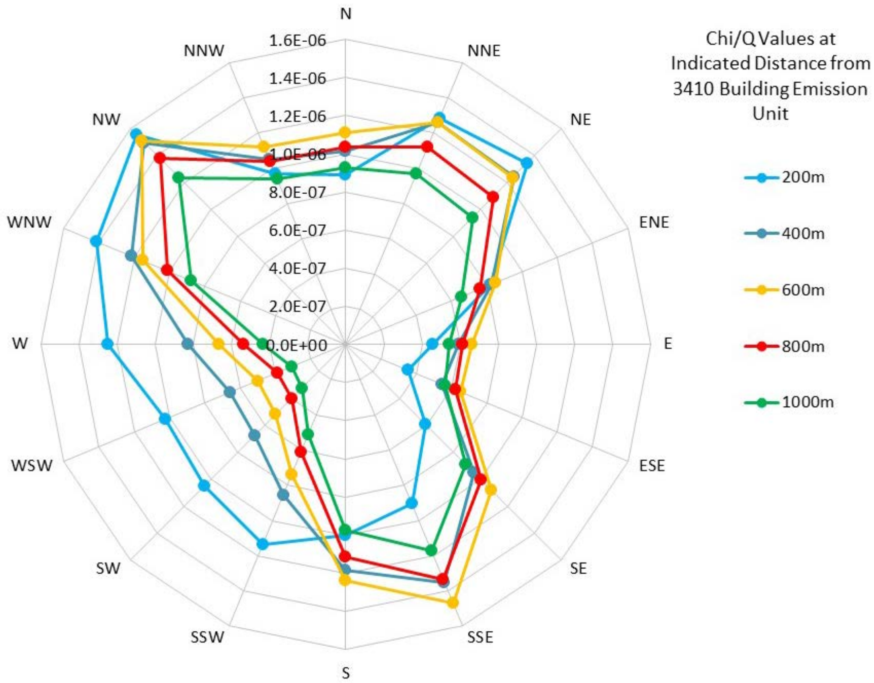

Figure 3.2. X/Q Values (s/m^3) for Indicated Location for Five Distances from PSF 3410 Building (Barnett et al. 2010)

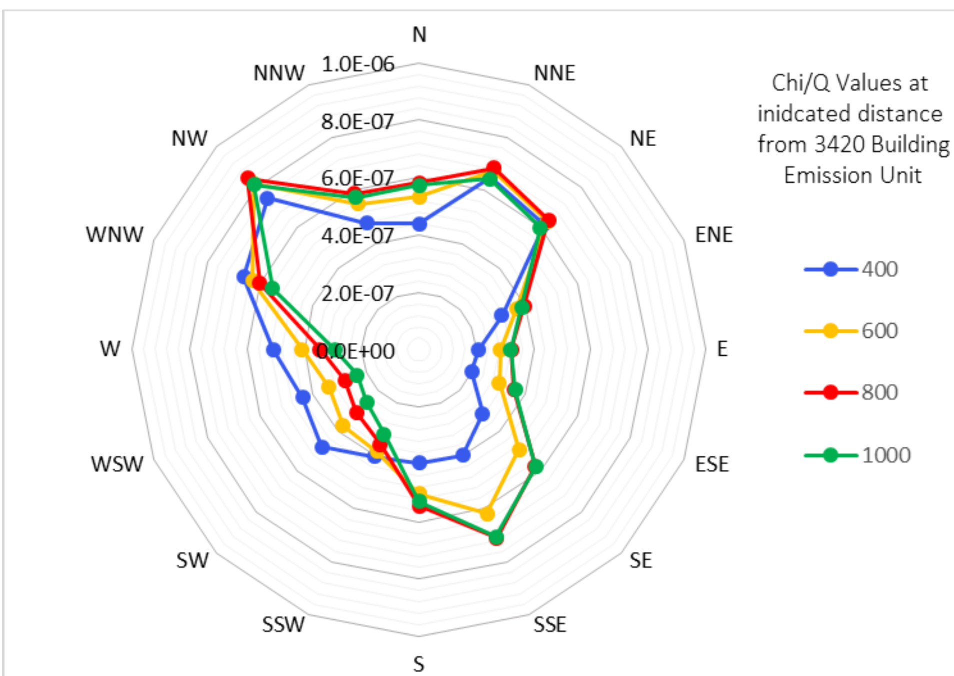

Figure 3.3. Updated X/Q Values (s/m^3) for Five Distances from PSF 3420 Building

Figure 3.4. Location of Maximum Offsite Air Concentrations from Modeled PSF Major Emission Units

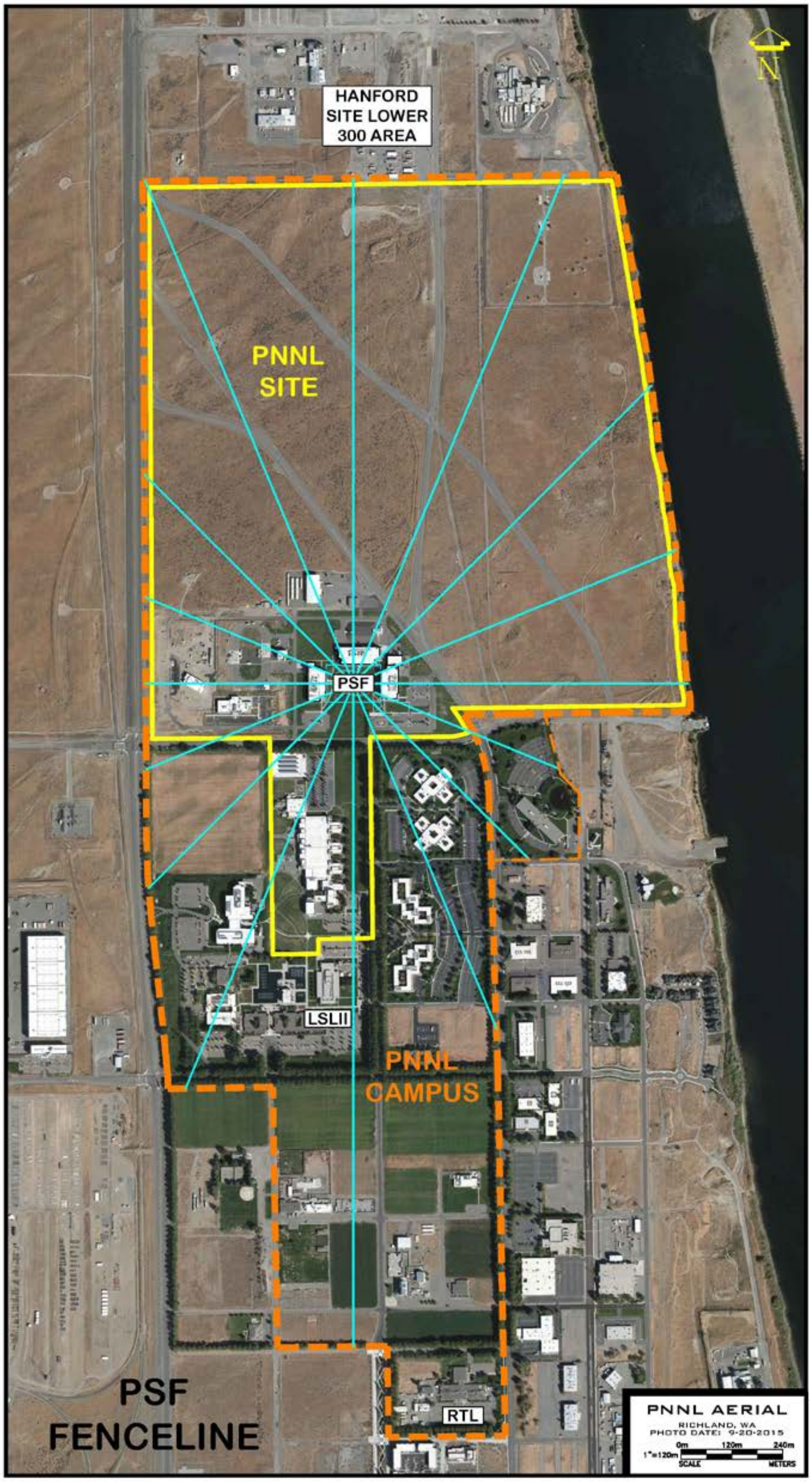

Figure 3.5. Boundary Visual with Blue Lines Indicating Centerline Compass Directions from PSF

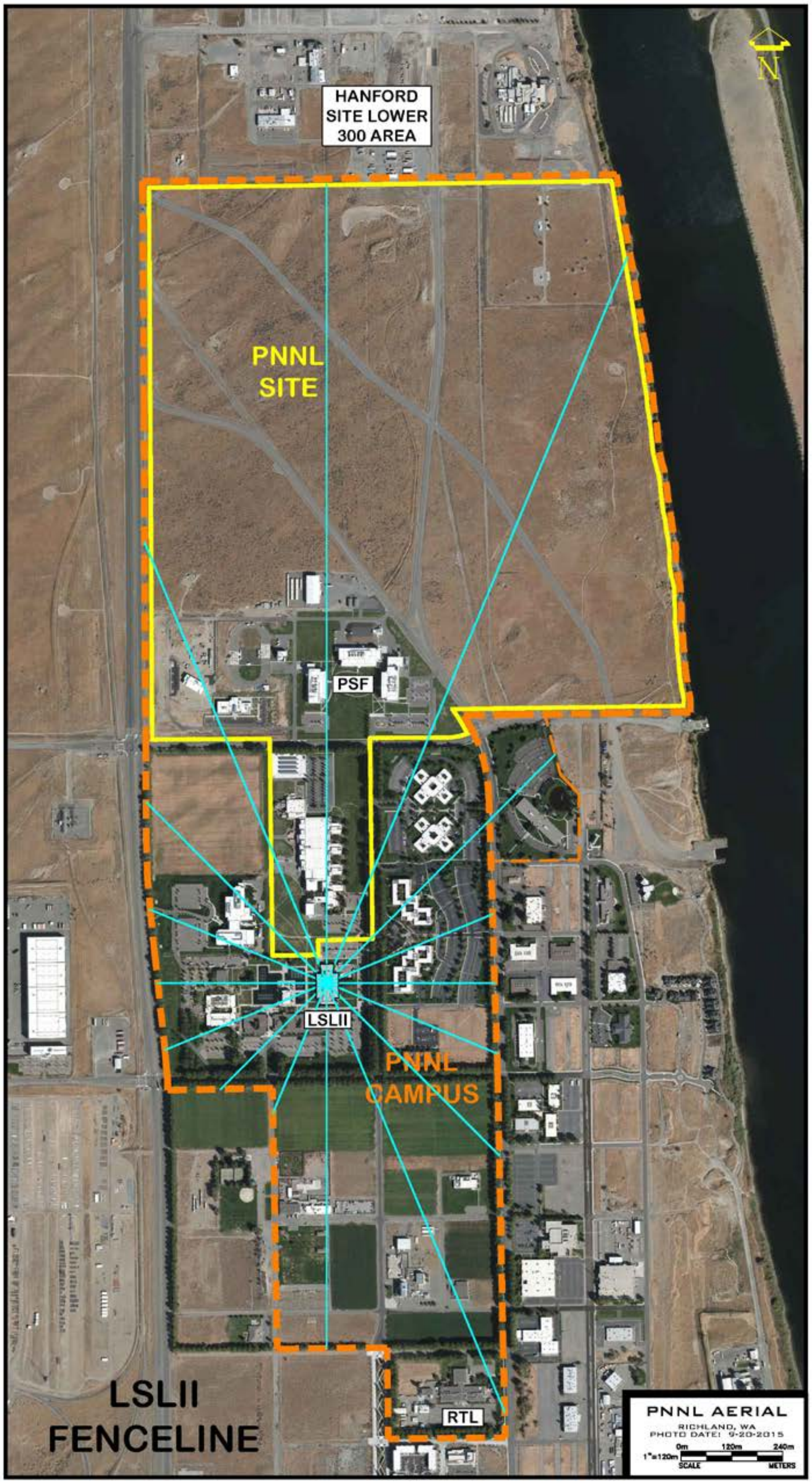

Figure 3.6. Boundary Visual with Blue Lines Indicating Centerline Compass Directions from LSLII

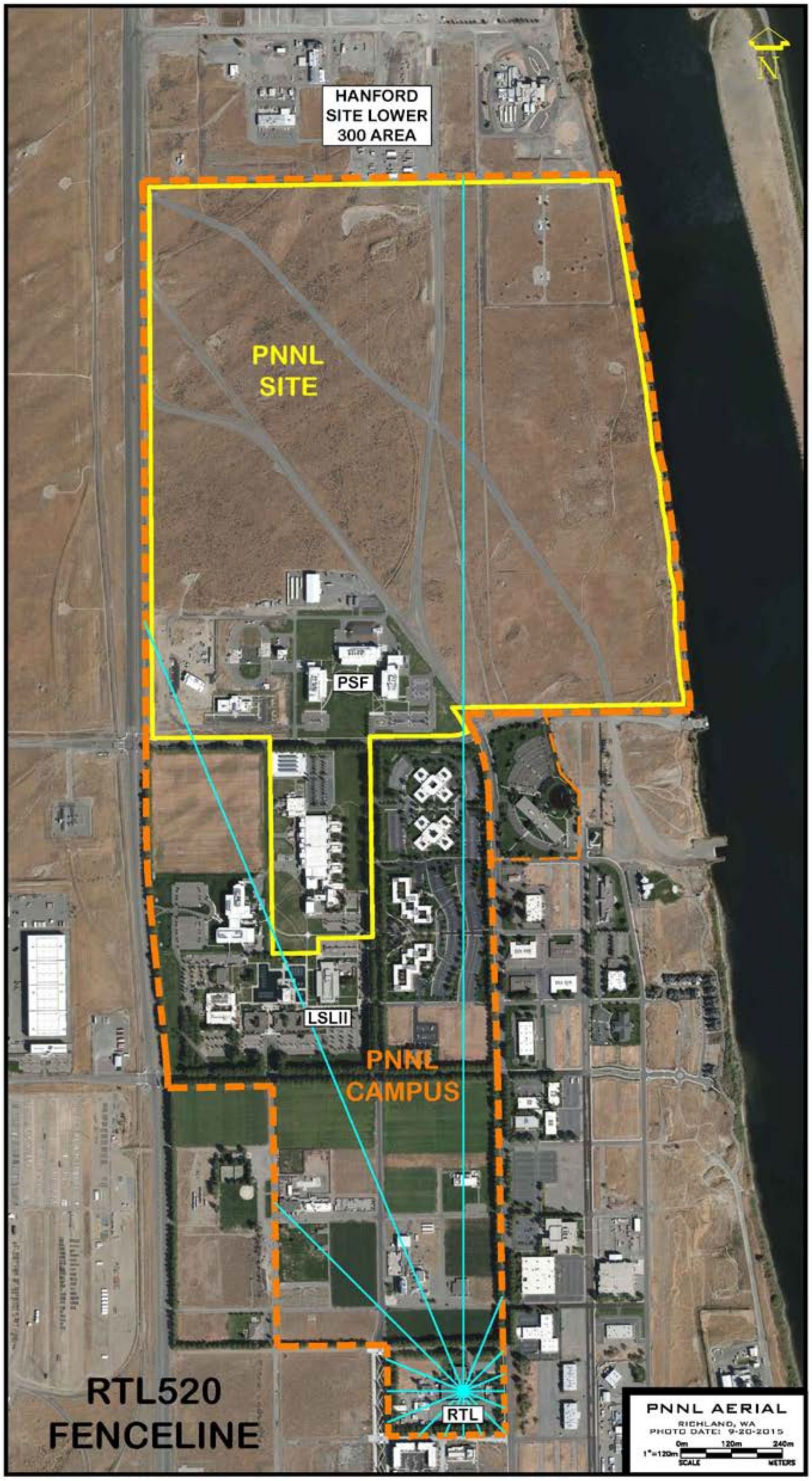

Figure 3.7. Boundary Visual with Blue Lines Indicating Centerline Compass Directions from RTL Complex

For each emission unit evaluated, the X/Q at the fenceline 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 3.8, reproduced from DQO Revision 0). If X/Q values of monitoring stations are equal to or greater than the current fenceline value, the modeling indicates that the monitoring station will adequately capture and characterize offsite annual radioactive emissions in the direction of the fenceline and monitoring station.

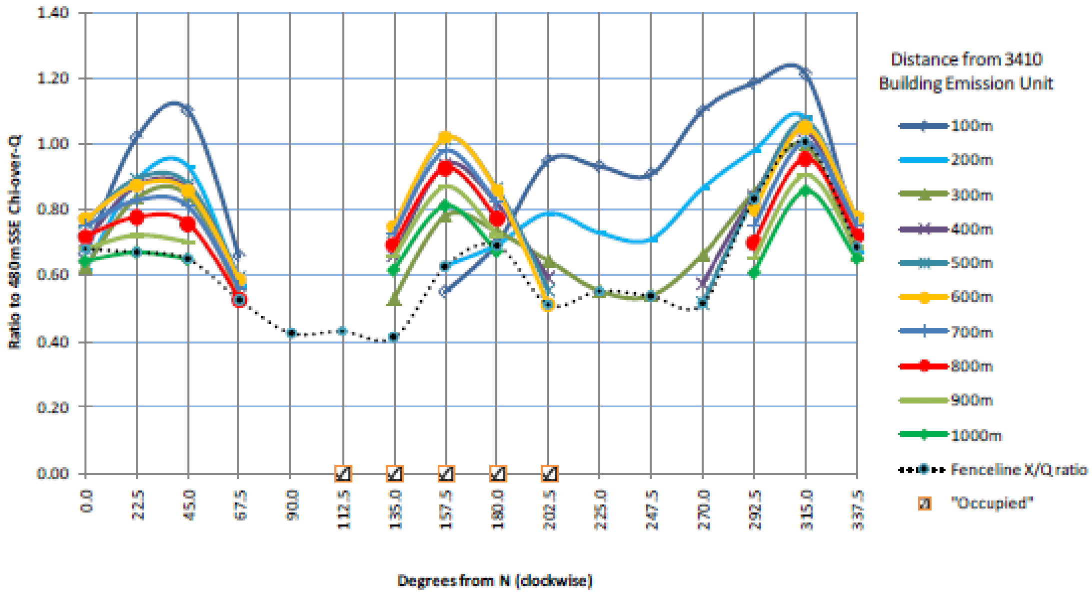

Figure 3.8. Example of Results Presentation Used in Barnett et al. 2010

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 fenceline in each direction from the evaluated facility. X/Q values are determined for each monitoring location based on emissions from each facility. The information is presented in graphics.

