PNNL-23930

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Establishment of a Background Environmental Monitoring Station for the PNNL Campus

December 2014

BG Fritz
SF Snyder
JM Barnett
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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

The environmental surveillance of background levels of radionuclides and, in particular, the siting of a background environmental surveillance (monitoring) station are examined. Many published works identify and stress the need for background monitoring; however, little definitive and comprehensive information for siting a station exists. A definition of an ideal background monitoring location and the generic criteria recommended for use in establishing such a background monitoring location are proposed. There are seven primary (mandatory) criteria described with two additional, optional criteria.

The criteria are applied to the Richland, Washington (WA), Pacific Northwest National Laboratory (PNNL) Campus, which currently uses background monitoring data from the nearby Hanford Site. Eleven potential background monitoring sites were identified, with one location in Benton City, WA found to meet all of the mandatory and optional criteria. It is expected that the new sampler will be installed and operating by the end of June, 2015.

Acronyms and Abbreviations

AC	alternating current
ALARA	As Low As Reasonably Achievable
amsl	above mean sea level
degrees (°) C	Celsius
CAP88-PC	Clean Air Act Assessment Package 1988 – Personal Computer
CFR	Code of Federal Regulations
COC	constituent of concern
DOE	U.S. Department of Energy
DQO	data quality objectives
EPA	U.S. Environmental Protection Agency
ESRI	Environmental Systems Research Institute
FR	Federal Register
g	gram(s)
HMS	Hanford Meteorological Station
hr	hour(s)
km	kilometer(s)
µCi	microcurie
mCi	millicurie
m	meter(s)
mi	mile(s)
NCRP	National Council on Radiation Protection and Measurements
NWS	National Weather Service
PNNL	Pacific Northwest National Laboratory
PNSO	Pacific Northwest Site Office – U.S. Department of Energy
PSF	Physical Sciences Facility
QA	Quality Assurance
QC	Quality Control
RAEL	Radioactive Air Emissions License
SC	Office of Science – U.S. Department of Energy
USDA	United States Department of Agriculture
V	volt(s)
WA	Washington (state)
WAC	Washington Administrative Code
WDOH	Washington State Department of Health
WSU	Washington State University

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1.0 Introduction

The U.S. Environmental Protection Agency (EPA) authorized and delegated the Washington State Department of Health (WDOH) to maintain regulatory oversight for radiological air emissions (Federal Register [FR] 2006). To comply with the EPA Clean Air Act regulations for radiological emissions in the State of Washington, U.S. Department of Energy (DOE) sites must meet the requirements in 40 CFR 61, Subpart H (2002) and Washington Administrative Code (WAC) 246−247 (2014). As a result of initiating operations at the DOE Office of Science (SC), Pacific Northwest Site Office (PNSO), Physical Sciences Facility (PSF), Pacific Northwest National Laboratory Campus (PNNL Campus),[1] the WDOH required PNSO to implement an environmental surveillance radiological air monitoring program as part of the facility's Radioactive Air Emissions License-005 (RAEL-005; WDOH 2010). Heretofore, the PNNL Campus environmental surveillance radiological air monitoring program has operated without an established background station.

An environmental surveillance program was established to monitor radioactive materials in ambient air near the PNNL Campus. A data quality objectives (DQO) process was used to determine the extent and needs of the initial environmental surveillance network. Air is sampled because it is the primary media in which radionuclides could be transported from the PNNL Campus to off-site areas and could impact the public. All radionuclides that require sampling at the PNNL Campus occur in particulate form; therefore, the environmental surveillance network currently consists of air sampling for particulate radionuclides. The PNNL off-site air surveillance program commenced in July 2010, at the same time radiological operations at the PSF began (Barnett et al. 2010; Barnett et al. 2012).

This document focuses on the measurement of background levels of radionuclides associated with an environmental surveillance program and the siting of a background environmental surveillance station. In this report, background levels will ideally indicate the measured concentration of analytes of interest that are equal to the concentrations that would be measured at a site if PNNL Campus operational emissions did not occur. The National Council on Radiation Protection and Measurements (NCRP) report number 94 covers the topic of sources of natural background radiation in detail, including geologic and cosmogenic sources (NCRP 1987). Other sources of background radioactivity might include medical, nuclear power production, nuclear weapons testing, and large-scale nuclear accidents.

1.1 Relevant Information

Environmental surveillance consists of collecting and analyzing samples to assess radiation exposures to the public and environment, and to demonstrate compliance with applicable standards and permit requirements. Operations at facilities with radioactive air emissions are managed with the philosophy of "As Low As Reasonably Achievable" (ALARA) applied to better control and minimize the releases into the environment. The Pacific Northwest National Laboratory Annual Site Environmental Report (Duncan

[1] The PNNL Campus is located in southeastern Washington state, mostly in the City of Richland and south of the DOE Hanford Site, 300 Area. It includes a mix of public and private land and facility ownership. The PNNL Campus is separated into core campus and non-core campus areas; it refers to a collection of facilities on and off the "PNNL Site" used by PNNL and is dynamic in that it is defined by utilization of federal and non-federal facilities. The PNNL Campus does not include the PNNL Marine Sciences Laboratory or the PNNL Other Areas (PNSO 2013).

et al. 2014) discusses the ongoing environmental management performance and compliance activities conducted during the course of the sampling year.