The standard established in prior revisions was that monitoring should capture 50% or more of the maximum fenceline 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 65%, to narrow and improve possible monitoring location options in both earlier DQO revisions. This DQO revision also adopts the use of the 65% maximum concentration X/Q from the release point to the sampling location.

3.9 Adequate Monitoring Program

The approach used to monitor Campus radioactive air emissions, described in the Environmental Monitoring Plan (EMP) (Snyder et al. 2011 and Attachments Meier 2011, Bisping 2011, and Snyder 2011), meets the guidance of DOE-HDBK-1216-2015. The PNNL approach grew from the methods and strategy used for the environmental surveillance program deployed at the Hanford Site. The PNNL surveillance program meets policy and guidance requirements established by the WDOH for air emissions monitoring. To summarize important aspects of the PNNL ambient 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. Those radionuclides released from the facility that are the major contributors to the effective dose (RAEL-005) must be collected and measured as part of the environmental measurement program at a concentration consistent with the minimum detectable amount criteria (see Table 3.5).
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 OSL dosimeters (OSLs) 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. 2017 will be the first full calendar year of environmental OSL monitoring.
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 3.5. Radionuclides To Be Monitored at the PNNL Richland Campus

Radioisotope Analysis	Approximate Half-life (yr)[(a)]	Table 2 Concentration (pCi/m^3)[(b)]	Notification Concentration (10% Table 2)[(b)]
^{241}Am	432	1.9E-03	1.9E-04
^{243}Am	7,370	1.8E-03	1.8E-04
^{244}Cm	18	3.3E-03	3.3E-04
^{60}Co	5.3	1.7E-02	1.7E-03
^{238}Pu	88	2.1E-03	2.1E-04
^{239}Pu	24,110	2.0E-03	2.0E-04
^{240}Pu	6,560	2.0E-03	2.0E-04
^{233}U	159,200	7.1E-03	7.1E-04

(a) ICRP 2008
(b) Table 2 of 40 CFR Part 61, Appendix E

3.10 Existing Monitoring Locations

As stated previously, 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 locations (PNL-1 and PNL-2) to onsite PNNL Richland Campus locations and added a third station (PNL-3) to monitor for the presumed PNNL Richland Campus MEI receptor. The relocated stations are solar-powered. Barnett et al., in 2012, also concluded that a fourth monitoring station would be necessary (PNL-4). In October 2016, a background monitoring station was added as PNL-5, and environmental dosimeters were added to each of the five monitoring stations for x-ray, beta-, and gamma-radiation supplemental monitoring.

To show how the new modeling, meteorology, and modified fenceline impact resulting X/Q values at the fenceline and current monitoring station locations, Figure 3.9 through Figure 3.13 are provided for the facilities of interest (PSF: 3410, 3420, 3430; LSLII; and RTL-520). Each compares the Revision 1 fenceline X/Q values with those of the current fenceline for that building, along with indications of the monitoring station X/Qs. The X/Q values indicated for the monitoring stations use the updated dispersion model and meteorology. Revision 1 monitoring station X/Qs are not presented on these figures to simplify the presentation.

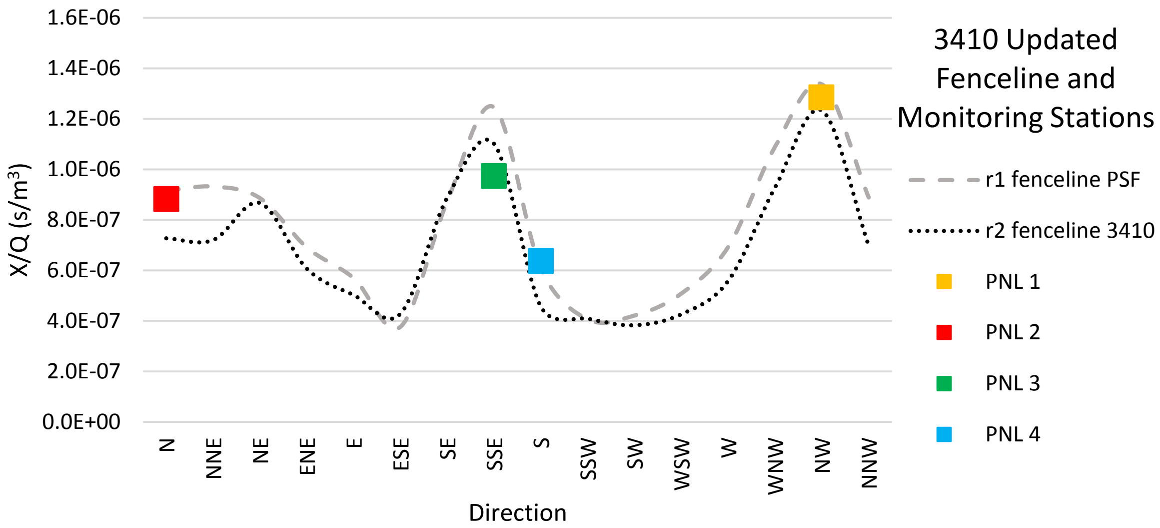

Figure 3.9. X/Q Values for a 3410 Emission Source with DQO Revision 1 (r1) Results and Updated DQO Revision 2 (r2) Fenceline and Dispersion Modeling

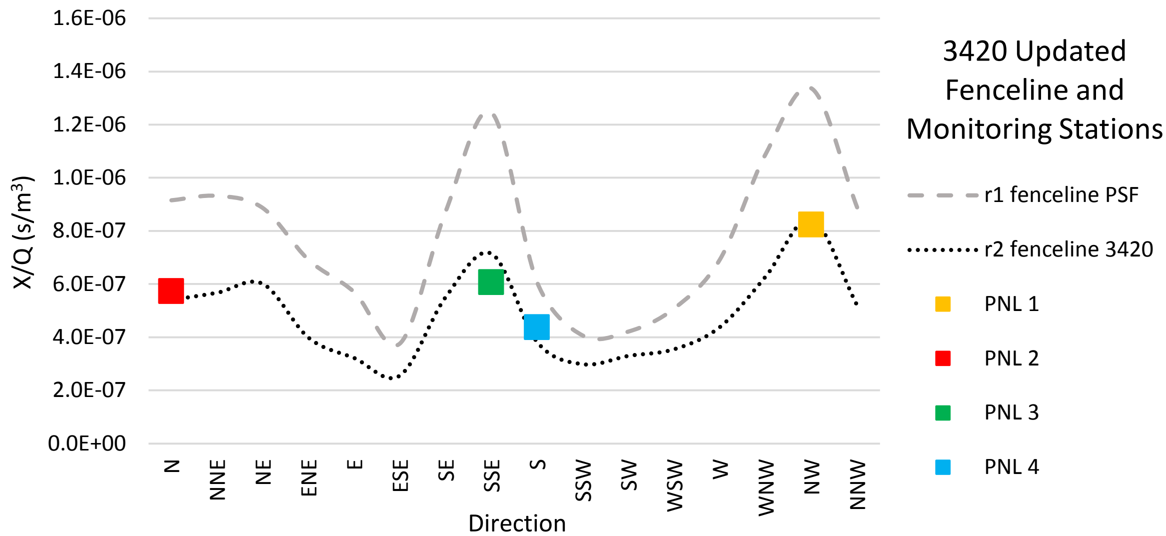

Figure 3.10. X/Q Values for a 3420 Emission Source with DQO Revision 1 (r1) Results and Updated DQO Revision 2 (r2) Fenceline and Dispersion Modeling

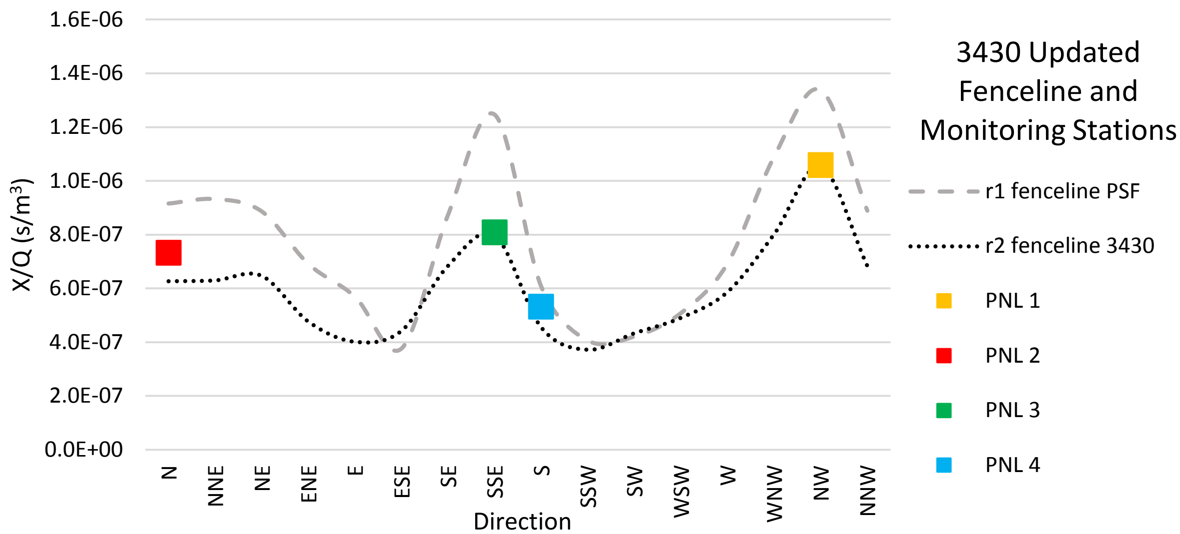

Figure 3.11. X/Q Values for a 3430 Emission Source with DQO Revision 1 (r1) Results and Updated DQO Revision 2 (r2) Fenceline and Dispersion Modeling

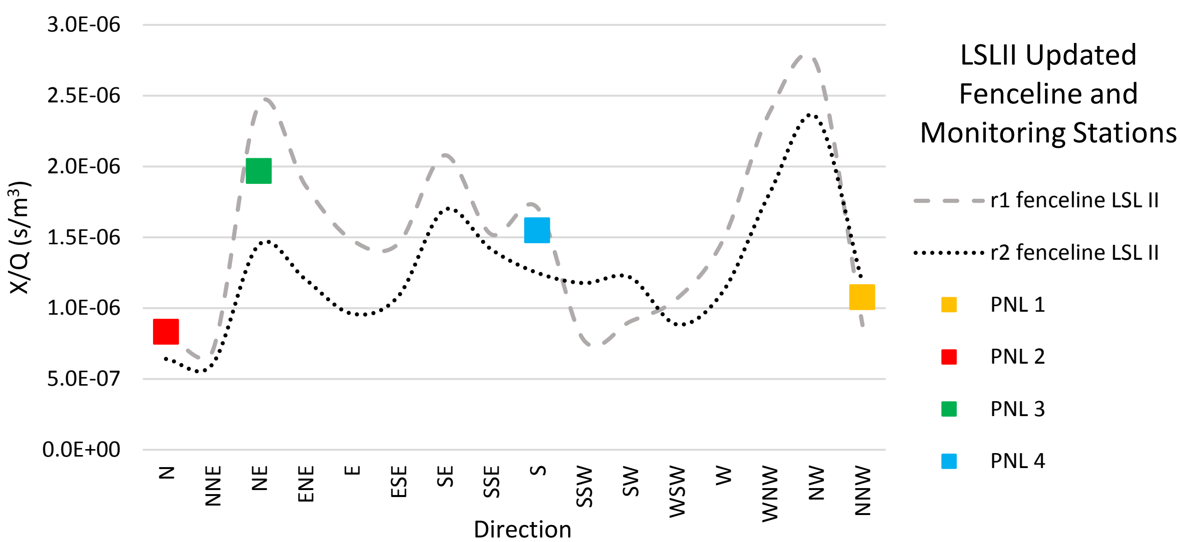

Figure 3.12. X/Q Values for a LSLII Emission Source with DQO Revision 1 (r1) and Updated DQO Revision 2 (r2) Fenceline and Dispersion Modeling

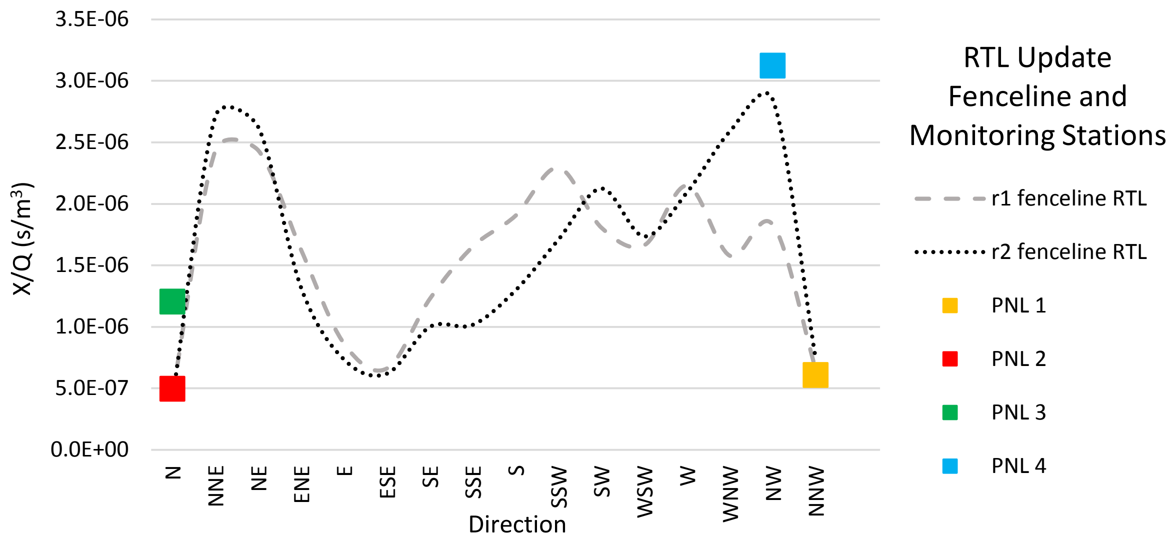

Figure 3.13. X/Q Values for an RTL-520 Emission Source with DQO Revision 1 (r1) Results and Updated DQO Revision 2 (r2) Fenceline and Dispersion Modeling

Figure 3.14 combines all three PSF major emission unit facilities on one graph. The higher relative X/Q values of 3410, resulting most significantly from its lower effective discharge height, are demonstrated in this figure. Conversely, the higher effective discharge height of 3420 contributes significantly to the lower values, compared to the other PSF facilities, also contributing to the 3420 maximum offsite X/Q location that is more distant than that of 3410 (see Figure 3.4).

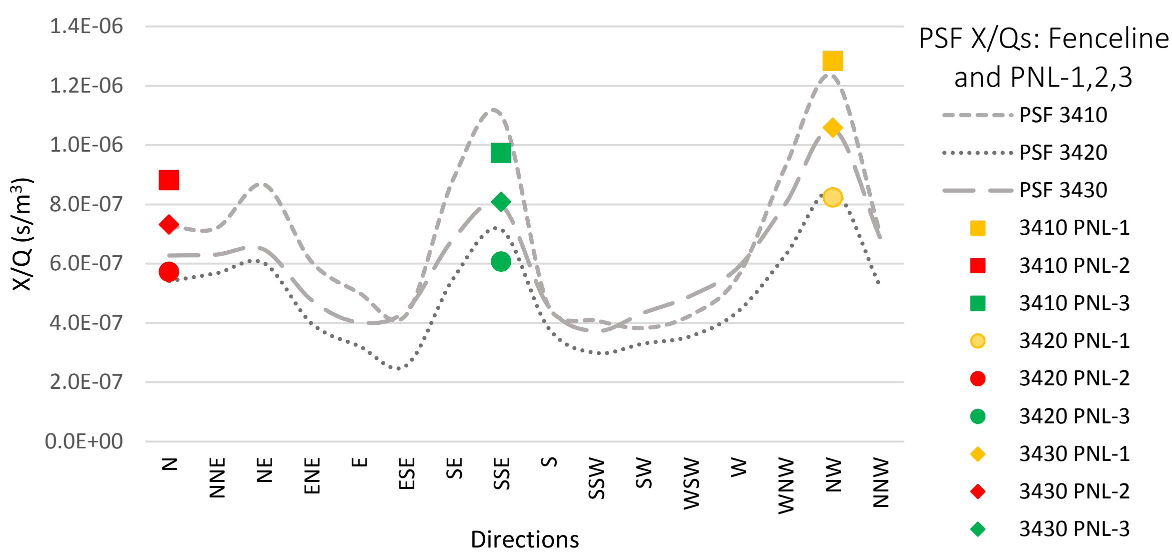

Figure 3.14. X/Q Values for All PSF Major Emission Unit Sources with Modified Fenceline

CAP88-PC V4 was used to estimate the X/Q values at the expanded fenceline locations from all compass directions for the PSF, RTL-520, and LSLII emissions and for the PNL-3 air sampling station to determine comparative X/Q values for the three emission units. Although Figure 3.12 and Figure 3.13 illustrate that the X/Q values of the minor emission units are greater than those of the PSF major emission units; the nuclide activity (Ci) emitted from RTL-520 and LSLII is much less than that of PSF. As a result, the maximum dose impact from RTL-520 emissions is lower than that of PSF, and the maximum dose impact from LSLII emissions is also lower than that of PSF.

As an additional evaluation, it is anticipated that the flow of the 3420 Building emission unit will be almost doubled in the next few years to support future operational needs. The increased flow rate would increase the effective release height of this stack from 38.2 to 44.7 m. Figure 3.15 indicates how this would impact the expected fenceline X/Q values from a 3420 emission. As expected, the higher release height results in lower X/Q values. The point where the maximum offsite X/Q falls would be about 215 m farther from that of the current 3420 Building emission result (see Figure 3.4).

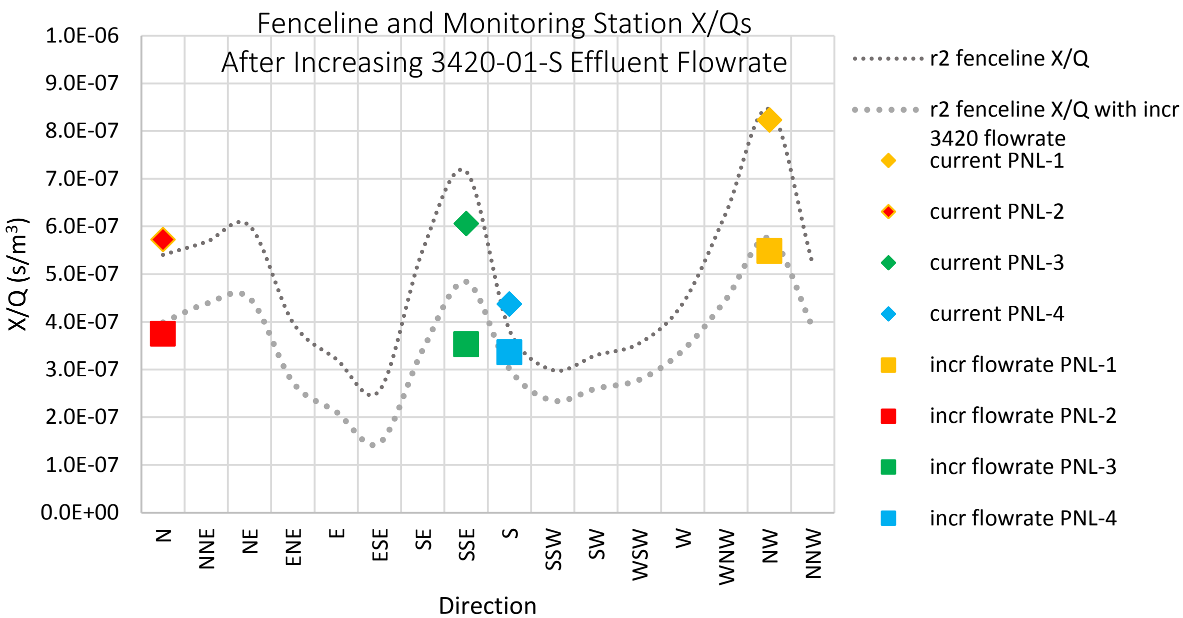

Figure 3.15. X/Q Reductions from an Increased 3420 Building Major Emission Unit Flow Rate

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 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 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 non-issue as the PNNL Richland Campus is relatively flat. As noted previously, meteorological data collected at the Hanford Site's 300 Area between 2004 and 2013 were selected as the most appropriate dataset to determine long-term atmospheric dispersion of Campus emissions. This time frame represents the most recent set of long-term meteorological data available and will represent 2017 conditions.

The output of atmospheric dispersion calculations from the CAP88-PC V4 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, ^{239}Pu 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. Besides the non-reactive particulate, ^{239}Pu, Barnett et al. (2010) previously modeled two other kinds of radioactive materials: longer lived, non-depositing gases (represented by ^{3}H) and longer lived, reactive particulates with a higher deposition rate (represented by ^{129}I). Current analysis found that, at the receptor and fenceline distances and directions relevant to this Revision 2 evaluation, 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 non-reactive particulates. Given the current non-reactive 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 ^{239}Pu in modeling is necessary.

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 (the 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 boundary of the Campus 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.[1] The LSB, 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
- Existence 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

[1] 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.

5.1 Question #1: What radionuclides of concerns 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.

c. List the primary radionuclides of concern and their form (e.g., particulate, vapor, gas).

Action 1: Use the available isotope information from permitting applications (the NOCs) and air emission registrations to establish a list of radionuclides of concern and their particular form.

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. 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. To determine the final ambient sampling list, three sources of information are used: emission unit NOC applications, the annual NESHAP Assessment, and the analytical lab contract.

The list of ambient sample analytes from the original DQO (^{241}Am, ^{243}Am, ^{244}Cm, ^{60}Co, ^{238}Pu, ^{239}Pu, and ^{233}U), are still measured. These nuclides are all included in the analytical contract that is reviewed annually in December. In addition, the analytical contract includes ^{243}Cm, ^{240}Pu, ^{234}U, ^{235}U, and ^{238}U; these are analyzed because they are measured with other required nuclides for technical reasons. ^{243}Cm with ^{244}Cm, ^{240}Pu with ^{239}Pu, and all the uranium isotopes come as an analysis set. The required analytes were determined from the original NOC applications, and most remain applicable according to the current NESHAP Assessment.[1]

The major emission units are expected to produce unabated impacts to the MEI that are three orders of magnitude greater than the minor emission units and abated impacts about 70 times greater than minor emission units, at maximum licensed release rates. Therefore, the radionuclides of concern for the major emission units are determined to be of greatest interest. The radionuclides that have been identified as

[1] M Ballinger to M Barnett. December 28, 2016, *2016 NESHAPs Assessment for PNNL-DOE Facilities*, EHSS-EPRP-16-026.

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 3.2) are ^{241}Am, ^{243}Am, ^{244}Cm, ^{60}Co, ^{238}Pu, ^{239}Pu, and ^{233}U.

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 major emission units.

Decision #1: The radionuclides of concern that have been identified from the license are particulate forms of ^{241}Am, ^{243}Am, ^{244}Cm, ^{60}Co, ^{238}Pu, ^{239}Pu, ^{240}Pu, and ^{233}U. While ^{240}Pu is new to this DQO revision, it has always been measured due to analytical limitations with the ^{239}Pu measurement. If the list results in a change, the analytical contract would require revision during its December review.

5.1.2 Error Assessment #1

The radionuclides of concern have been established based on the inventory mix (i.e., the annual possession quantities) of radionuclides identified in the license. Normal operations at these research laboratories may result in a different mix of actual radionuclide inventories monitored at their point source; 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.

There is a potential for a major permit application revision to contain new radionuclides meeting the requirements identified in Section 4.2, thereby resulting in the need for possible additional and/or different offsite 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). 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 and the annual NESHAP Assessment. 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: 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 #2: Determine which PNNL Richland Campus emission unit(s) generates the greatest offsite impacts, based on qualitative or, if needed, quantitative criteria.

5.2.1 Decision #2

The input data provided in Section 3.3, Radionuclide Release Quantities, also indicate the estimated impact from emissions, as documented in the NOC applications. PSF major stack emissions are the primary concern for this DQO revision because they are closest to the northern boundary change. RTL-520 information is presented, only as it relates to the SW boundary change (see Sections 3.8 and 3.10). Impacts from LSLII are not further evaluated because annual reporting (e.g., Snyder and Barnett 2017) has indicated impacts far below regulatory concern (i.e., 2E-9 mrem/yr).

Decision #2: No new radioactive air emissions facilities are added in this DQO revision. RTL-520 and LSLII are far into the process of inventory reduction in preparation for closure actions. These two facilities are also furthest from the boundary change reviewed in this DQO. Using only major emission units of PSF, and their 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.

5.2.2 Error Assessment #2

Considering major and minor emission units on Campus, the major emission units potentially generate the greatest offsite impacts. 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 environmental surveillance program 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 under-reporting 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 Radioactive Material Tracking System, and major emission unit releases are measured through continuous stack sampling.

5.3 Question #3: 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 #3: 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.

5.3.1 Decision #3

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 expected to be low-level and relatively constant over time. Therefore, they may be characterized as chronic releases and are adequately modeled by the EPA-approved software. If acute releases are anticipated from non-sampled stacks, alternative methods for modeling atmospheric transport may be warranted for the radionuclides involved.

Decision #3: A chronic release rate of radionuclides of concern can be used for modeling release and exposure (i.e., dose). Normal facility operations as currently planned 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.

5.3.2 Error Assessment #3

A chronic release rate of radionuclides of concern can be used for modeling release and exposure (i.e., dose). Normal facility operations as currently planned 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.

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 models uniform release and uniform exposure over the entire year. The MEI exposure and intake rates are overestimated in the CAP88-PC V4 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 NESHAPs Assessment and the use of the PNNL Radioactive Materials Tracking System for day-to-day activities.

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 fenceline or offsite locations of the maximum nuclide concentrations resulting from the PNNL Richland Campus emissions, 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 criteria for a major emission unit and select at least one location to install an air monitoring station that meets the percentage capture requirement. Existing locations may be re-assessed, as needed.

d. Determine the impact if the source changes (i.e., RTL-520 becomes a major emission unit).

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. New for this DQO revision, the maximum air concentration in an area northwest of Campus that was recently transferred from Federal (Hanford Site) to public ownership and will be imminently developed, was considered as the potential location of maximum impact. Modeling considers long-term meteorology. Locations of estimated maximum air concentrations are directly proportional to the locations of maximum dose impacts when no previous build-up of atmospheric depositions has occurred.

Action #4: Determine the most desirable locations of air monitoring 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 monitoring stations are at any of these locations.

5.4.1 Decision #4

An air monitoring 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 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 model uses the appropriate meteorological data (see Section 3.5) and emission unit characteristics (see Section 3.4).

In the original DQO (Barnett et al. 2010), the criteria for determining the ideal location for the air monitoring 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.
- Locations where air concentrations were expected to be 65% of the maximum. The original DQO team determined that using 50% of the maximum air concentration, while suitable, was too broad a set of candidate sites.

In general, the model presented in the original DQO determined that locations within 500 m and 1000 m of each PSF source in the S and SSE sectors satisfy the criteria above (see Figure 5.1) 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 (Figure 5.2).

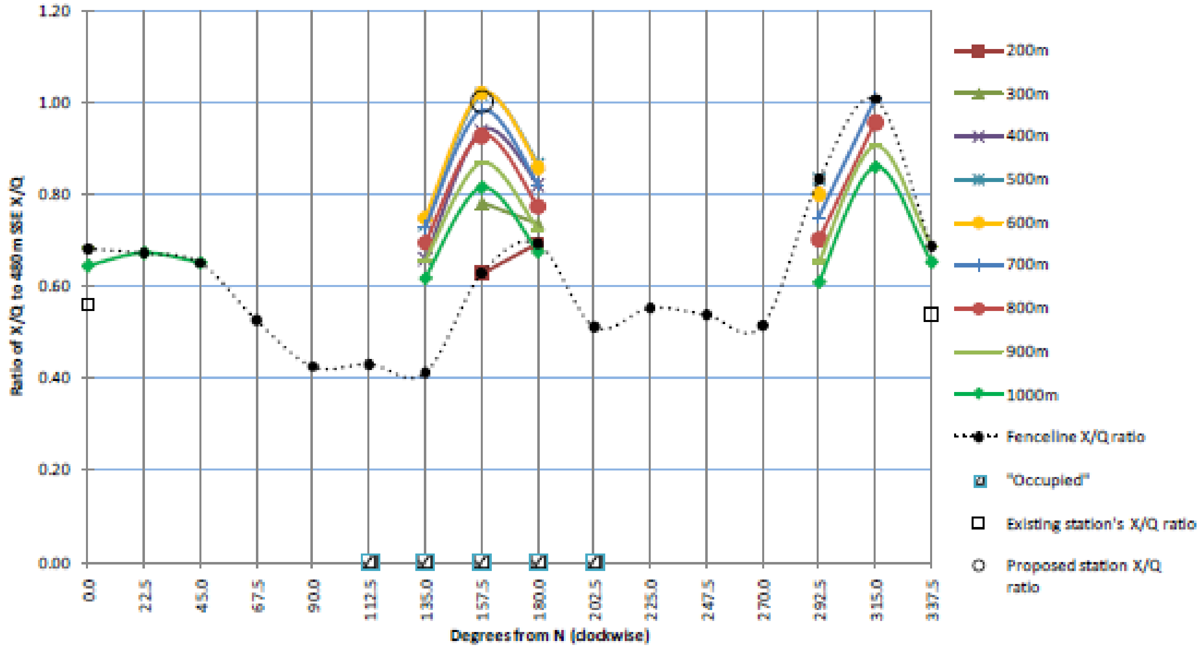

Figure 5.1. Air Concentration Ratios of Indicated Location to the Maximum Location (480 m SSE of 3410) when >65% AND beyond the DQO Revision 0 PNNL Site Fenceline (Barnett et al. 2010)

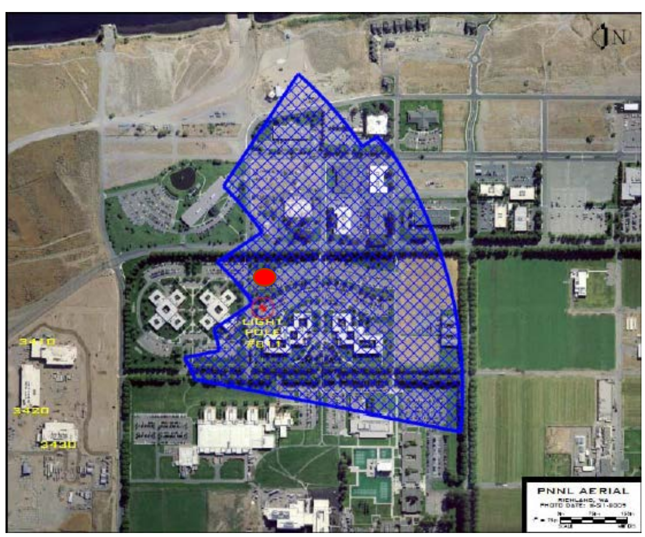

Figure 5.2. Red Circle Indicates the Location of the Proposed Monitoring Station. The Blue Hatchmarks Indicate Overlap of the Three "65% Regions" for the PSF Facilities (Barnett et al. 2010).

Subsequent changes to the 3410 stack configuration and Campus boundary indicate a more ideal location would be more distant in the SSE sector. After re-evaluation with updated meteorology and software, the SSE sector results indicate that the PNL-3 station (X/Q = 9.73E-7 s/m^3) is 88.4% of the maximum SSE sector fenceline value (X/Q = 1.10E-6 at 640 m SSE) for a 3410 Building emission. PNL-3 is 79% of the maximum offsite X/Q (1.23E-6 s/m^3) for a 3410 Building emission. PNL-3 remains adequate for monitoring 3410 Building emissions because it exceeds the 65% criteria (also see Figure 3.13, and Figure 5.5 through Figure 5.7 for all PSF facilities).

After the boundary expansion in 2012 (Revision 1 of the DQO), it was determined that an additional sampling location would be necessary to monitor potential particulate emissions from the RTL-520 minor emission units. The MEI for this location is 300 m SSE of RTL-520. However, the PNL-4 air sampling location was ultimately sited 500 m NW of RTL-520, which is equivalent to the RTL-520 MEI location based on modeling. Figure 5.3 is a visual representation of the data for both onsite and offsite acceptable locations, along with an indication of the location of the related monitoring station. This location represents a dominant NW sector region of higher X/Q values. Figure 5.4 from Revision 1 shows offsite and onsite data from Figure 5.3 in an alternative format, as well as boundary information. After re-evaluation with updated meteorology and software, this location remains adequate for PNL-4 (see Figure 3.13).