The PNNL Campus environmental surveillance program currently consists of four air sampling stations at locations around the PNNL Campus and relies on the Hanford Site background station data for background reporting (Snyder et al. 2014). The program operates two distinct types of sampling systems: 120-volt (V) AC air samplers and 24-V DC solar powered samplers. Both systems capture particulates on glass fiber filters. The filters are collected every 2 weeks and analyzed for gross alpha and gross beta activity. Every 6 months (January to June and July to December), a composite analysis of filters for gamma-emitting isotopes and $^{233/234}$U, ^{238}Pu, $^{239/240}$Pu, ^{241}Am, ^{243}Am and $^{243/244}$Cm isotopes is conducted. Data for 2013 are available in the Pacific Northwest National Laboratory Site Radionuclide Air Emissions Report for Calendar Year 2013 (Snyder et al. 2014).

Environmental surveillance is not real-time; once a particulate filter is submitted and analytical results received, there may be a lag time of approximately 15 days. As a result, an unknown elevated emission would not be detected until 2-4 weeks after it occurred, and even then, activity captured may still compete with natural background particulates (^{232}Th chain, ^{222}Rn chain, ^{238}U, and ^{40}K). The current low emissions rates and resultant off-site doses, driven by mature and stable emissions control and programmatic planning of operational radioactive air operations, eliminate the technical need for frequent composite analysis. Due to the fact that measured concentrations are low (requiring larger sample volume for detection), and because off-site exposures are driven by annual average concentrations, six-month composite sample windows allow for sufficient operational oversight.

Background monitoring data used for the PNNL Campus comes from the Hanford Site station located in Yakima, WA (about 54 kilometers [km; 34 miles {mi}] and 96 km [60 mi] west of the Hanford Site and the PNNL Campus, respectively). The Hanford Site environmental surveillance program has operated for decades. The Hanford Site is located adjacent to the northern boundary of the PNNL Campus; the Hanford Site 300 Area facilities are less than 2 km (1 mi) north of the PNNL Campus facilities. The Hanford Site 300 Area emissions are known to disperse toward the PNNL Campus some portion of the year. PNNL Campus emissions currently are "low" in the several microcurie (µCi) range. Hanford Site 300 Area operations emissions are in the hundred-Ci range for gases (tritium and radon) and 10 µCi range for particulates, while the remainder of all other Hanford Site operations generally result in total emissions in the millicurie (mCi) range (DOE 2013). In addition, environmental contamination from early Hanford Site operations results in low level diffuse emissions. Data from 2012, typical of recent years, are shown in Table 1.1.

Table 1.1. Summary of 2012 atmospheric radiological emissions from the Hanford Site and the PNNL Campus

Constituent Form	**Hanford Site, 300 Area** (Ci/yr)	**All Other Hanford Sources** (Ci/yr)	**PNNL Campus** (Ci/yr)
Gas phase	9.7×10^{-4}	2.8×10^{-3}	3.1×10^{-6}
Particulates	4.0×10^{-6}	4.5×10^{-4}	9.9×10^{-7}

Sources: Duncan et al. 2014; DOE 2013

1.2 Necessity of Background Measurements

Background (or control) monitoring data generally is considered a necessary component of an environmental surveillance program (DOE 1991; Klement 1982; NCRP 2010; Kathren 1984; Keith 1991; Noll and Miller 1977; WHO 1968). Also, public dose limits allow for the exclusion of the dose contribution from background. Background concentrations of airborne radioactivity provide a point of reference for the boundary measurements or just off-site (hereafter, near-field) measurements. For example, if near-field samples were reported to have elevated radionuclide concentrations, the initial assumption would be that the elevated concentrations resulted from on-site releases. On the other hand, having results from samples collected at a background location could provide evidence for another explanation (e.g., regionally elevated concentrations of natural background). The DQO process used to establish the PNNL environmental surveillance program identified the need for background results (Barnett et al. 2012).

In situations with independent facilities (i.e., independently managed and permitted) that emit radioactive materials in close proximity, distinguishing natural background from the emissions of the other nearby facility(s) can become problematic. With multiple sources of nearby radioactive air emissions, the potential for elevated concentrations from one facility on another (or vice versa) is a plausible scenario. In particular, the PNNL Campus and the Hanford Site share a common boundary whereby the determination of PNNL-specific background levels should consider the natural background as well as the other-emitter background to the extent necessary and useful.

Based on these considerations, it is necessary for the PNNL environmental surveillance program to have independent background concentration data available. The remainder of the document considers the potential options for obtaining background concentration data and the methodology used for implementing the selected option.

2.0 Generic Background Location Selection Criteria

Although many published works identify and stress the need for background monitoring locations when establishing monitoring networks (i.e., IAEA 2010; NCRP 2010; Meinke and Essig 1991a, 1991b; Glantz 1990), there is little published comprehensive guidance provided about how to select or establish a background location. When establishing the criteria for choosing a background monitoring location, it is useful to first establish the definition of a background location, and then consider additional siting criteria and approaches.