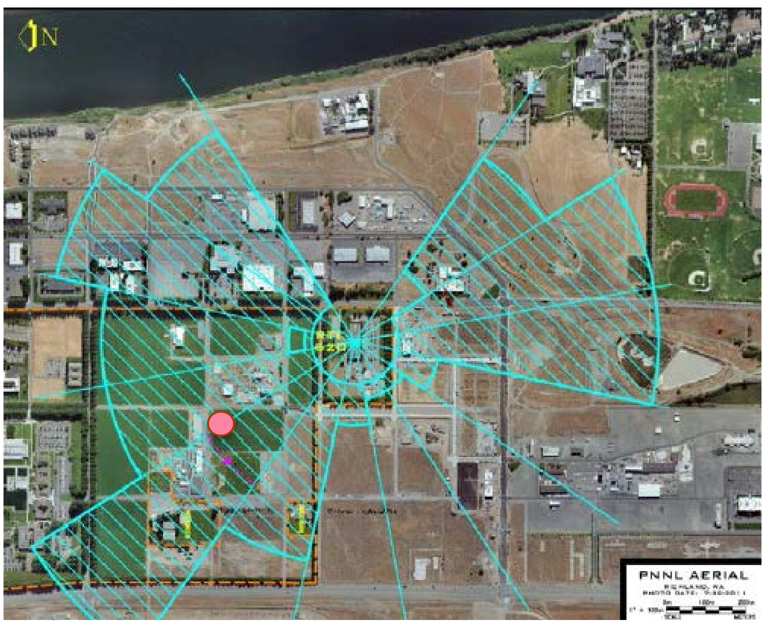

Figure 5.3. Offsite and Onsite Locations Relative to RTL-520 That Are at Least 65% of the RTL-520 MEI Air Concentration (PNL-4 location at pink circle)

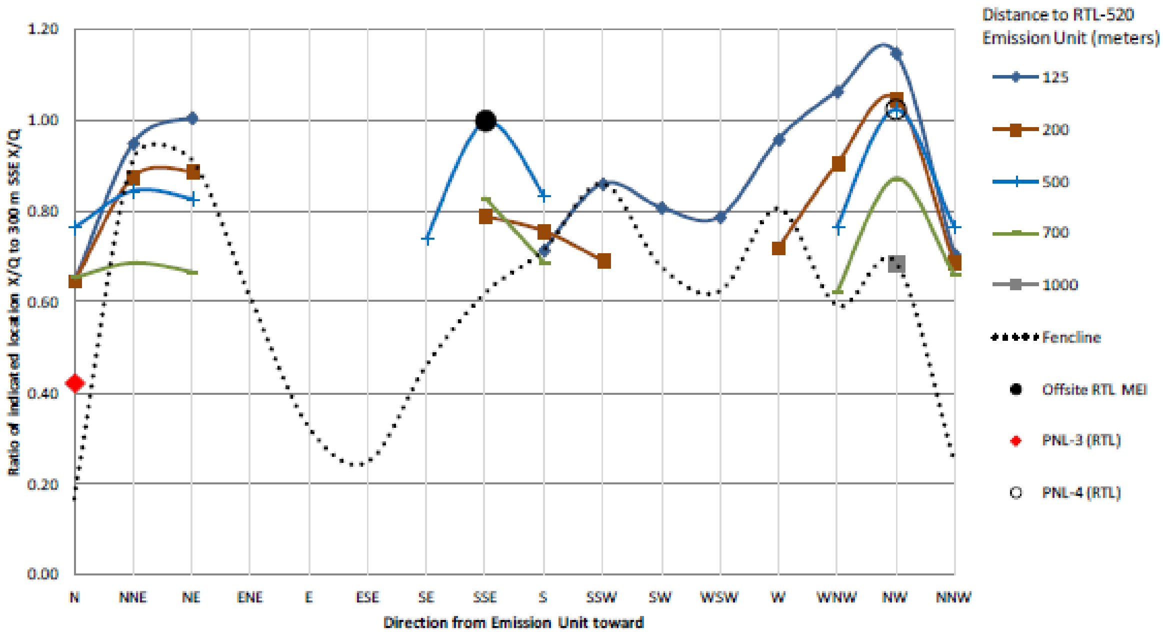

Figure 5.4. Offsite and Onsite: Air Concentration Ratios of Indicated Location, RTL-520 MEI Location, and Second Sampling Location when >65%

The 2017 fenceline, updated meteorology, and software were used to evaluate X/Q values for the three PSF facilities with major emission units. X/Qs were determined for fenceline locations and existing monitoring locations. Given the maturity of the environmental surveillance program and years of experience with facility operations, modeling for each individual PSF emission unit was done to aid in the current evaluation. Of particular interest was the northern boundary change to the fenceline and PNL-1 and PNL-2 X/Q values (see Figure 5.5 through Figure 5.7).

Relative to fenceline locations, modeling indicates that PNL-1 and -2 sample stations capture more than 75% of emissions from the PSF facilities and almost none from LSLII and RTL. These locations would lead to adequate but not necessarily conservative concentration measurements compared to those measured at fenceline or even offsite. PNL-3 is included in the graphs even though it is not a focus of this revised assessment.

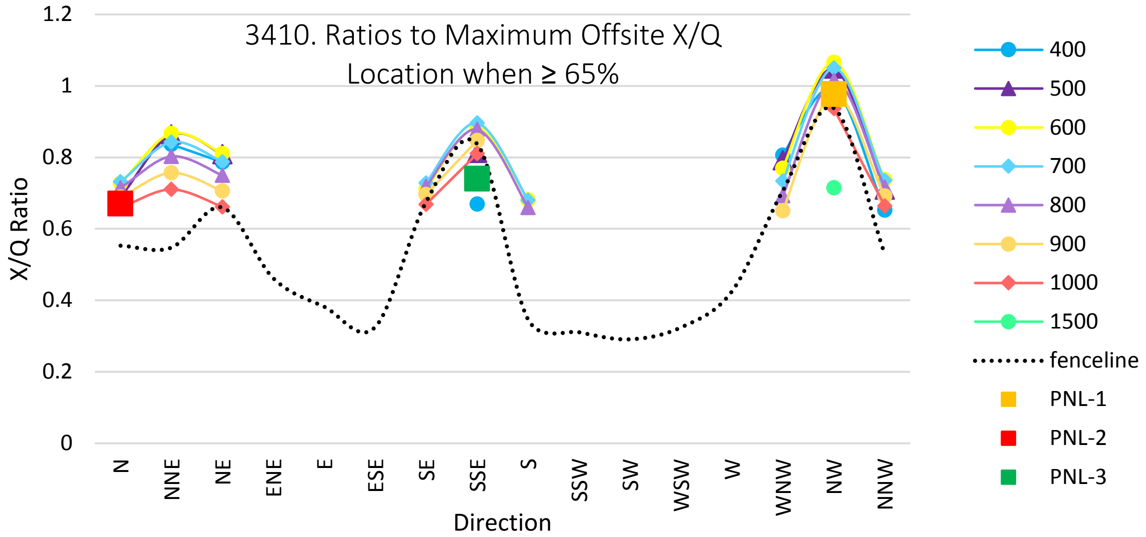

Figure 5.5. Air Concentration Ratios of 3410 Building Emissions. Location X/Q to Maximum Offsite X/Q (840 m NW of 3410; at fenceline) when >65% AND beyond the Campus Fenceline

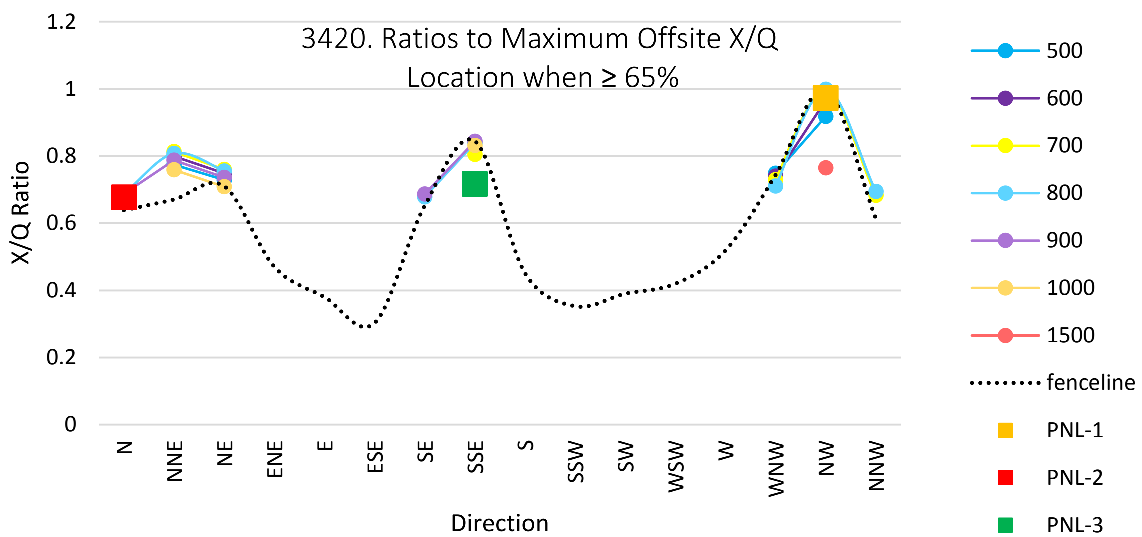

Figure 5.6. Air Concentration Ratios of 3420 Building Emissions. Location X/Q to Maximum Offsite X/Q (780 m NW of 3420; southbound lane of Stevens Drive) when >65% AND beyond the Campus Fenceline

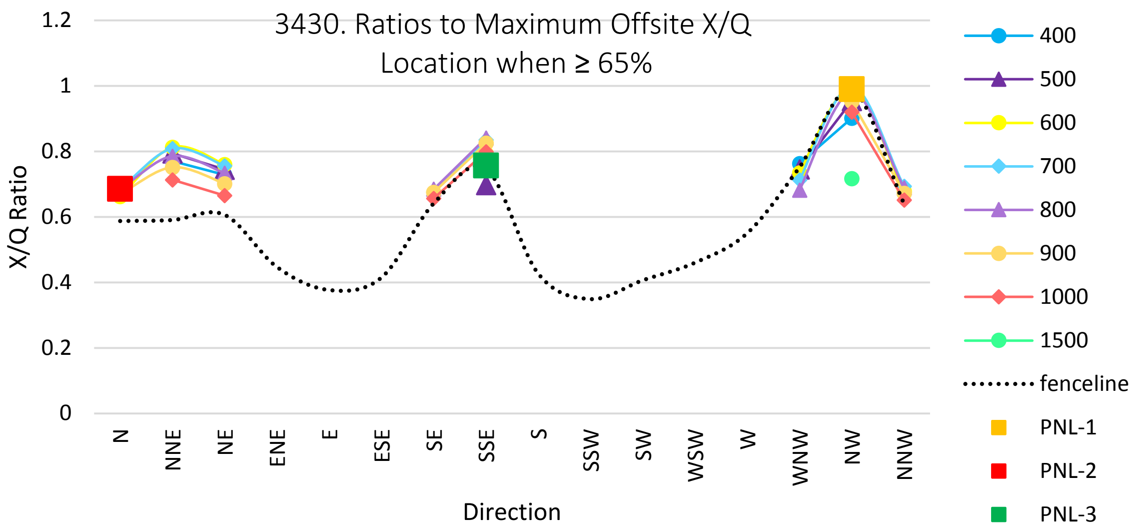

Figure 5.7. Air Concentration Ratios of 3430 Building Emissions. Location X/Q to Maximum Offsite X/Q (665 m NW of 3430; on private land between railroad tracks and Stevens Drive) when >65% AND beyond the Campus Fenceline

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 Figures 5.5 through 5.7, above. Areas associated with a 65% or greater capture for each facility's emissions are presented in Figure 5.8 through Figure 5.10. Figure 5.11 indicates the overlapping area of the these figures. The hatched areas indicate the same information presented in Figure 5.6 through Figure 5.7 for the NW sector. If the 3420 Building major emission unit flow rates are doubled, as described earlier in section 3.10 and Figure 3.15, the areas where a sampler would capture ≥ 65% of the maximum X/Q the 3420 Building emissions would correspond to that indicated in Figure 5.9 and Figure 5.13, but also cover an even broader area, beyond.

An additional regional assessment was done for the northern Campus area for both onsite and offsite locations because the PNL-2 station is onsite in that area. Figure 5.12 through Figure 5.15 display areas associated with the 65% or greater criteria in the northern Campus regions, all of which are onsite.

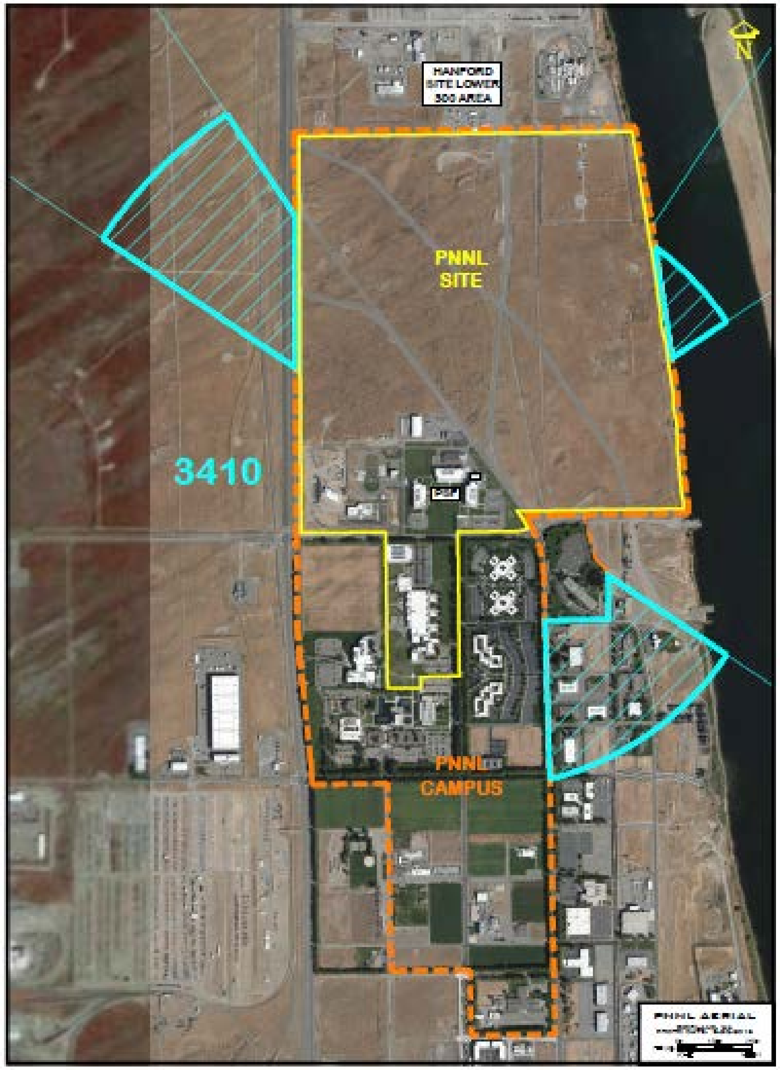

Figure 5.8. Hatched Areas Indicate Offsite Locations Acceptable for Siting a Particulate Monitoring Station for 3410 Building Emissions

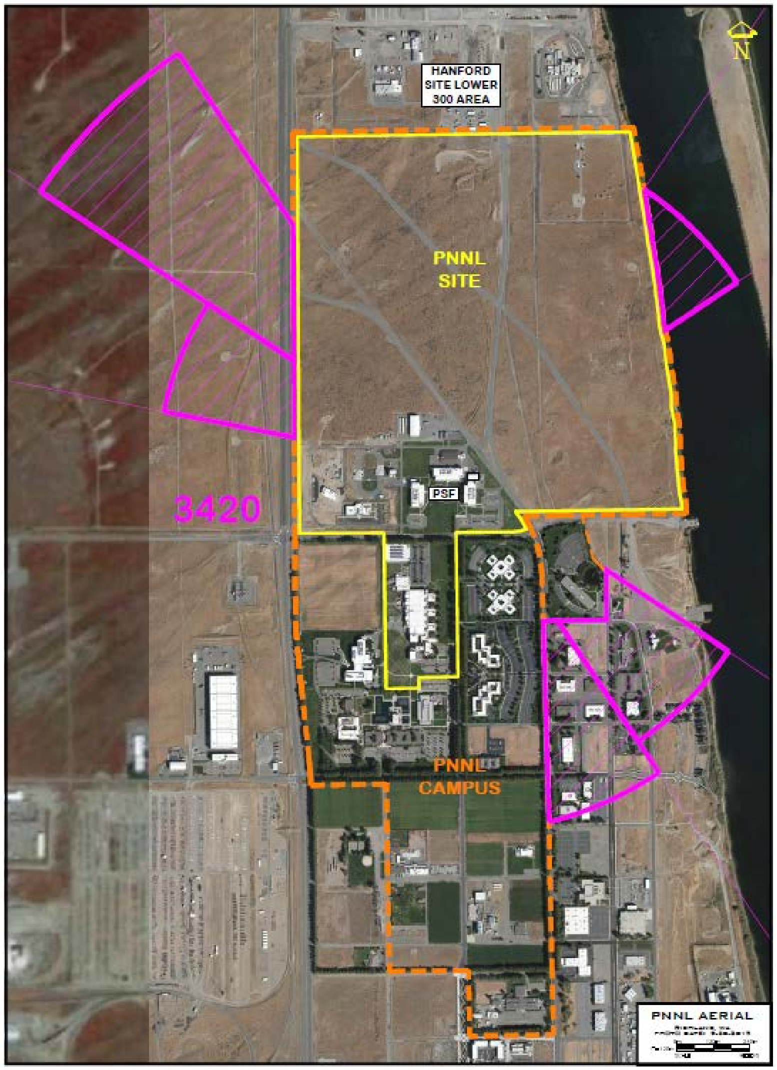

Figure 5.9. Hatched Areas Indicate Offsite Locations Acceptable for Siting a Particulate Monitoring Station for 3420 Building Emissions

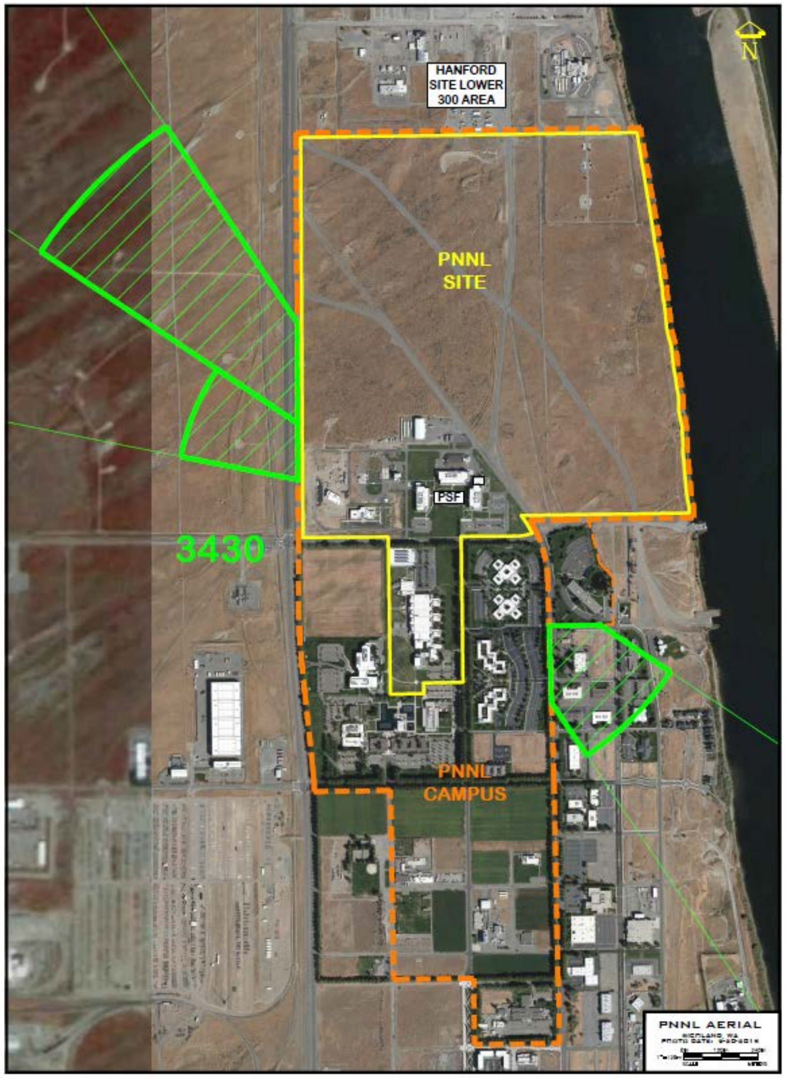

Figure 5.10. Hatched Areas Indicate Offsite Locations Acceptable for Siting a Particulate Monitoring Station for 3430 Building Emissions

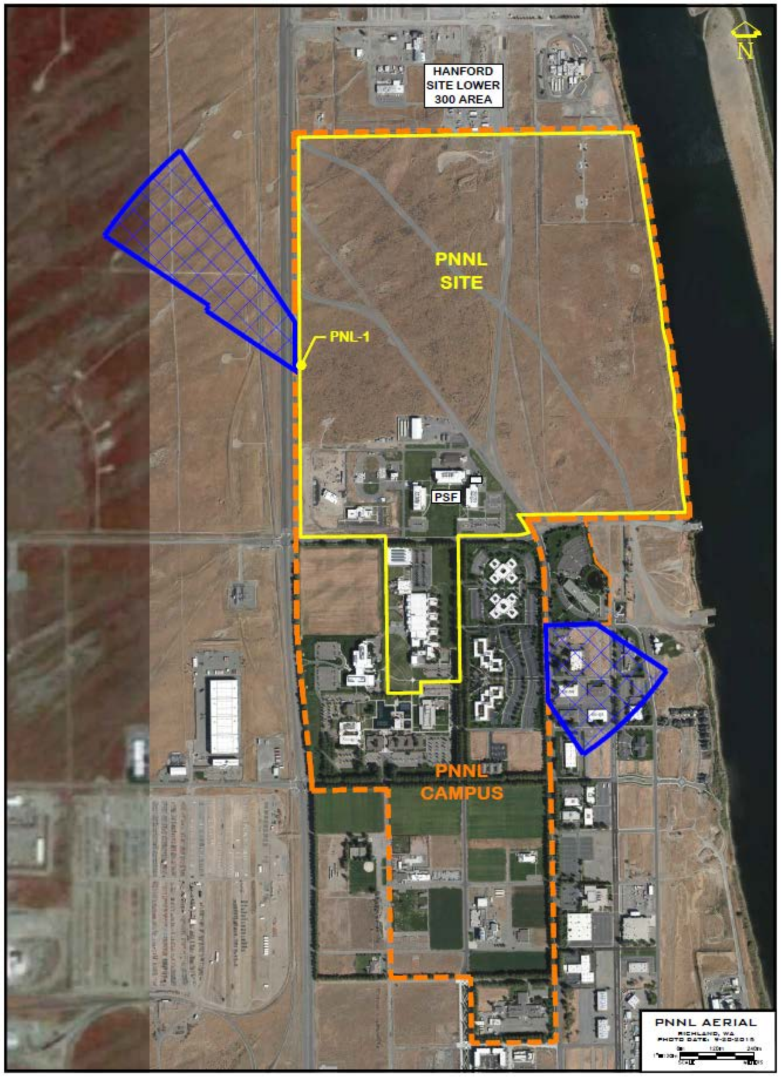

Figure 5.11. Hatched Areas Indicate Offsite Locations Acceptable for Siting a Particulate Monitoring Station for All Three PSF Building Emissions

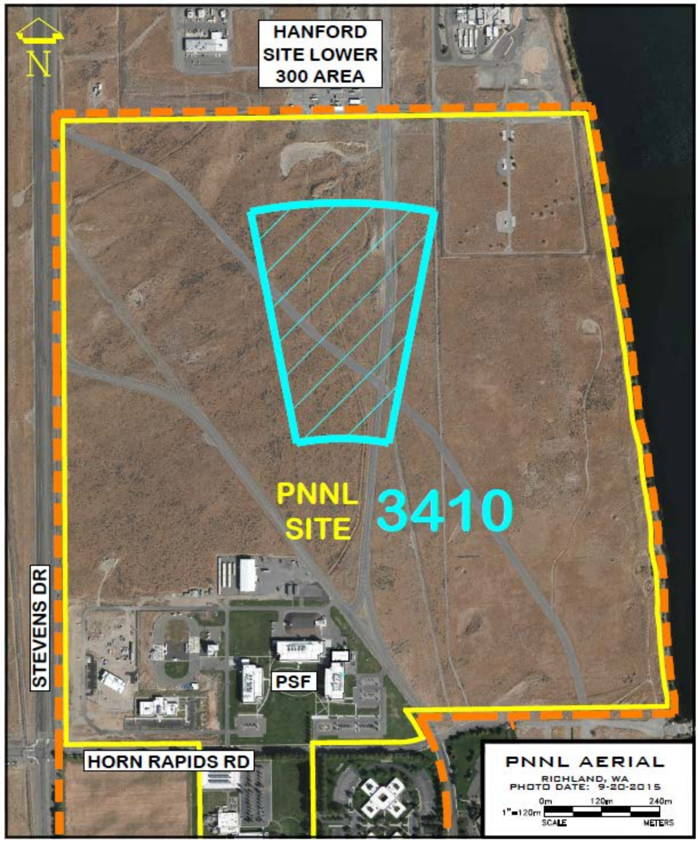

Figure 5.12. Hatched Area Indicates Onsite and Offsite Northern Campus Locations with ≥ 65% of maximum X/Q Ratios for a 3410 Building Particulate Emission

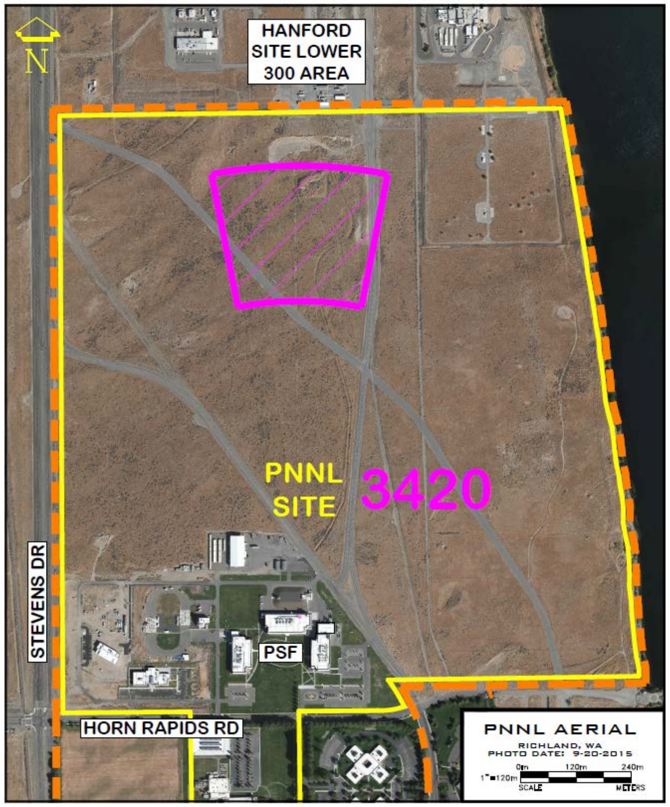

Figure 5.13. Hatched Area Indicates Onsite and Offsite Northern Campus Locations with ≥ 65% of maximum X/Q Ratios for a 3420 Building Particulate Emission

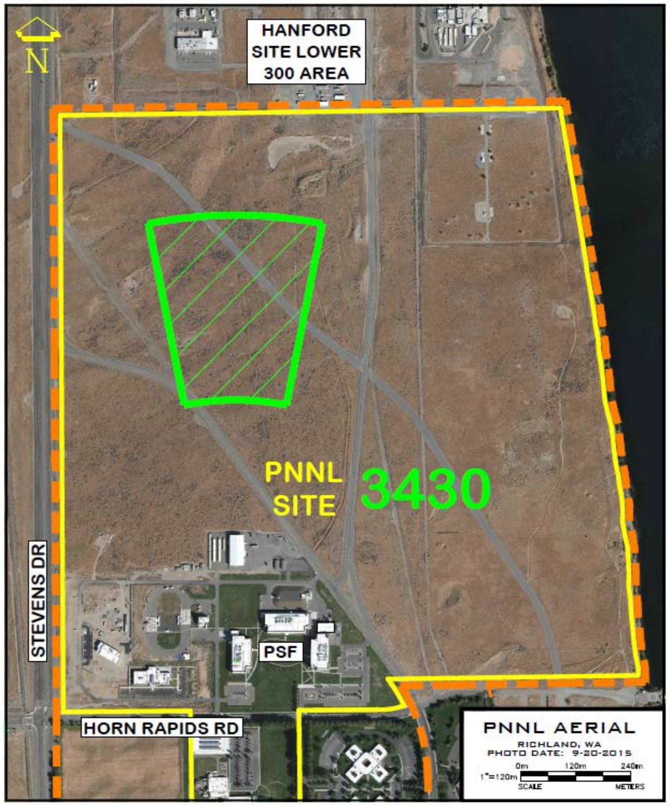

Figure 5.14. Hatched Area Indicates Onsite and Offsite Northern Campus Locations with ≥ 65% of maximum X/Q Ratios for a 3430 Building Particulate Emission

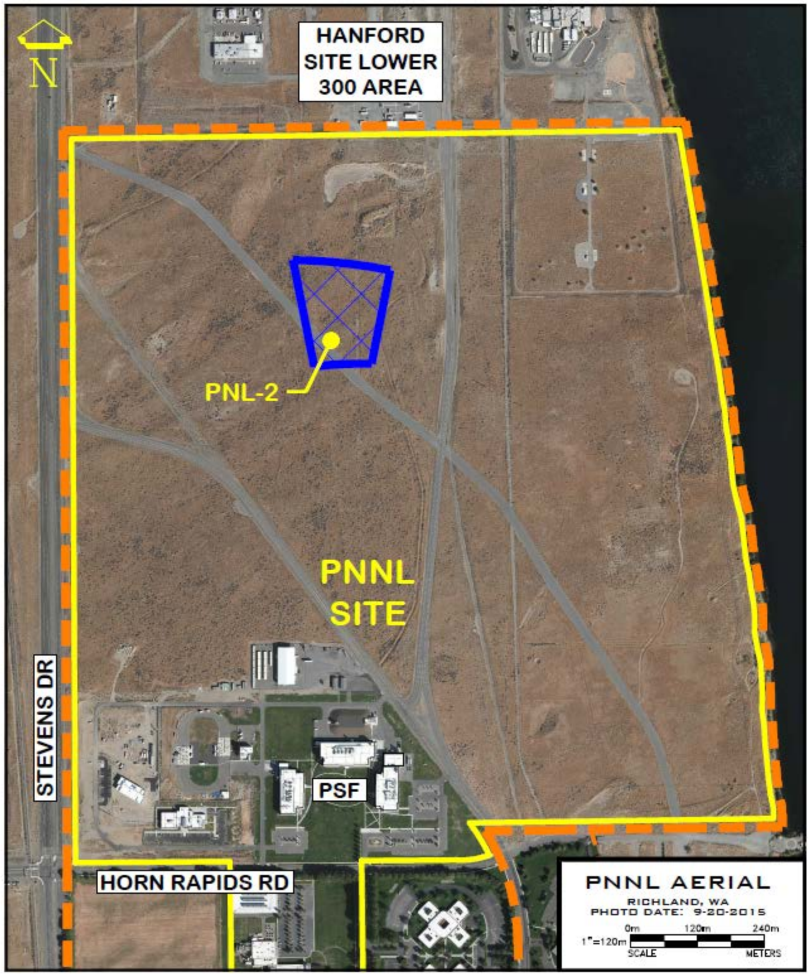

Figure 5.15. Hatched Area Indicates Northern Campus Locations Acceptable for Siting a Particulate Monitoring Station for All Three PSF Building Emissions

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 et al. 2015, Figure 5.16 indicates X/Q values at PNL-1 and PNL-2 from the 300 Area emissions.

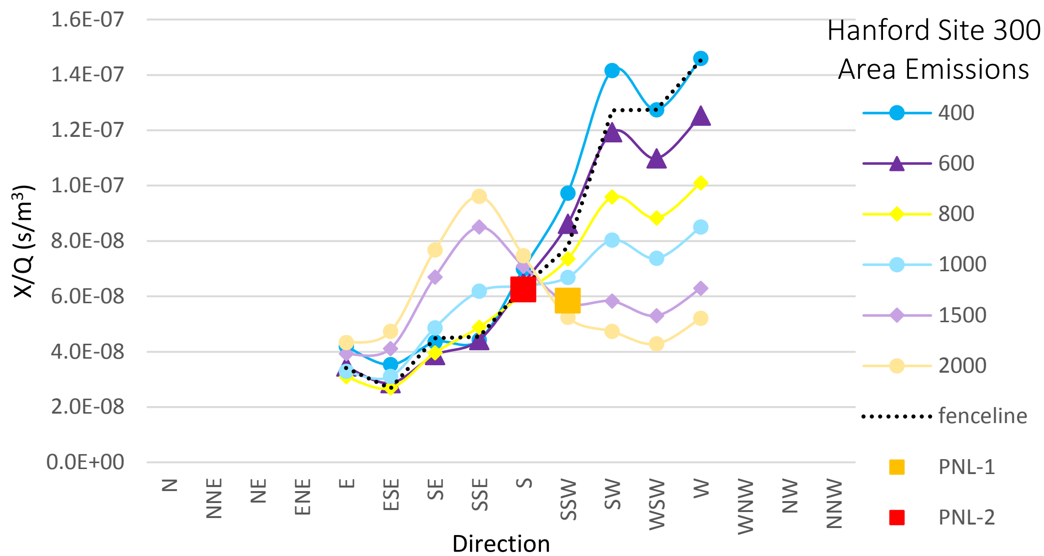

Figure 5.16. Hanford Site, 300 Area, RPL Emissions Dispersion Estimates to the Current Fenceline, Various Distances, and also PNL-1 and PNL-2

Figure 5.17 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, the modeling of the respective stack configurations indicates that the 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. Additionally, the wind only blows in the general direction from the Hanford Site 300 Area toward PNNL monitoring stations about 10% of the time. 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.

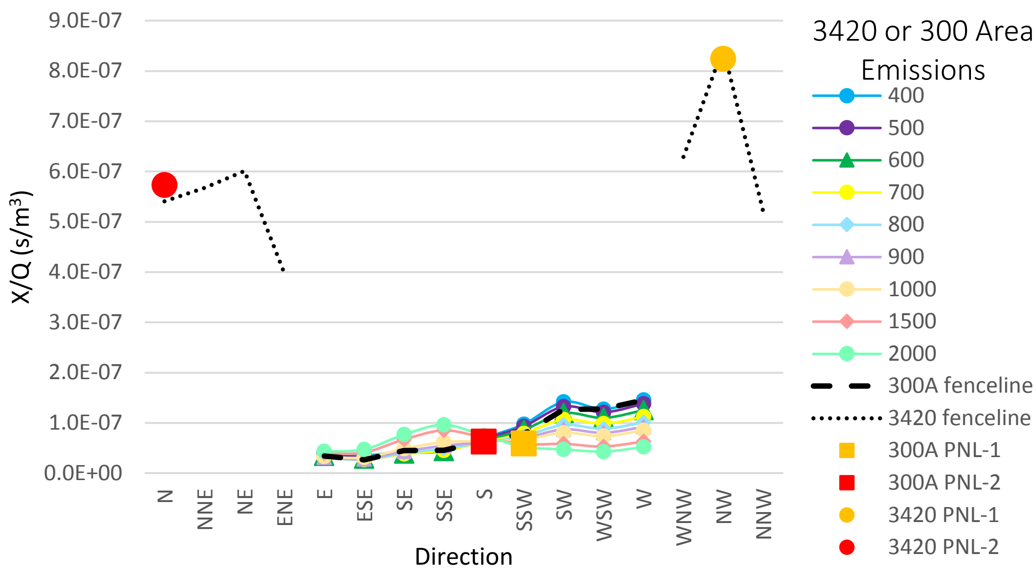

Figure 5.17. Relative to PNL-1 and PNL2, Particulate X/Q Results from 3420 Building Emissions and Hanford Site 300 Area Emissions

The question of the quantities of Hanford Site 300 Area particulate emissions compared to PSF particulate emissions was reviewed. Table 5.1 indicates the particulate emission rates of the PNNL Richland Campus and Hanford Site 300 Area according to each site's air emissions compliance reporting. The reported annual emissions include both measured and calculated particulate releases. These reported releases taken in conjunction with Figure 5.16 and Figure 5.17 show better capture for the Campus emissions at PNL-1 and PNL-2; while for the 300 Area only the PNL-2 sampling station appears to be adequate. Dispersion coefficients (X/Qs), representing emissions capture, at PNL-1 and PNL-2 are much better for releases from the Campus rather than from the 300 Area even though the 300 Area usually has higher particulate releases.