Various definitions of a background (or control or monitoring) location have been published. The NCRP defines background radiation as "the level of radiation from sources other than the source of interest" (NCRP 2010). Control samples are defined as being collected near the time and place where the analytes of interest may exist, and be used to demonstrate if concentrations measured on a site are truly different from background concentrations (Keith 1991). Additionally, a PNNL environmental monitoring DQO identified a local background as, "the air concentrations that would exist at the PNNL Campus boundary if there were no PNNL Campus emissions" (Barnett et al. 2012). While these definitions can cover all sources of background radiation, it can be applied specifically to background concentrations of radionuclides in ambient air. Using these definitions as a guide, the following definition of an *ideal* background monitoring location is proposed:

> An ideal background monitoring location is a point where the measured concentrations of analytes of interest are equal to the concentrations that would be measured at the site *if* operational emissions did not occur.

Based on this definition of an ideal background monitoring location, a list of general criteria, and approaches for evaluating sites against those criteria, were developed. These are generic requirements that could be applied anywhere to assist in establishing an environmental surveillance background air monitoring station. These criteria are presented below in their order of importance. It is recommended that a check-list or score sheet of these requirements be developed for location assessments.

A. Air concentration of each constituent of concern measured at a background location is uninfluenced by facility emissions, meaning that the increase in concentration at the background location caused by facility emissions is less than the acceptable error associated with the measurement.
    1. Atmospheric modeling can be used to estimate the dilution of emissions, and simple numerical approaches can be used to determine the change in the measured concentration.
    2. If the monitoring program has quality assurance (QA) program, then the estimated change in measured background concentrations caused by capture of facility emissions can be evaluated relative to the program's stated acceptable error.

B. The air sampled at a background location is typical of the air sampled at or near the facility (except for those constituents of concern [COCs] emitted from the facility). Analytes other than the COCs should have similar concentrations at the background location and the facility.
    1. Qualitative assessment of the source facility and potential background locations are sufficient to meet this criterion. Background monitoring locations should be in an area with comparable land use and cover, similar anthropogenic emissions, etc.

C. Typical weather conditions (e.g., inversions, dust storms, precipitation) at the facility should also occur at the background station.

   1. Knowledge of current and historic local weather patterns is sufficient to qualitatively assess the representativeness of the background location with respect to weather.

   2. The background locations is located within the same wind shed zone as the facility.

D. The background location is a reasonable distance from the emission source (i.e., not too close or too far away). A reasonable distance is a function of the size of the emission source, but generally should be as close as possible while still meeting the other requirements listed here. The reasonable distance should also consider a worst-case scenario with wind blowing directly from the source to the background location.

   1. Gaussian plume dispersion modeling is sufficient for determining the minimum distance for a background location.

   2. Project needs (e.g., budget, staff availability) may be a factor in determining the maximum distance.

E. Terrain effects may be a factor in this evaluation and considered after the initial modeling effort since many models do not include terrain as an input parameter.

   1. Atmospheric modeling or an evaluation of wind patterns and topographic maps can be used to qualitatively assess the representativeness of the background location.

F. All necessary infrastructure is available (i.e., power, pavement, communications)

   1. Once a general area is identified as meeting the above requirements, then potential specific locations within that area need to be identified.

G. The background sampling location meets general siting requirements for an air sampling location (e.g., minimal obstructions, no nearby sources, minimal impact to environment, adequate security and safety provisions, accessible by staff).

   1. Potential sampling locations are evaluated against siting requirements.

Optional considerations include:

H. Co-located sampling by other agencies can be used to provide backup data in the event of equipment failure, and for QA purposes.

   1. The local (regulatory) agency should be able to provide a list of other active and relevant monitoring programs in the area.

I. Historic data from previous or other sampling program(s) can be used for comparison and QA purposes.

   1. A literature review may provide information about other sampling programs within the area.

3.0 Options for Obtaining Background Data for the PNNL Campus Environmental Radiological Monitoring Program

PNNL staff identified a number of potential options for acquiring background concentration data for radionuclides in air samples. All of the potential options identified were considered. A summary of the advantages and disadvantages of each option is included (Table 3.1). Costs associated with the evaluation include materials and analysis, staff, maintenance, data storage, and transportation. Contract items include both sample analysis and staff services resulting in subcontractor relations, contract oversight and management, liabilities, land use agreements, and compliance to negotiated terms. The background options in Table 3.1 do not include the technical requirements for siting a background environmental surveillance station which are addressed later in this document. Three main aspects of background monitoring were identified: background station custodian, air sample collection, and air sample analysis.

For each of the options listed in Table 3.1, a summary of ownership/control for each of the three aspects is summarized in Table 3.2.