Table 5.1. PNNL Richland Campus and Hanford Site 300 Area Radioactive Particulate Emissions Summary

Calendar Year	PNNL Campus PSF (Ci/yr)	Hanford Site 300 Area (Ci/yr)
2012	1.2E-7	8.4E-6
2013	6.5E-5	4.1E-6
2014	1.4E-6	7.7E-6
2015	1.2E-5	1.3E-4
2016	1.2E-5	1.2E-4

Decision #4: Modeling results were used to determine how the current locations of air monitoring stations would adequately capture the PNNL Richland Campus emissions and adequately represent the preferred air monitoring 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 existing monitoring locations PNL-1, PNL-2, PNL-3, and PNL-4 determined that the number and location of the monitoring stations was still appropriate and adequate. It also determined no additional monitoring stations were necessary.

The PNL-3 station, 480 m SSE of the PSF 3410 Building emission unit at light pole #811, continues to be an adequate sampling station location. Updated modeling in this Revision 2 indicates that PNL-3 X/Q is 75% of the maximum offsite PSF X/Q, meeting the criteria that the sampling station capture at least 65% of the maximum offsite (NW) air concentration from routine emissions of the major emission units.

Modeling results indicate that the PNL-4, RTL-520 sampling location (500 m NW of RTL-520) remains adequately located to capture any RTL emissions.

5.4.2 Error Assessment #4

Based on the criteria of capturing at least 65% of the maximum fenceline emissions (i.e., PNL-1 X/Q for PSF emissions), the current locations of the environmental surveillance stations PNL-1 through PNL-4 remain adequate for monitoring radiological emissions from Campus facilities.

The locations were originally selected based on potential radionuclide release quantities, emission unit operations parameters, atmospheric modeling using site-specific meteorology collected over a long period, locations of occupied offsite facilities, and practical monitoring-station siting considerations. This re-evaluation considers updated fencelines, meteorology, and dispersion software to determine whether the locations monitored remain adequate.

To demonstrate compliance with the NESHAP dose standard, MEI impact estimates must be calculated annually. This calculation uses meteorology and release quantities (either measured or conservatively estimated) from emission units for the reporting year. Environmental surveillance program particulate sampling results from the specific year of interest would be used to confirm compliance with the standard.

Given the conservative assumptions that went into several steps of the process, any dose impact estimates calculated in CAP88-PC V4 for the existing sampling locations would likely overestimate any actual impacts to an MEI. Due to fenceline and stack configuration changes, the PNL-3 location would underestimate maximum impacts of Building 3410 emissions. It is the current practice to use the meteorology from the specific year of interest and the measured emission rates from Campus facilities to determine each year's MEI location, and the dose for the modeled maximum location is calculated to demonstrate compliance with the standard. Although the MEI location for a given year may differ slightly from the location selected for PNL-3, atmospheric dispersion conditions are sufficiently consistent from year to year that air concentrations at the sampling station should still be detectable to confirm compliance with the dose standard.

The locations of ambient air surveillance stations were based on the estimated offsite air concentrations from the PNNL Richland Campus emission units. Table 5.2 indicates the X/Q at the monitoring station locations from modeling emissions at each PSF major emission unit, as well as LSLII and RTL-520. The current PTE document (Snyder and Barnett 2016) indicates that the maximum public receptor location (530 m SSE of PSF) X/Q is 6.73E-6 sec/m^3. It also indicates the maximum fenceline location (currently unoccupied by a receptor) is located 500 m NW of PSF with a particulate X/Q of 8.86E-6 sec/m^3. These distances from the PTE document are based on the closest distance in the sector rather than the sector mid-points distances used in this revision.

The ambient air surveillance station 500 m NW of RTL-520 continues to provide concentration measurements similar to those expected at the offsite MEI location for RTL-520 emissions. Additionally, environmental modeling permits the calculation of the expected maximum air concentrations annually by use of each year's meteorological data. If air dispersion results for a particular year are abnormal, as determined by comparison with the long-term meteorological record, adjustments can be made. The error associated with monitoring somewhere other than the offsite maximum MEI location is considered acceptable.

If other changes occur that might affect sample collection or results from the proposed air monitoring station, their effect on the capability to detect potentially significant radionuclide air emissions from the Campus would be re-evaluated. Such events might include changes in operations at the PSF (e.g., major facility modifications or altered radionuclide inventories), construction of new offsite facilities near the Campus, and other activities near the proposed monitoring station. As circumstances require, the station could be relocated in response to those external events.

Table 5.2. Revision 2 X/Q Values (s/m^3) from the Emission Unit to Each Existing Environmental Surveillance Location

Emission Location		PNL-1[(a)] Location X/Q	PNL-2[(b)] Location X/Q	PNL-3[(c)] Location X/Q	PNL-4[(d)] Location X/Q
3410 Building	Location	730 m NW	800 m N	480 m SSE	1240 m S
	X/Q (s/m^3)	1.28E-06	8.82E-07	9.73E-07	6.36E-07
3420 Building	Location	620 m NW	730 m N	580 m SSE	1390 m S
	X/Q (s/m^3)	8.24E-07	5.73E-07	6.06E-07	4.37E-07
3430 Building	Location	600 m NW	800m N	560 m SSE	1310 m S
	X/Q (s/m^3)	1.06E-06	7.32E-07	8.08E-07	5.32E-07
LSLII	Location	1240 m NNW	1530 m N	370 m NE	590 m S
	X/Q (s/m^3)	1.08E-06	8.33E-07	1.97E-06	1.55E-06
RTL-520	Location	2270 m NNW	2510 m N	1200 m N	500 m NW
	X/Q (s/m^3)	6.06E-07	4.97E-07	1.20E-06	3.12E-06
Total	X/Q (s/m^3)	4.85E-06	3.52E-06	5.56E-06	6.28E-06

(a) PNL-1: 46º21'22.4", -119º16'59.7".
(b) PNL-2: 46º21'34.6", -119º16'37.3".
(c) PNL-3: 46º20'52.8", -119º16'28.4".
(d) PNL-4: 46º20'26.1", -119º16'41.9".

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

a. Consider all potential media (air, soil, water, food, etc.).

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 sampling program.

5.5.1 Decision #5

The air pathway is the only pathway that could contribute a significant dose to the hypothetical receptor that necessitates monitoring. The 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 the PSRP. PNNL Richland Campus operations contribute an extremely 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 Columbia River. Campus releases to water or soil resulting in radiation dose to aquatic and terrestrial biota are conservatively calculated (Duncan et al. 2016) and consistently below the radiation dose limits prescribed by DOE (2002). For this reason, all liquid pathways (e.g., irrigation, immersion, and ingestion) can be discounted and need not be considered further.

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. However, a small amount of food may be grown on the PNNL Richland Campus at garden plots maintained for staff use. If maximum NOC amounts of each radionuclide were released, unabated, only ^{60}Co would be of concern for ingestion. ^{60}Co 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 ^{60}Co.

Some fields on the PNNL Richland Campus south of PSF and south of LSLII have been rented out for commercial farming. This practice will be discontinued at the end of FY17.

Inhaling re-suspended dust containing PNNL Richland Campus emissions that had deposited on the ground is a potential exposure pathway. However, atmospheric monitoring 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 the emissions from the Campus are primarily (nearly exclusively) particulates, only particulate monitoring will be necessary. No monitoring of gaseous radionuclides is necessary.

Decision #5: Establish an environmental monitoring program that samples particulate radionuclides in air.

5.5.2 Error Assessment #5

All possible exposure routes (air, water, soil, food, and biota) were reviewed. No potential errors can be identified based on anticipated operations described in the NOCs. If operations at the PNNL Richland Campus 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 re-evaluated and implemented as necessary.

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

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

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) as referenced in WAC 246-247.

c. The regulatory guidance establishes the analytical and QA requirements that are applied to air monitoring networks.

d. 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.

e. 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 original Campus EMP was published in 2011 in four documents (Snyder et al. 2011 [main text]; Meier 2011 [EMP Att. 1]; Bisping 2011 [EMP Att. 2]; and Snyder 2011 [EMP Att. 3]).

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

5.6.1 Decision #6

The PNNL Richland Campus environmental monitoring program has matured since the publication of the first DQO report. Today, there are four Campus sampling sites for ambient air and a background monitoring station that have been sited and are operational; each station also has an environmental OSL dosimeter. Information regarding the environmental surveillance program is documented in the Campus EMP, data are maintained in a compliant database, and the program meets programmatic and regulatory needs. Sample collection, analysis, sample results, record-keeping, and reporting are done in a compliant manner. A review against DOE-HDBK-1216-2015 environmental surveillance requirements was completed in 2016.

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 procedures.

Additional guidance for program development may be found in National Council on Radiation Protection & Measurements (NCRP) Report No. 169, *Design of Effective Radiological Effluent Monitoring and Environmental Surveillance Programs* (NCRP 2012).

Decision #6: The Campus air monitoring network is composed of four air surveillance stations and a background surveillance station; it also includes environmental dosimeter with each station. A PSRP

Hanford Station is co-located with the Campus background station. The EMP (including the sampling and analysis plan) should be updated to describe the current ambient air surveillance program.

The new evaluations conducted for this DQO revision indicate the Campus air monitoring network of four air surveillance stations and a background station is still adequate.

5.6.2 Error Assessment #6

Based on the very well documented wind patterns in the 300 Area and the PNNL Richland Campus, current models indicate the likelihood that the four sampling locations are adequate and cover essential operating areas of the Campus. Background measurements provide an additional source of 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.

5.7 Question #7: Are there non-PNNL monitoring programs on or near the site that could be useful in design/implementation of the PNNL Richland Campus monitoring plan?

a. Are there any non-PNNL monitoring locations at or near the MEI location?

b. What radionuclides are monitored by other programs?

c. Are there any monitoring locations not at or near the MEI location that could provide concentration data useful to the Campus monitoring plan?

d. Are any data from other programs of sufficient quality to be used in conjunction with, or in lieu of, data collected by PNNL?

e. Are there procedures, equipment, infrastructure, analytical services contracts, or other useful aspects of other environmental monitoring programs that can be used for the PNNL Richland Campus?

Action #7: Identify what aspects, if any, of other monitoring programs that would be usable by the PNNL Richland Campus Site environmental monitoring program; consider results, procedures, locations and equipment.

5.7.1 Decision #7

The following information is summarized from the initial DQO, with updates that consider the current Campus ambient surveillance program. As of 2008, DOE collected environmental monitoring data for the nearby Hanford Site with a network operated as the Surface Environmental Surveillance Project (SESP), which was renamed Public Safety and Resource Protection (PSRP) in 2012. There are also a number of commercial operations, such as Energy Northwest, that conducted environmental monitoring near the Hanford Site and the PNNL Richland Campus. No non-PNNL monitoring programs' sample locations are ideal for particulate sampling of Campus emissions.

The PSRP Hanford network had several established monitoring locations that may be suitable to verify emissions from the PNNL Richland Campus. There are two existing stations in predominantly downwind directions where there would be a reasonable probability of detecting emissions from the PNNL Richland Campus. Information for radionuclides sampled as part of the PSRP monitoring program may be useful as supplementary data for interpretation and comparison with the Campus data. However, PSRP samples are not analyzed for all PNNL Richland Campus radionuclides of concern.

The PSRP has surveillance stations located to the NNW (N918) and N/NNE (N903) of PSF (Figure 2.3). These Hanford Site stations are about 1.2 km from the PSF and 10–50 m north of the newly modified fenceline at the new northern Campus boundary. For PSF emissions, the modeled X/Q values at those stations are around 60-70% of the modeled maximum ground level X/Qs from each PSF facility. The N903 station would be slightly more likely to capture PSF Building particulate emissions. There are no potential public receptors between the PSRP sampling locations and the PNNL facilities. Therefore, the established locations in the N/NNE and NNW sectors could provide adequate backup detection capability for radionuclide emissions from the Campus. A third existing station (N937) is located about 1.4 km in the S/SSW direction; the modeled X/Q at that location makes it less desirable for use as a monitoring station for PSF emissions, but it could be useful as backup for RTL emissions modeling.

Two types of background concentrations could be determined from the data reported by the PSRP: a regional background and a local background. A regional background would be the concentrations that might be expected if there were no Hanford Site emissions. Regional background concentrations would be represented by the concentrations measured in Yakima, Washington, by the PSRP. A local background would be indicative of the air concentrations that would exist at the Campus boundary if there were no Campus emissions. This local background could be determined by integrating concentrations of radionuclides reported by the PSRP near the Campus, but not near known emission sources. This would likely include four to six air samplers operated by the PSRP at locations more than 5 miles from the 300 Area and the PNNL Richland Campus, and less than 15 miles away from the Campus. Analysis of air samples collected on and around the Hanford Site by the PSRP does not include the quantification of ^{243}Am and ^{244}Cm concentrations (two isotopes of interest to the Campus); however, the other isotopic analyses and the gross radiological analyses conducted would provide sufficient data for PNNL Monitoring Program staff to determine either a regional or local background concentration for comparison purposes.

Additionally, the State of Washington and the Hanford Site PSRP currently operate air samplers near the Battelle Staff Association softball field location. This location was considered onsite to the Campus in the Revision 1 DQO, but is considered offsite in this revision because of the SW boundary change. As in the previous DQO revisions, a sampler located 400 m away from another program's monitoring locations would be considered co-located. This is particularly true at the spatial scale of the Hanford Site, but not necessarily so on the PNNL Richland Campus scale. Therefore, comparisons to PSRP results could, nevertheless, be made to PNL-4 results because of the relative proximity of the two stations.

Decision #7: Two existing Hanford Site PSRP monitoring stations (N918 and N903, DOE 2016) are located N/NNE and NNW of the PSF, respectively. They are just north of the new (2017) Campus boundary. These monitoring stations could be used for backup, but are not as ideally located as the currently established (PNL-1 and PNL-2) Campus surveillance stations. The equipment, procedures, and analytical methods employed by the PSRP may be suitable to provide comparable monitoring analysis for the Campus emissions.

Since 2012, the Hanford Site PSRP has been responsible for monitoring ambient air concentrations of radiological constituents from and around the Hanford Site; meteorological monitoring; and other natural resources type monitoring. The meteorological data collected at the 300 Area meteorological tower (see Figure 2.3) are the closest, and most representative, data for use in dispersion modeling from Campus stacks or diffuse sources. The meteorological data are essential and ambient air monitoring results are useful for the PNNL Richland Campus EMP. The meteorological data are necessary to conduct dispersion modeling. Hence, these data are important to the PNNL EMP.

While Hanford Site Yakima Station (N909) background monitoring results were used in the past, starting in 2017, the Campus background station PNL-5 in Benton City will be used for background reporting. The results from the Hanford Site background station in Yakima will remain available for use as backup and confirmatory measurements.

The PNNL Richland Campus will continue to use the Hanford Site 300 Area meteorological tower data. Hanford Site monitoring stations (N918, N903, and N937) are located near the PNNL Richland Campus such that they would be useful for the comparison of data or for potential backup data in lieu of some operational ambient air sampling failure at the Campus. The Yakima Station (N909) is no longer the source of the PNNL Richland Campus background data; however, it also could be used as a backup reference.

5.7.2 Error Assessment #7

The PNNL Richland Campus has a robust ambient air monitoring system consisting of four onsite stations and a background station. Bi-weekly sampling provides sufficient samples for overall program reliability. The use of PSRP monitoring results would be considered in the event of inadvertent loss of or failure to obtain Campus monitoring results. Not using the PSRP data has little overall impact to the overall Campus program. Loss of the annual meteorological data from the Hanford Site 300 Area could be sufficiently substituted with historical multi-year averaged data.

6.0 Optimization Guidelines

PNNL currently operates five ambient air monitoring stations: four within the Campus and one background station (see Figure 2.3). The WDOH administers an air permit for radiological air releases at the Hanford Site, the much larger DOE site located adjacent to the PNNL Richland Campus. The PSRP operates an air monitoring network in support of the Hanford Site Air Operating Permit (i.e., AIR-10-308). The methods and equipment used on that program are compatible with expected requirements for the PNNL Richland Campus. Two existing PSRP air monitoring stations in the 300 Area (see Figure 2.1) have been identified as potentially meeting the needs of the air monitoring program for the Campus.

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-in. glass-fiber filter paper. The filters are routinely analyzed for gross alpha activity and gross beta activity and periodically composited to analyze 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 2016).

PNNL uses two different types of particulate ambient air samplers: 1) a 24-V direct current solar operated system (Figure 6.1), and 2) a 120-V alternating current operated system (Figure 6.2); both samplers include an air volume meter, flow controller, and 1/4 HP vacuum pump contained in a sampling hutch. 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 semi-annual 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.

Figure 6.1. Example of 24-V solar operated particulate sampling system (PNL-2)

Figure 6.2. Example of 120-V AC operated particulate sampling system (PNL-4)

6.2 Analytical Detection Limits

Particulate air samples are submitted to an 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 minimum detectable activity (MDA). For the purposes of this report, the RDL is the calculated detection level from idealized sampling. The minimum detectable concentration of activity in an air sample (MDC) 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.

EPA expects a site to be able 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 build-up; dose includes ingrowth of progeny), the CAP88-PC V4 model was used to estimate the air concentration that would result a 1 mrem/yr receptor dose (Table 6.1). Under this modeling and 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 V4 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 a minimum detectable activity (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 mrem air concentrations" were multiplied by the nominal sampled volume of 10,400 m^3. The 10,400 m^3 sample volume is the 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 m^3/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 modeling indicates the sample MDA can be greater than Appendix E Table 2-based values, the Appendix E Table 2-based values are conservative (risk protective).

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 2016 sampling at all PNNL sample stations, are indicated in Table 6.1. The maximum 2016 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. Radionuclide-specific Sample Analysis Criteria with 2016 Results

Analyte	Annual Average Notification Value (10% Table 2)[(a)] (pCi/m^3)	CAP88-PC V4 Air Concentration for a 1 mrem/yr Annual Dose (pCi/m^3)	Average Sample MDCs, 2016 (pCi/m^3)	Maximum Sample MDCs, 2016 (pCi/m^3)	Nominal MDA 10% Appendix E, Table 2-Based (pCi)	Nominal MDA CAP88-PC V4- Based (pCi)
^{241}Am	1.9E-04	1.2E-03	1.7E-05	4.1E-05	2.0	12
^{243}Am	1.8E-04	1.2E-03	1.6E-05	2.9E-05	1.9	12
^{244}Cm[(b)]	2.6E-04[(c)]	1.6E-03[(c)]	1.2E-05	2.3E-05	2.7	17
^{60}Co	1.7E-03	1.6E-02	6.4E-04	1.1E-03	18	170
^{137}Cs	1.9E-03	1.1E-02	6.3E-04	1.2E-03	20	114
^{238}Pu	2.1E-04	1.1E-03	4.7E-06	9.1E-06	2.2	11
$^{239/240}Pu$[(d)]	2.0E-04	1.0E-03	5.1E-06	1.1E-05	2.1	10
^{233}U[(e)]	7.1E-04[(c)]	1.6E-02[(c)]	1.2E-05	2.9E-05	7.4	170

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

The analytical laboratory should meet a contractual MDC to assure that samples can be detected at concentrations of regulatory significance. The prior DQO laboratory contract-required RDLs are indicated in Table 6.2. These were based on past receptor assumptions and CAP88-PC Version 3 dose modeling. A review of these values against the Appendix E and CAP88-PC V4 values indicates that a the contract-required RDL should be revised so that the contract-required RDLs are based on the same level of risk (dose) using current modeling. The proposed laboratory contract-required RDL is 1% of the more conservative Appendix E Table 2 air concentration values, starting with the 2018 sampling. These values would 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 modeling would be expected to indicate radionuclide-specific doses of about 0.02 mrem. For reference, the nominal MDA corresponding to the proposed RDL and nominal 10,400 m^3 sample volume is also indicate in Table 6.2.

Table 6.2. PNNL Richland Campus Monitored Radionuclide Contract-required Detection Levels

Analyte	Prior DQOs Contract-required[(a)] RDL (pCi/m^3)	Proposed Contract-required RDL (pCi/m^3)	Annual Average 40 CFR Part 61, Appendix E, Table 2 (1% Table 2)[(b)] (pCi/m^3)	Nominal MDA 1% Appendix E, Table 2-Based (pCi)
^{241}Am	5.0E-05	1.9E-05	1.9E-05	0.20
^{243}Am	5.0E-05	1.8E-05	1.8E-05	0.19
^{244}Cm[(c)]	5.0E-05	2.6E-05	2.6E-05	0.27
^{60}Co	1.5E-03	1.7E-04	1.7E-04	1.8
^{137}Cs	1.1E-01	1.9E-04	1.9E-04	2.0
^{238}Pu	5.0E-06	2.1E-05	2.1E-05	0.22
$^{239/240}$Pu[(d)]	5.0E-06	2.0E-05	2.0E-05	0.21
^{233}U[(e)]	5.0E-05	7.1E-05	7.1E-05	0.74

(a) CY2017 contract with the analytical laboratory, based on ideal sampling and semiannual composites (see EMP, Attachment 1 [Meier 2011] for details).
(b) Table 2 of 40 CFR Part 61, Appendix E.
(c) Analytical laboratory provides combined $^{243/244}$Cm results. $^{243/244}$Cm combined sample conservatively based on lower ^{243}Cm value.
(d) Analytical laboratory provides combined $^{239/240}$Pu results.
(e) Analytical laboratory provides combined $^{233/234}$U results. $^{233/234}$U combined sample conservatively based on lower ^{233}U value.
RDL = required detection level
MDC = minimum detectable concentration

Gross alpha and gross beta/gamma samples are collected biweekly. 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. However, gross alpha and gross beta/gamma in air filters is routinely part of the analytical laboratory’s intercomparison performance testing protocol.

Contract-required RDLs are specified for gross alpha and gross beta analyses. The values in the current contract are listed in Table 6.3; the gross alpha value is a historically used value and gross beta results are based on 10% of the Appendix E Table 2 value for ^{137}Cs. 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 2016 Campus air samples.

In order to provide a uniform technical basis for the gross alpha and gross beta contract-required RDLs, 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) is determined. From Table 6.1, this would be $^{239/240}$Pu. ^{239}Pu is commonly used as the nuclide to represent a generic alpha-emitter (e.g., see Snyder et al. 2017).

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 MDCs would be expected.

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 the fact 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 contract-required RDLs in biweekly gross alpha samples would be acceptable. In addition, gross alpha results at this RDL level over a 10 bi-week period (40% of the year) may drive the need for an early composite analysis if no other reason for the elevated results are known (e.g., an offsite gross-alpha release event).

In the same manner, a similar technical basis is applied for the gross beta RDL.

a. The site-specific beta/gamma-emitter with the lowest air concentration limit using current modeling (i.e., CAP88-PC V4) is determined. From Table 6.1, this would be ^{60}Co, the only beta/gamma emitter currently requiring ambient sampling. However, ^{137}Cs 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. 2017).

b. The annual air concentration for ^{137}Cs that results in a 1 mrem annual dose from CAP88-PC V4 modeling is determined (1.1E-2 pCi/m^3). This ^{137}Cs value is more limiting than the ^{60}Co value from Table 6.1 (1.6E-2 pCi/m^3). In order to meet the ^{137}Cs detection level, the analytical laboratory would evaluate samples (e.g., consider counting time) so that a lower MDCs would be expected. In fact, currently, routine MDCs are in the range of 5E-04 pCi/m^3.

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 proposed 1.1E-2 pCi/m^3 RDL that is based on a nuclide-specific 1 mrem/yr ^{137}Cs-based level. Radionuclide-specific analyses cover a full suite of beta and gamma emitters[1] beyond the Campus required ^{60}Co. Due to the large contributions of non-Campus emissions to gross

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

beta/gamma results, gross beta analyses would not be particularly informative for Campus emissions monitoring but could be indicative of offsite sources.

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

Analyte	2017 Contract-required[(a)] RDL (pCi/m^3)	Proposed Contract-required RDL (pCi/m^3)	2016 Laboratory reported MDCs (min-max pCi/m^3)	Nominal MDA[(b)] of 2017 Contract-required RDLs (pCi)	Nominal MDA[(b)] Proposed Contract-required RDL (pCi)
Gross alpha	1.0E-03	1.0E-03	3.2E-04 – 6.7E-04	0.8	0.8
Gross beta	1.9E-03	1.1E-02	4.0E-04 – 7.5E-04	1.5	8.8

(a) CY2017 contract with the analytical laboratory.
(b) Based on nominal 800 m3 biweekly sample volume.
RDL = required detection level
MDC = minimum detectable concentration
MDA = minimum detectable activity

7.0 References

40 CFR Part 61, Subpart H. 2002. "National Emission Standards for Radionuclides Other Than Radon from Department of Energy Facilities." *U.S. Code of Federal Regulations*, U.S. Environmental Protection Agency.

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

Ballinger MY, TL Gervais, JM Barnett. 2012. *Potential Impact Categories for Radiological Air Emissions Monitoring*. PNNL-19904, Rev. 4, Effluent Management, Pacific Northwest National Laboratory, Richland, Washington.

Barnett JM, KM Meier, SF Snyder, BG Fritz, TM Poston, K Rhoads. 2010. *Data Quality Objectives Supporting Radiological Air Emissions Monitoring for the PNNL Site*. PNNL-19427, Pacific Northwest National Laboratory, Richland, Washington.

Barnett JM, KM Meier, SF Snyder, BG Fritz, TM Poston, E Antonio. 2012. *Data Quality Objectives Supporting Radiological Air Emissions Monitoring for the PNNL Site*. PNNL-19427, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

Barnett JM, MY Ballinger, TL Gervais. 2015. *Pacific Northwest National Laboratory Facility Radionuclide Emission Units and Sampling Systems*. PNNL-15992, Rev. 3, Pacific Northwest National Laboratory, Richland, Washington.

Bauer RG, V Johnson, RL Dirkes, TM Poston, BL Tiller, JL Downs, and N Lane. 2005. *100-NR-2 Groundwater Operable Unit Ecological Risk Assessment Data Quality Objectives Summary Report*. WMP-23141. Fluor Hanford, Richland, Washington.

Bisping LE. 2016. *Air Particulate/Dosimeter Sampling and Routine Maintenance of Environmental Monitoring Stations for the PNNL Campus*. EPRP-AIR-029, Rev. 3, Pacific Northwest National Laboratory, Richland, Washington.

Bisping LE. 2011. *EMP Attachment 2, DOE-SC PNNL Site, Data Management Plan*. PNNL-20919-2, Pacific Northwest National Laboratory, Richland, Washington.

DOE. 1991. *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*. DOE/EH-0173T. U.S. Department of Energy, Washington, D.C.

DOE. 2002. *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*. DOE-STD-1153-2002. U.S. Department of Energy, Washington, D.C.

DOE. 2015. *Environmental Radiological Effluent Monitoring and Environmental Surveillance*. DOE-HDBK-1216-2015, U.S. Department of Energy, Washington, D.C.

DOE. 2016. *Hanford Site Environmental Report for Calendar Year 2015*. DOE-RL-2016-33, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE Order 458.1, "Radiation Protection of the Public and Environment." U.S. Department of Energy, Washington, D.C.

Duncan, JP (ed.), KW Burk, MA Chamness, RA Fowler, BG Fritz, PL Hendrickson, EP Kennedy, GV Last, TM Poston, MR Sackschewsky, MJ Scott, SF Snyder, MD Sweeney, and PD Thorne . 2007. *Hanford Site National Environmental Policy Act (NEPA) Characterization*. PNNL-6415 Rev. 18, Pacific Northwest National Laboratory, Richland, Washington.

Duncan, JP, MR Sackschewsky, HT Tilden, TW Moon, JM Barnett, BG Fritz, GA Stoetzel, J Su-Coker, BY Ballinger, JM Becker, and JL Mendez. 2016. *Pacific Northwest National Laboratory Annual Site Environmental Report for Calendar Year 2015*. PNNL-25738, Pacific Northwest National Laboratory, Richland, Washington.

EPA. 2006. *Guidance on Systematic Planning Using the Data Quality Objective Process (EPA QA/G-4)*. EPA/240/B-06/001, U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC.

EPA. 2007. *Systematic Planning: A Case Study of Particulate Matter Ambient Air Monitoring, EPA QA/CS-2*. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC.

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.

Hoitink DJ, KW Burk, JV Ramsdell, and WJ Shaw. 2005. *Hanford Site Climatological Data Summary Calendar Year 2004 with Historical Data*. PNNL-15160, Pacific Northwest National Laboratory, Richland, Washington. Online at: http://hanford-site.pnl.gov/envreport/2004/15160.htm

ICRP—International Commission on Radiological Protection. 2008. *Nuclear Decay Data for Dosimetric Calculations*. ICRP Publication 107, Ann.ICRP 38(3).

Meier KM. 2011. *EMP Attachment 1, DOE-SC PNNL Site, Sampling and Analysis Plan*. PNNL-20919-1, Pacific Northwest National Laboratory, Richland, Washington.

NCRP. 2012. *Design of Effective Radiological Effluent Monitoring and Environmental Surveillance Programs*. NCRP Report No. 169, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

Rosnick RJ. 2007. *CAP88-PC Version 3.0 User Guide*. Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington, DC.

Rosnick RJ. 2015. *CAP88-PC Version 4.0[.1.17] User Guide*. Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington, DC.

Snyder SF. 2011. *EMP Attachment 3, DOE-SC PNNL Site, Dose Assessment Guidance*. PNNL-20919-3, Pacific Northwest National Laboratory, Richland, Washington.

Snyder SF, KM Meier, JM Barnett, LE Bisping, TM Poston, and K Rhoads. 2011. *Pacific Northwest Site Office Environmental Monitoring Plan for the DOE-SC PNNL Site*. PNNL-20919, Pacific Northwest National Laboratory, Richland, Washington.

Snyder SF and JM Barnett. 2016. *PNNL Campus Dose-per-Unit-Release Factors for Calculating Radionuclide Emissions Potential-to-Emit Doses*. PNNL-17847, Rev.4, Pacific Northwest National Laboratory, Richland, Washington.

Snyder SF, JM Barnett, and LE Bisping. 2017. PNNL Richland Campus Radionuclide Air Emissions Report for Calendar Year 2016. PNNL-20436-7, Pacific Northwest National Laboratory, Richland, Washington.

WAC 173-480. 2007. "Ambient Air Quality Standards and Emission Limits for Radionuclides." *Washington Administrative Code*, Statute Law Committee, Washington State, Olympia, Washington.

WAC 246-247. 2017. "Radiation Protection – Air Emissions." *Washington Administrative Code*, Statute Law Committee, Washington State, Olympia, Washington.

WDOH. 2015. *Radioactive Air Emissions License for the Department of Energy Office of Science, Pacific Northwest National Laboratory Site, License Number RAEL-005*, Issued by the Washington State Department of Health, Office of Radiation Protection, Olympia, Washington, June 17, 2015.

Wiemers KD, ME Lerchen, and MS Miller. 1999. *Regulatory Data Quality Objectives Supporting Tank Waste Remediation System Privatization Project*. PNNL-12040, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Appendix A

Meteorological Data

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 based on more recent data from 2004-2013 and is used in this DQO revision.

Table A.1. 1983-2006 Meteorology

Average	Atmospheric Stability Class	1983-2006 – Percentage of Time Wind Blows in the 300 Area toward the Direction Indicated															
Wind Speed	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

References

Barnett, JM, KM Meier, SF Snyder, BG Fritz, TM Poston, K Rhoads. 2010. *Data Quality Objectives Supporting Radiological Air Emissions Monitoring for the PNNL Site*. PNNL-19427, Pacific Northwest National Laboratory, Richland, Washington.

Barnett, JM, KM Meier, SF Snyder, BG Fritz, TM Poston, E Antonio. 2012. *Data Quality Objectives Supporting Radiological Air Emissions Monitoring for the PNNL Site*. PNNL-19427, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

Duncan, JP (ed), KW Burk, MA Chamness, RA Fowler, BG Fritz, PL Hendrickson, EP Kennedy, GV Last, TM Poston, MR Sackschewsky, MJ Scott, SF Snyder, MD Sweeney, and PD Thorne. 2007.

Hanford Site National Environmental Policy Act (NEPA) Characterization. PNNL-6415 Rev. 18, Pacific Northwest National Laboratory, Richland, Washington.

Appendix B

Chi-over-Q Tables

Appendix B

Chi-over-Q Tables

The Chi/Q values listed here use a more recent meteorology and current stack configurations, and were modeled using CAP88-PC Version 4.0.1.17 (V4).

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

	Distance (meters)													
Direction	100	200	300	400	500	600	700	800	900	1000	1500	2000	5000	10000
N	6.23E-07	6.85E-07	6.81E-07	7.60E-07	8.49E-07	8.97E-07	9.02E-07	8.82E-07	8.49E-07	8.13E-07	6.07E-07	4.67E-07	1.64E-07	6.93E-08
NNE	1.10E-06	1.14E-06	1.02E-06	1.03E-06	1.07E-06	1.07E-06	1.04E-06	9.90E-07	9.33E-07	8.76E-07	6.18E-07	4.61E-07	1.54E-07	6.36E-08
NE	1.08E-06	1.10E-06	9.76E-07	9.70E-07	9.97E-07	9.99E-07	9.71E-07	9.24E-07	8.70E-07	8.15E-07	5.72E-07	4.25E-07	1.40E-07	5.80E-08
ENE	5.41E-07	5.22E-07	4.89E-07	5.33E-07	5.87E-07	6.15E-07	6.14E-07	5.95E-07	5.69E-07	5.40E-07	3.91E-07	2.95E-07	9.95E-08	4.07E-08
E	2.84E-07	2.92E-07	3.18E-07	3.91E-07	4.59E-07	4.95E-07	5.03E-07	4.93E-07	4.75E-07	4.54E-07	3.34E-07	2.55E-07	8.67E-08	3.53E-08
ESE	2.48E-07	2.47E-07	3.00E-07	4.02E-07	4.94E-07	5.46E-07	5.63E-07	5.60E-07	5.46E-07	5.28E-07	4.04E-07	3.15E-07	1.12E-07	4.61E-08
SE	2.85E-07	3.36E-07	4.68E-07	6.52E-07	7.99E-07	8.77E-07	8.98E-07	8.86E-07	8.58E-07	8.25E-07	6.20E-07	4.79E-07	1.69E-07	7.10E-08
SSE	2.79E-07	3.82E-07	5.89E-07	8.26E-07	1.00E-06	1.09E-06	1.11E-06	1.08E-06	1.05E-06	9.99E-07	7.44E-07	5.72E-07	2.01E-07	8.61E-08
S	4.51E-07	5.36E-07	6.05E-07	7.12E-07	8.00E-07	8.40E-07	8.38E-07	8.13E-07	7.79E-07	7.41E-07	5.45E-07	4.17E-07	1.46E-07	6.26E-08
SSW	6.18E-07	7.00E-07	6.39E-07	6.15E-07	5.95E-07	5.67E-07	5.30E-07	4.91E-07	4.53E-07	4.19E-07	2.86E-07	2.10E-07	6.81E-08	2.81E-08
SW	9.25E-07	9.66E-07	7.73E-07	6.51E-07	5.68E-07	5.03E-07	4.46E-07	3.98E-07	3.57E-07	3.22E-07	2.06E-07	1.46E-07	4.43E-08	1.77E-08
WSW	7.94E-07	8.85E-07	7.10E-07	5.94E-07	5.17E-07	4.56E-07	4.04E-07	3.59E-07	3.22E-07	2.90E-07	1.84E-07	1.29E-07	3.85E-08	1.53E-08
W	9.15E-07	1.01E-06	8.19E-07	6.99E-07	6.21E-07	5.58E-07	5.02E-07	4.52E-07	4.09E-07	3.71E-07	2.42E-07	1.73E-07	5.35E-08	2.16E-08
WNW	1.17E-06	1.23E-06	1.05E-06	9.94E-07	9.76E-07	9.49E-07	9.05E-07	8.53E-07	8.02E-07	7.54E-07	5.41E-07	4.10E-07	1.41E-07	6.00E-08
NW	1.09E-06	1.23E-06	1.17E-06	1.22E-06	1.29E-06	1.32E-06	1.30E-06	1.25E-06	1.20E-06	1.16E-06	8.82E-07	6.93E-07	2.55E-07	1.12E-07
NNW	6.28E-07	7.41E-07	7.43E-07	8.04E-07	8.75E-07	9.09E-07	9.07E-07	8.84E-07	8.53E-07	8.19E-07	6.22E-07	4.86E-07	1.75E-07	7.51E-08