Table 3.1. Summary of the potential background data collection options

Option	Advantages	Disadvantages
1. Continue to use data from the Hanford Site background station, Yakima, WA	• No cost to PNNL • No station maintenance	• Data not available for all COCs • No control of QA/quality control (QC) program or schedule
2. Use existing data from another program's environmental surveillance station as the PNNL background location	• Minimal to no cost to PNNL • No station maintenance	• Data not available for all COCs • No control of QA/QC program or schedule
3. Use data from an existing environmental surveillance station, with PNNL funding analytical laboratory costs for additional radionuclide analyses	• Nominal cost for PNNL • Provides results for all COCs • No station maintenance	• Little or no control of QA/QC program, sample collection or schedule • Potential contract issues
4. Contract with another environmental surveillance program to collect and/or split PNNL background air samples from an existing or new station	• Provides results for all COCs • No station maintenance	• Moderate to high cost • Little control of QA/QC program, sample collection or schedule • Potential contract issues • Complex interfaces
5. Operate PNNL environmental surveillance network without consideration of any background monitoring data	• No cost to PNNL, • No station maintenance	• No way to separate regional fluctuations from actual facility emissions • No data for explaining elevated PNNL COC results • Inconsistent with best practices
6. Establish an independent PNNL environmental surveillance background radiological air monitoring station to control both near-field and background monitoring and analyses	• PNNL maintains complete control of sampling • Full control of QA/QC program • Provides results for all COCs • Opportunity for public relations outreach/information	• Highest initial costs to PNNL • Moderate operational costs • Potential contract issues • Security/vandalism

Option 1 is how the PNNL environmental surveillance program currently obtains background concentration data. However, the Hanford Site environmental monitoring program does not analyze air samples for all of the radionuclides present in PNNL Campus air effluent (Barnett et al. 2012), and in some cases uses different analytical methods than the PNNL Campus Environmental Monitoring program. This is not a desirable outcome for long-term environmental surveillance.

Option 2 would identify other existing environmental surveillance stations from which background concentrations could be obtained. This could include other Hanford Site air sampling locations, or air sampling locations operated by the WDOH, Energy Northwest, Areva, or some other local facility that operates an environmental surveillance program. This option would likely have the same drawbacks as Option 1.

Option 3 is similar to options 1 and 2, but would pay another environmental monitoring program to conduct supplemental analyses on the background samples. A major shortcoming of this approach is that PNNL would have little or no control on the QA/QC program used for sample collection or analysis (e.g., collection procedures, instrument calibration, analytical QA, collection schedule).

Option 4 would resolve sample analysis issues by transferring the physical sample to PNNL. However, it still results in QA/QC issues associated with sample collection; while PNNL would oversee the sample analysis, there would be no direct oversight or control of the sample collection. Further, this option could have contracting difficulties and requires complicated logistics for sample transfer.

Option 5 may be a viable option; the PNNL Campus air permit does not strictly require the collection of background data. However, the lack of background measurements does not adhere to best practices (section 1.2). Further, the DQO report identified that the PNNL Campus monitoring network needed background measurements (Barnett et al 2010).

Option 6 has no technical disadvantages. However, this option is likely the most expensive as it will require an initial capital investment for station equipment as well as annual costs for station operation, maintenance, sample collection and analysis, and contract interfaces.

Table 3.2 lists the responsible party for each option with regard to a sampling station site, sample collection process, and sample analysis.

Table 3.2. Summary of responsible party for various aspects of each option

Option	Site Custodian	Sample Collection	Sample Analysis
1	Other	Other	Other
2	Other	Other	Other
3	Other	Other	PNNL
4	Other or PNNL	Other	PNNL
5	N/A	N/A	N/A
6	PNNL	PNNL	PNNL

After considering the various background data options, Option 6, installation and operation of a background air monitoring station as part of the PNNL Campus monitoring network, is recommended. It is the only option that provides data of the quality and pedigree necessary to meet project needs.

4.0 PNNL Campus-Specific Criteria

A formal DQO process could be used to establish a suitable background monitoring location. However, the time and expense of a formal DQO is typically not necessary for establishing a single monitoring location. Applying the general criteria and approaches outlined in sections 2.0 and 3.0 to the PNNL Campus results in the following specific criteria that are used in selecting potential areas for placement of a background environmental monitoring station. In section 5.0, these criteria are used in the development of potential sampling areas, followed by specific locations being identified within each area.

A. The modeled concentration of particulate radionuclides of concern (assuming no background contribution) at the background sampling location should be a very small percentage of the concentration modeled at the PNNL Campus boundary. A minimum dilution ratio of $1/50^{th}$ was chosen as appropriate for the PNNL Campus (see Appendix A for an explanation of the $1/50^{th}$ criterion).

    1. The EPA-approved dispersion model CAP88-PC Version 3.0 (EPA 2013) will be used to determine where the $1/50^{th}$ criterion is met. PNNL Campus emissions typically occur at a relatively uniform rate over the entire year, so annual atmospheric dispersion modeling meets the needs of this evaluation. The normalized concentration (X/Q [s/m^3]) will be calculated at each of the 16 compass points, and the radial distances where the $1/50^{th}$ criterion is met will be calculated.

B. Similar air composition between the background location and the PNNL Campus is required. Therefore, sampling high up the Yakima River valley will be avoided due to the different agricultural practices relative to the lower valley and Tri-Cities region. Specifically, the use of smudge pots in Yakima Valley orchards during the spring are of concern.

    1. No sampling areas farther west up the Yakima River valley than Sunnyside will be considered to minimize change in the air composition.

    2. The elevation difference between the PNNL Campus and the background location will preferably be less than 200 m to stay within a similar mixing zone within the atmospheric boundary layer. This should also minimize differences in precipitation rates between the background location and the PNNL Campus (see next criteria).

C. Weather conditions (e.g., inversions, dust storms, precipitation) at the facility should also exist at the background station.

    1. Weather patterns in and around Richland are similar within the Lower Columbia Basin. This rectangular area (as defined by the National Weather Service (NWS; 2014) stretches roughly from Boardman OR north to Washington State Highways 24 and 26, and east to Touchet, WA. Therefore, the background location will be located within this zone, and no more than 50 mi (80 km) from the PNNL Campus.

D. The location is a reasonable distance from the emission source (i.e., not too close or too far away). The minimum distance will be determined such that under poor dispersion conditions the ground level maximum concentration of radionuclide particulates from facility emissions is at least 10 times greater than the concentration at the background location. The maximum distance will be set at a 1-hour (hr) drive time to manage labor costs for sample collection.

1. Gaussian plume dispersion modeling will be used to evaluate the concentration as a function of distance from the facility under poor dispersion conditions (stable atmosphere, winds 50% of winter average wind speed blowing from the PNNL Campus toward the background location).
2. Internet mapping tools will be used to identify 1-hr drive time distances in various directions.

E. Terrain effects between the background station and the facility include ground cover, land use and topography. Predominant air transport is from the background location toward the facility for much of the year, based on wind rose data.

1. Qualitative evaluation of the wind roses in and around the Tri-Cities (reference Hanford Meteorological Station [HMS] weather summary) will be done to determine which directions are generally upwind of the PNNL Campus.
2. Winds channeling around Rattlesnake, Red, Candy, and Badger mountains needs to be considered.

F. Necessary infrastructure available

1. After suitable sampling areas are identified (based on the above steps), specific locations with available power (15 amp, 120 V AC) will be identified by one or more of the following: reconnaissance trips, prior knowledge, and phone calls.
2. Cooperation with potential background location site owner(s).

G. The sampling location must meet general siting requirements. The location should have gravel or paved access to within 5 m of the sampler. The background sampling location should be at least 50 m from a major road. The sampler inlet should be 1.5 m above ground, and obstructions should be 10 times the height of the obstruction away from the sampler (i.e., a 20-m tall tree should be more than 200 m away from the sampler). Any known atmospheric sources of radionuclides should be at least half as far from the background monitoring station as from the PNNL Campus.

1. For each potential site, a site inspection will be conducted to determine if the site meets these requirements. This will require the use of a GPS (or other survey equipment), and a camera.

Optional criteria evaluated specific to the PNNL Campus was also conducted for completeness of the overall evaluation.

H. Co-located sampling by other agencies (e.g., WDOH, Hanford Site) can be used to provide backup data in the event of equipment failure, and for QA purposes.

1. A map of sampling locations operated by the WDOH, Hanford Site, Energy Northwest, and Areva will be generated and considered as possible background sampling locations.

I. Historic data from previous/other sampling program(s) may be available for comparison and QA purposes.

1. This criterion will not be applied in the decision making process for the PNNL Campus background sampling location. The COC isotopes of interest and estimated concentrations resulting from PNNL Campus emissions make it very unlikely that any historic information would be useful.

5.0 Potential Background Monitoring Locations

Criteria A through E of section 4.0 were implemented for identifying potential sampling areas. A map was developed that identified areas meeting these criteria (Figure 5.1).