Table B.2. Chi/Q (sec/m^3) for 3420 Building Stack Parameters – Effective Stack Height with Buoyant and Momentum Plume Rise

	Distance (meters)													
Direction	100	200	300	400	500	600	700	800	900	1000	1500	2000	5000	10000
N	3.20E-07	4.72E-07	4.32E-07	4.39E-07	4.82E-07	5.32E-07	5.67E-07	5.83E-07	5.82E-07	5.73E-07	4.55E-07	3.68E-07	1.43E-07	6.20E-08
NNE	5.64E-07	8.06E-07	6.93E-07	6.49E-07	6.56E-07	6.77E-07	6.88E-07	6.84E-07	6.67E-07	6.43E-07	4.82E-07	3.75E-07	1.36E-07	5.79E-08
NE	5.57E-07	7.87E-07	6.68E-07	6.17E-07	6.17E-07	6.34E-07	6.44E-07	6.39E-07	6.23E-07	6.00E-07	4.49E-07	3.48E-07	1.25E-07	5.31E-08
ENE	2.83E-07	3.75E-07	3.18E-07	3.13E-07	3.38E-07	3.69E-07	3.90E-07	3.98E-07	3.96E-07	3.87E-07	3.00E-07	2.37E-07	8.82E-08	3.73E-08
E	1.48E-07	2.03E-07	1.87E-07	2.08E-07	2.47E-07	2.85E-07	3.11E-07	3.23E-07	3.25E-07	3.21E-07	2.54E-07	2.03E-07	7.65E-08	3.22E-08
ESE	1.31E-07	1.70E-07	1.63E-07	1.99E-07	2.53E-07	3.04E-07	3.40E-07	3.59E-07	3.65E-07	3.64E-07	2.98E-07	2.45E-07	9.72E-08	4.15E-08
SE	1.46E-07	2.16E-07	2.36E-07	3.15E-07	4.10E-07	4.93E-07	5.48E-07	5.75E-07	5.82E-07	5.76E-07	4.64E-07	3.77E-07	1.47E-07	6.35E-08
SSE	1.43E-07	2.28E-07	2.84E-07	3.98E-07	5.20E-07	6.19E-07	6.82E-07	7.11E-07	7.15E-07	7.05E-07	5.61E-07	4.52E-07	1.75E-07	7.63E-08
S	2.32E-07	3.52E-07	3.56E-07	3.96E-07	4.51E-07	5.01E-07	5.33E-07	5.44E-07	5.41E-07	5.29E-07	4.14E-07	3.31E-07	1.27E-07	5.54E-08
SSW	3.14E-07	4.83E-07	4.35E-07	4.04E-07	3.92E-07	3.84E-07	3.73E-07	3.57E-07	3.38E-07	3.19E-07	2.28E-07	1.73E-07	6.05E-08	2.54E-08
SW	4.74E-07	6.92E-07	5.73E-07	4.78E-07	4.17E-07	3.74E-07	3.39E-07	3.09E-07	2.82E-07	2.58E-07	1.71E-07	1.24E-07	4.00E-08	1.63E-08
WSW	3.99E-07	6.27E-07	5.27E-07	4.39E-07	3.81E-07	3.40E-07	3.08E-07	2.80E-07	2.55E-07	2.33E-07	1.53E-07	1.11E-07	3.49E-08	1.40E-08
W	4.61E-07	7.18E-07	6.04E-07	5.08E-07	4.48E-07	4.07E-07	3.75E-07	3.45E-07	3.18E-07	2.93E-07	1.98E-07	1.46E-07	4.79E-08	1.96E-08
WNW	5.96E-07	8.73E-07	7.40E-07	6.61E-07	6.34E-07	6.27E-07	6.18E-07	6.02E-07	5.79E-07	5.54E-07	4.15E-07	3.27E-07	1.23E-07	5.34E-08
NW	5.57E-07	8.47E-07	7.66E-07	7.47E-07	7.78E-07	8.18E-07	8.43E-07	8.46E-07	8.34E-07	8.13E-07	6.48E-07	5.33E-07	2.18E-07	9.75E-08
NNW	3.19E-07	4.98E-07	4.75E-07	4.78E-07	5.11E-07	5.51E-07	5.78E-07	5.88E-07	5.85E-07	5.74E-07	4.60E-07	3.77E-07	1.51E-07	6.64E-08

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

	Distance (meters)													
Direction	100	200	300	400	500	600	700	800	900	1000	1500	2000	5000	10000
N	4.66E-07	5.73E-07	5.43E-07	5.82E-07	6.52E-07	7.08E-07	7.33E-07	7.32E-07	7.16E-07	6.93E-07	5.33E-07	4.20E-07	1.54E-07	6.58E-08
NNE	8.20E-07	9.66E-07	8.43E-07	8.23E-07	8.48E-07	8.68E-07	8.64E-07	8.39E-07	8.03E-07	7.62E-07	5.53E-07	4.21E-07	1.46E-07	6.09E-08
NE	8.08E-07	9.41E-07	8.09E-07	7.78E-07	7.95E-07	8.12E-07	8.07E-07	7.83E-07	7.49E-07	7.10E-07	5.13E-07	3.89E-07	1.33E-07	5.57E-08
ENE	4.08E-07	4.45E-07	3.94E-07	4.11E-07	4.54E-07	4.88E-07	5.01E-07	4.97E-07	4.83E-07	4.64E-07	3.47E-07	2.68E-07	9.43E-08	3.91E-08
E	2.14E-07	2.45E-07	2.43E-07	2.89E-07	3.45E-07	3.87E-07	4.06E-07	4.09E-07	4.01E-07	3.88E-07	2.95E-07	2.30E-07	8.20E-08	3.38E-08
ESE	1.88E-07	2.05E-07	2.21E-07	2.88E-07	3.64E-07	4.21E-07	4.50E-07	4.59E-07	4.56E-07	4.46E-07	3.52E-07	2.82E-07	1.05E-07	4.39E-08
SE	2.13E-07	2.69E-07	3.33E-07	4.63E-07	5.90E-07	6.79E-07	7.21E-07	7.31E-07	7.21E-07	7.01E-07	5.44E-07	4.31E-07	1.59E-07	6.74E-08
SSE	2.08E-07	2.94E-07	4.13E-07	5.89E-07	7.44E-07	8.47E-07	8.92E-07	8.98E-07	8.81E-07	8.53E-07	6.55E-07	5.15E-07	1.89E-07	8.14E-08
S	3.37E-07	4.36E-07	4.66E-07	5.38E-07	6.14E-07	6.66E-07	6.85E-07	6.80E-07	6.61E-07	6.36E-07	4.81E-07	3.76E-07	1.37E-07	5.91E-08
SSW	4.59E-07	5.88E-07	5.30E-07	5.03E-07	4.90E-07	4.75E-07	4.52E-07	4.25E-07	3.97E-07	3.70E-07	2.58E-07	1.92E-07	6.45E-08	2.68E-08
SW	6.90E-07	8.28E-07	6.70E-07	5.62E-07	4.91E-07	4.39E-07	3.94E-07	3.55E-07	3.21E-07	2.91E-07	1.89E-07	1.36E-07	4.23E-08	1.70E-08
WSW	5.87E-07	7.56E-07	6.16E-07	5.14E-07	4.48E-07	3.98E-07	3.57E-07	3.21E-07	2.90E-07	2.62E-07	1.69E-07	1.21E-07	3.68E-08	1.47E-08
W	6.77E-07	8.64E-07	7.08E-07	6.00E-07	5.33E-07	4.83E-07	4.39E-07	4.00E-07	3.65E-07	3.33E-07	2.21E-07	1.60E-07	5.08E-08	2.07E-08
WNW	8.70E-07	1.05E-06	8.85E-07	8.15E-07	7.96E-07	7.84E-07	7.61E-07	7.28E-07	6.91E-07	6.55E-07	4.79E-07	3.70E-07	1.33E-07	5.69E-08
NW	8.14E-07	1.03E-06	9.48E-07	9.63E-07	1.02E-06	1.06E-06	1.07E-06	1.05E-06	1.02E-06	9.82E-07	7.66E-07	6.16E-07	2.37E-07	1.05E-07
NNW	4.67E-07	6.13E-07	5.96E-07	6.25E-07	6.80E-07	7.24E-07	7.41E-07	7.35E-07	7.18E-07	6.96E-07	5.42E-07	4.34E-07	1.64E-07	7.09E-08

Table B.4. Chi/Q (sec/m^3) for LSLII Building Stack Parameters – 23.1 m Stack Height with No Buoyant and Momentum Plume Rise

	Distance (meters)													
Direction	100	200	300	400	500	600	700	800	900	1000	1500	2000	5000	10000
N	1.32E-06	1.34E-06	1.56E-06	1.74E-06	1.75E-06	1.67E-06	1.57E-06	1.46E-06	1.36E-06	1.26E-06	8.49E-07	6.10E-07	1.96E-07	7.95E-08
NNE	2.28E-06	2.04E-06	2.06E-06	2.10E-06	2.01E-06	1.86E-06	1.70E-06	1.54E-06	1.40E-06	1.28E-06	8.25E-07	5.81E-07	1.78E-07	7.15E-08
NE	2.23E-06	1.95E-06	1.94E-06	1.97E-06	1.88E-06	1.74E-06	1.58E-06	1.43E-06	1.30E-06	1.18E-06	7.59E-07	5.32E-07	1.62E-07	6.46E-08
ENE	1.09E-06	9.69E-07	1.09E-06	1.19E-06	1.19E-06	1.13E-06	1.04E-06	9.60E-07	8.81E-07	8.08E-07	5.30E-07	3.75E-07	1.15E-07	4.50E-08
E	5.81E-07	6.20E-07	8.17E-07	9.53E-07	9.75E-07	9.35E-07	8.75E-07	8.12E-07	7.50E-07	6.91E-07	4.59E-07	3.27E-07	1.01E-07	3.94E-08
ESE	4.94E-07	5.78E-07	8.53E-07	1.04E-06	1.09E-06	1.07E-06	1.02E-06	9.59E-07	9.00E-07	8.40E-07	5.75E-07	4.16E-07	1.33E-07	5.21E-08
SE	6.01E-07	8.92E-07	1.38E-06	1.68E-06	1.74E-06	1.68E-06	1.59E-06	1.49E-06	1.38E-06	1.28E-06	8.69E-07	6.26E-07	2.02E-07	8.15E-08
SSE	6.10E-07	1.11E-06	1.75E-06	2.09E-06	2.14E-06	2.05E-06	1.93E-06	1.79E-06	1.66E-06	1.54E-06	1.03E-06	7.44E-07	2.43E-07	1.01E-07
S	9.63E-07	1.17E-06	1.47E-06	1.63E-06	1.62E-06	1.54E-06	1.43E-06	1.32E-06	1.22E-06	1.13E-06	7.53E-07	5.40E-07	1.76E-07	7.33E-08
SSW	1.33E-06	1.27E-06	1.21E-06	1.13E-06	1.03E-06	9.13E-07	8.13E-07	7.27E-07	6.54E-07	5.91E-07	3.74E-07	2.61E-07	7.98E-08	3.20E-08
SW	1.94E-06	1.56E-06	1.24E-06	1.03E-06	8.63E-07	7.32E-07	6.29E-07	5.48E-07	4.82E-07	4.28E-07	2.59E-07	1.77E-07	5.08E-08	1.97E-08
WSW	1.73E-06	1.44E-06	1.13E-06	9.34E-07	7.81E-07	6.61E-07	5.66E-07	4.91E-07	4.31E-07	3.81E-07	2.29E-07	1.55E-07	4.41E-08	1.69E-08
W	1.99E-06	1.66E-06	1.34E-06	1.14E-06	9.72E-07	8.34E-07	7.24E-07	6.36E-07	5.63E-07	5.02E-07	3.08E-07	2.11E-07	6.25E-08	2.45E-08
WNW	2.45E-06	2.11E-06	1.96E-06	1.88E-06	1.75E-06	1.60E-06	1.46E-06	1.34E-06	1.23E-06	1.12E-06	7.43E-07	5.30E-07	1.70E-07	6.96E-08
NW	2.35E-06	2.31E-06	2.47E-06	2.58E-06	2.51E-06	2.37E-06	2.23E-06	2.10E-06	1.97E-06	1.84E-06	1.28E-06	9.32E-07	3.15E-07	1.33E-07
NNW	1.36E-06	1.46E-06	1.63E-06	1.77E-06	1.76E-06	1.68E-06	1.58E-06	1.49E-06	1.39E-06	1.30E-06	8.90E-07	6.47E-07	2.13E-07	8.76E-08

Table B.5. Chi/Q (sec/m^3) for RTL-520 Building Stack Parameters – 20.5 m Stack Height with No Buoyant and Momentum Plume Rise

	Distance (meters)													
Direction	100	200	300	400	500	600	700	800	900	1000	1500	2000	5000	10000
N	1.69E-06	1.82E-06	2.16E-06	2.29E-06	2.20E-06	2.05E-06	1.89E-06	1.73E-06	1.59E-06	1.45E-06	9.38E-07	6.62E-07	2.08E-07	8.26E-08
NNE	2.89E-06	2.65E-06	2.74E-06	2.68E-06	2.47E-06	2.22E-06	1.99E-06	1.78E-06	1.60E-06	1.44E-06	9.00E-07	6.23E-07	1.88E-07	7.39E-08
NE	2.83E-06	2.52E-06	2.56E-06	2.51E-06	2.30E-06	2.07E-06	1.85E-06	1.65E-06	1.48E-06	1.33E-06	8.25E-07	5.69E-07	1.70E-07	6.66E-08
ENE	1.36E-06	1.30E-06	1.50E-06	1.56E-06	1.48E-06	1.36E-06	1.24E-06	1.12E-06	1.01E-06	9.17E-07	5.80E-07	4.03E-07	1.20E-07	4.61E-08
E	7.37E-07	8.87E-07	1.17E-06	1.27E-06	1.23E-06	1.14E-06	1.05E-06	9.55E-07	8.69E-07	7.89E-07	5.04E-07	3.52E-07	1.07E-07	4.05E-08
ESE	6.22E-07	8.64E-07	1.25E-06	1.41E-06	1.39E-06	1.32E-06	1.24E-06	1.15E-06	1.06E-06	9.73E-07	6.38E-07	4.52E-07	1.41E-07	5.37E-08
SE	7.85E-07	1.38E-06	2.02E-06	2.26E-06	2.21E-06	2.07E-06	1.92E-06	1.76E-06	1.62E-06	1.48E-06	9.60E-07	6.79E-07	2.15E-07	8.47E-08
SSE	8.24E-07	1.74E-06	2.54E-06	2.78E-06	2.69E-06	2.51E-06	2.31E-06	2.12E-06	1.93E-06	1.76E-06	1.14E-06	8.08E-07	2.60E-07	1.05E-07
S	1.26E-06	1.66E-06	2.04E-06	2.13E-06	2.03E-06	1.87E-06	1.71E-06	1.56E-06	1.42E-06	1.29E-06	8.30E-07	5.86E-07	1.89E-07	7.68E-08
SSW	1.72E-06	1.64E-06	1.54E-06	1.39E-06	1.22E-06	1.07E-06	9.38E-07	8.30E-07	7.39E-07	6.60E-07	4.07E-07	2.80E-07	8.45E-08	3.32E-08
SW	2.47E-06	1.89E-06	1.49E-06	1.21E-06	9.92E-07	8.30E-07	7.07E-07	6.11E-07	5.34E-07	4.70E-07	2.78E-07	1.87E-07	5.34E-08	2.02E-08
WSW	2.23E-06	1.74E-06	1.35E-06	1.09E-06	8.96E-07	7.47E-07	6.34E-07	5.46E-07	4.75E-07	4.17E-07	2.45E-07	1.64E-07	4.63E-08	1.73E-08
W	2.55E-06	2.02E-06	1.62E-06	1.35E-06	1.13E-06	9.55E-07	8.20E-07	7.14E-07	6.27E-07	5.54E-07	3.32E-07	2.25E-07	6.61E-08	2.53E-08
WNW	3.12E-06	2.67E-06	2.52E-06	2.36E-06	2.13E-06	1.91E-06	1.72E-06	1.56E-06	1.41E-06	1.28E-06	8.18E-07	5.74E-07	1.81E-07	7.26E-08
NW	3.02E-06	3.07E-06	3.31E-06	3.32E-06	3.12E-06	2.90E-06	2.70E-06	2.51E-06	2.33E-06	2.15E-06	1.43E-06	1.02E-06	3.39E-07	1.39E-07
NNW	1.77E-06	1.96E-06	2.23E-06	2.31E-06	2.20E-06	2.06E-06	1.92E-06	1.77E-06	1.64E-06	1.50E-06	9.91E-07	7.07E-07	2.28E-07	9.15E-08

References

Barnett, JM, KM Meier, SF Snyder, BG Fritz, TM Poston, K Rhoads. 2010. *Data Quality Objectives Supporting Radiological Air Emissions Monitoring for the PNNL Site*. PNNL-19427, Pacific Northwest National Laboratory, Richland, Washington.

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