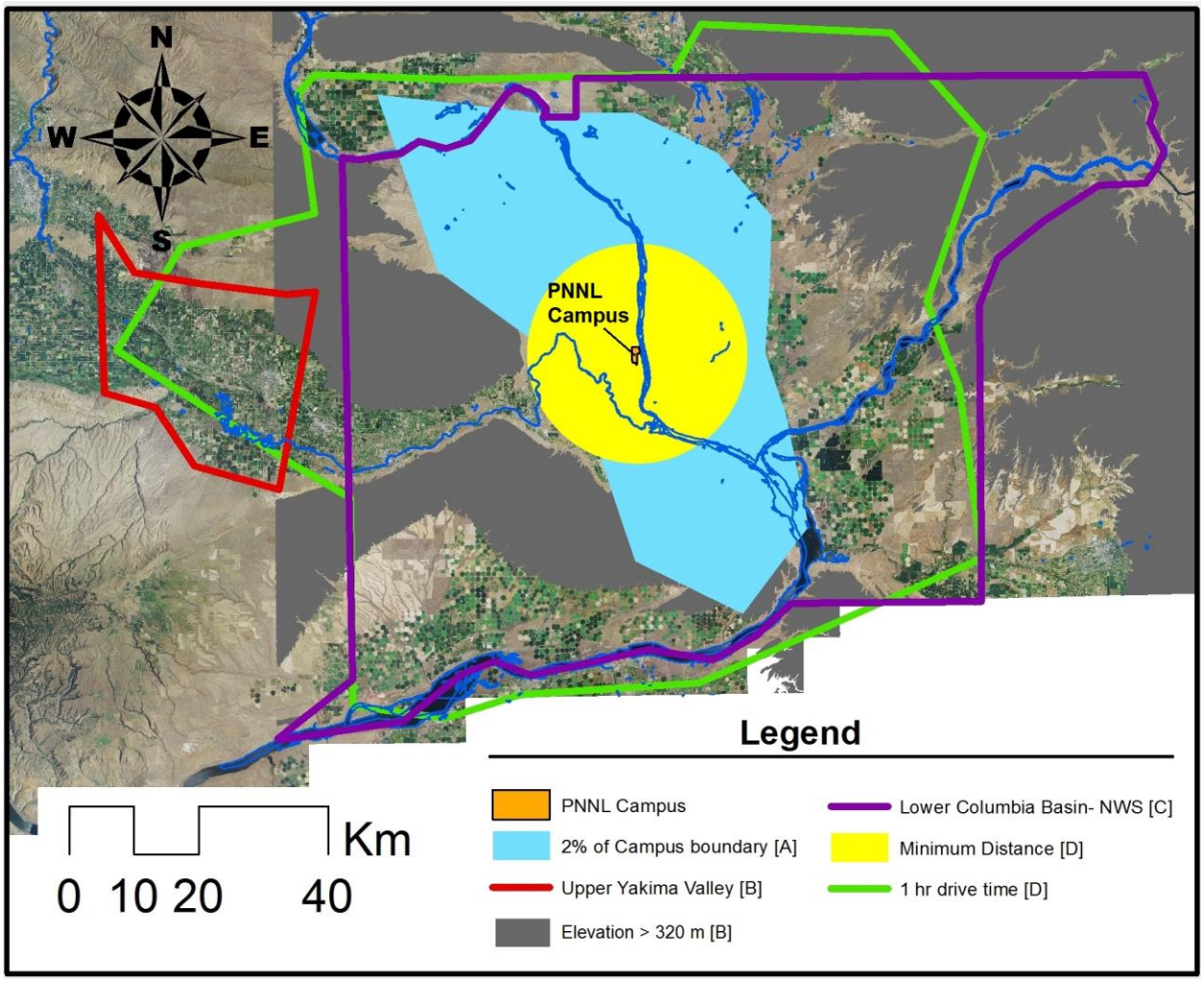

Figure 5.1. Locations for inclusion and exclusion of potential background air monitoring locations for Criteria A through D (bracketed)

Criterion A was implemented by running CAP88-PC with site-specific inputs (Table 5.1) to determine the air concentrations of each constituent of concern. The resultant maximum modeled concentration at the boundary of the PNNL Campus was identified. Then, the modeled concentrations were evaluated in each of 16 compass directions. The distance in each direction where the modeled concentration was equal to 2% of the campus boundary maximum was converted to map coordinates, and mapped with GIS software (Environmental Systems Research Institute [ESRI] 2013). Areas inside of this 2% (i.e., 1/50th) boundary were excluded from consideration for a background air monitoring location.

Table 5.1. CAP88-PC model inputs

Parameter	Data	Reference
Wind speed/direction	2002–2011 average meteorology	Hanford Site, Station 11, 10m, Meteorological Data
Annual average temperature	12°C	Snyder et al. (2014)
Annual average precipitation	160 mm	Snyder et al. (2014)
Annual average mixing height (m)	1000	Snyder et al. (2014)
Annual average absolute humidity	8 g/m^3	Snyder et al. (2014)
Stack height	38 m	Assumed effective stack height (PNNL 2014)
Stack diameter	1.0 m	
Plume rise	0	(effective stack height used)

Criteria B and C were implemented by identifying an exclusion area around the Yakima Valley west of Sunnyside and an exclusion area where the elevation is greater than 320 m (i.e., 200 m higher than the PNNL Campus). Criterion B was somewhat less restrictive than Criterion C because the western boundary of the Lower Columbia Basin as defined by the NWS runs north-south through Prosser and is therefore slightly east of the Yakima Valley and west of the Sunnyside exclusion area. A digital elevation model (30-m resolution) for eastern Washington was obtained from the University of Washington and implemented into the GIS map to indicate exclusion areas from consideration as a background monitoring location.

Criterion D was implemented by Gaussian plume modeling and internet mapping. The 1-hour drive time distances in each direction were established using Google Maps (Google Inc. ["Google"], 1600 Amphitheatre Parkway, Mountain View, CA 94043, United States). The minimum distance from the PNNL Campus for establishing a background monitoring location was calculated to be 17 km (see Appendix A).

When Criteria A through E are implemented and displayed graphically, a limited number of areas remain for installation of viable background air monitoring locations. There are four general areas that meet the first five criteria (A–E): the lower Yakima Valley (between Prosser and Benton City), Franklin and Walla Walla Counties, an area near the Vernita Bridge, and the Horse Heaven Hills (Figures 5.1 and 5.2).

Wind roses from around the PNNL Campus (Figure 5.3) were used to further evaluate Criterion E (Hoitink et al 2005). While meeting Criteria A through D, the Franklin-Walla Walla area, is in the general "downwind" direction from the PNNL Campus; note wind roses for meteorological stations 1, 11, 15, 18, 26, 27, 30. These are the closest wind monitoring locations to the PNNL Campus, and all indicate that wind frequently blows from the PNNL Campus toward the northwest and southwest. Therefore, the Franklin-Walla Walla area should not be considered for a background air monitoring location. The Vernita Bridge area should also not be considered for a background air monitoring location; while generally upwind, it does not satisfy the "distance from known atmospheric sources" in Criterion G (i.e., the 200 West area of the Hanford Site is only 9 km from the Vernita Bridge area). After excluding these additional areas from further consideration, only the Yakima Valley and Horse Heaven Hills areas are left for evaluation against the remaining criteria for establishment of a background air monitoring location.

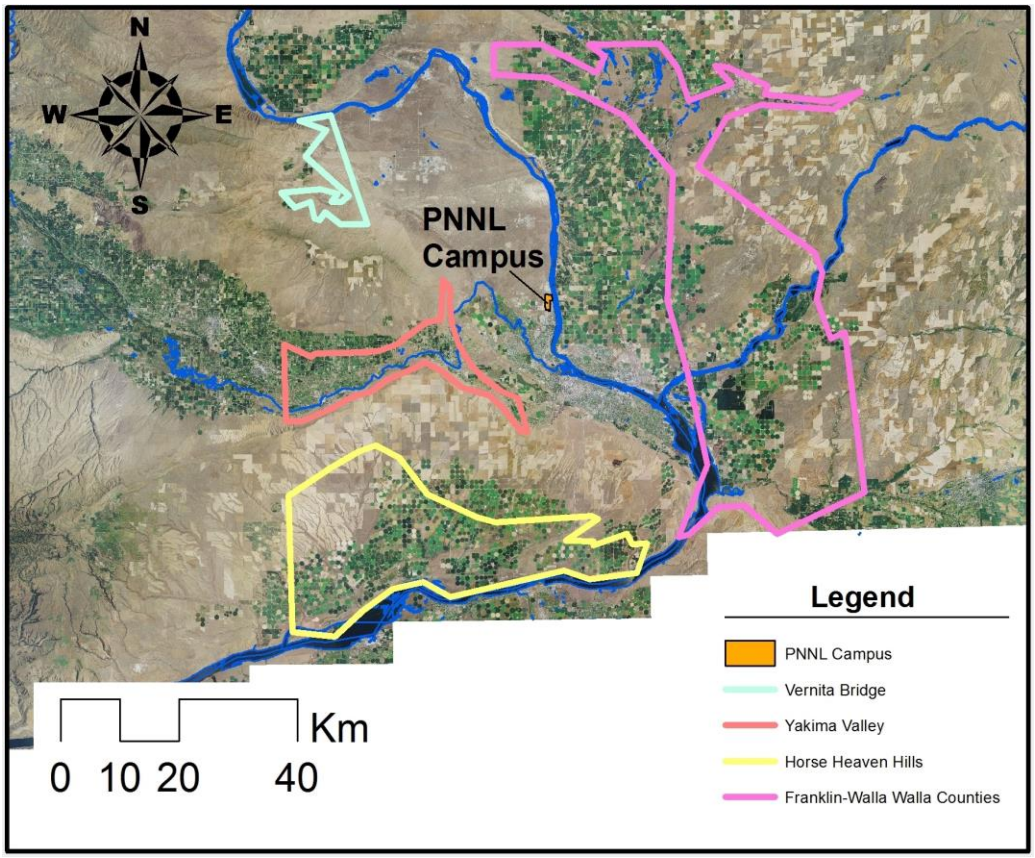

Figure 5.2. Areas that meet Criteria A through D for installation of a background air monitoring location

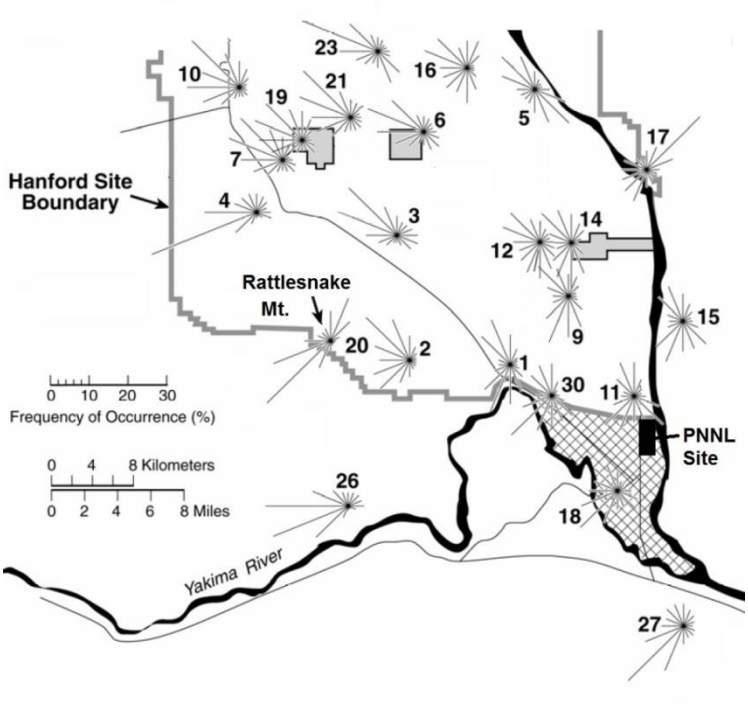

Figure 5.3. Wind Roses for the area around the PNNL Campus (Hoitink et al. 2005)

Criterion F is dependent on the previously discussed criteria and on identifying suitable infrastructure including a sampling area with sufficient power availability, access, and cooperation with the site owner. Criterion G is similar in identifying general siting requirements, including minimal obstructions, no nearby sources, minimal impact to the environment, and security that can be managed by site evaluations, prior knowledge, and phone calls.

Optional Criterion H was used to identify potential air background environmental surveillance areas where existing sampling operations are conducted by another agency program. Programs reviewed included those from the Hanford Site, WDOH, Areva, Perma-Fix, and the Energy Northwest. The Hanford Site and Energy Northwest were the only agencies to each have a single atmospheric monitoring station in or close to meeting the criteria for installation of a background air monitoring station (Figure 5.2). The two existing stations are in or near the Yakima Valley area (Figure 5.4).

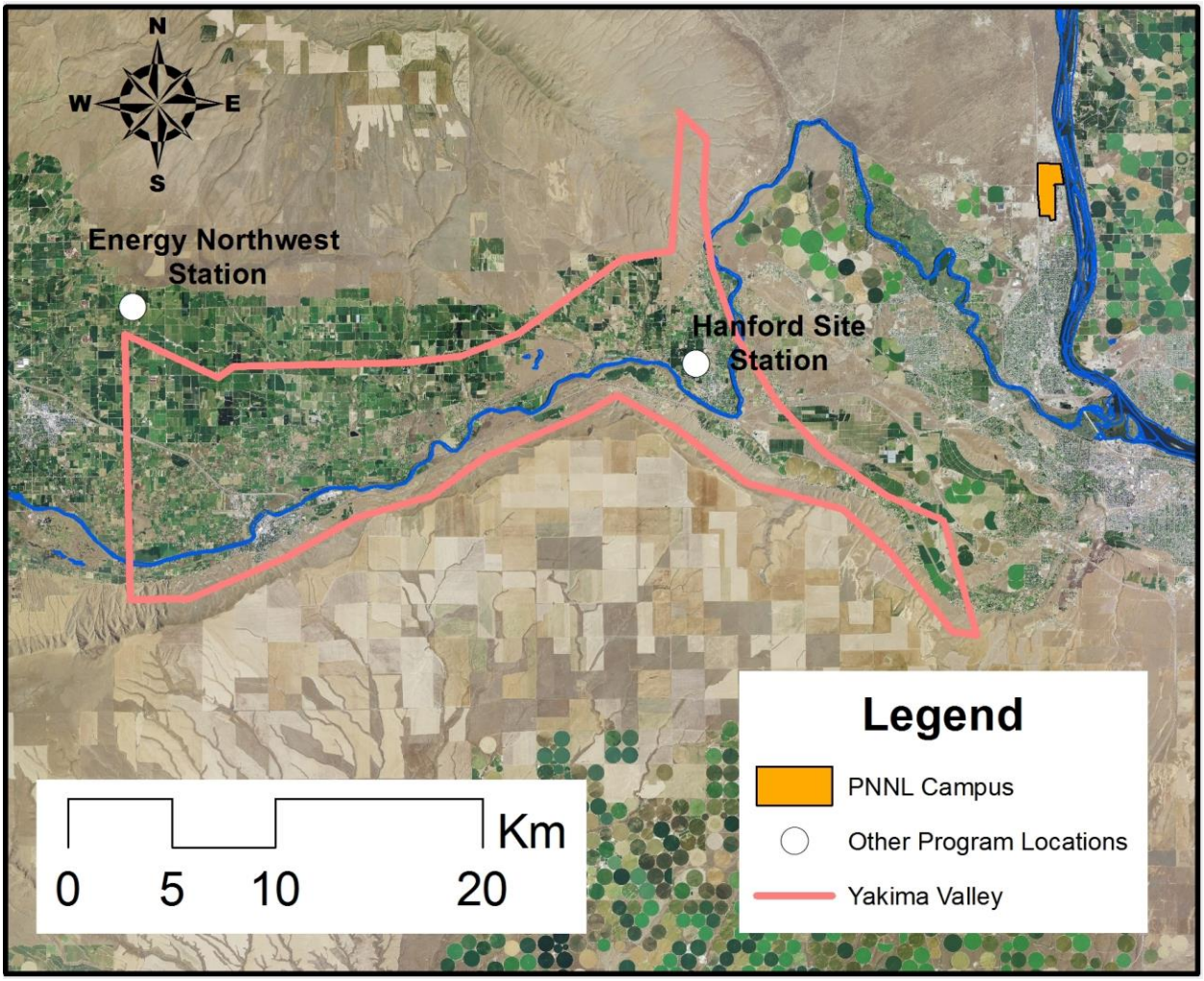

Figure 5.4. Air sampling stations operated by other programs located in or close to the Yakima Valley area

Optional Criterion I was evaluated and indicates there are “other program” locations in or near the Yakima Valley area that could potentially provide historical data (Figure 5.4). If one of these locations is a recommended location for background sampling, then looking for the data could prove useful.

6.0 PNNL Campus Background Monitoring Station Location Determination

After applying background location selection criteria described in the previous sections, four potential areas for installation of a background air monitoring station for the PNNL Campus were identified. Two of those areas (Vernita Bridge and Franklin-Walla Walla) were excluded based on more detailed evaluation of the selection criteria. Considering the two remaining areas (Horse Heaven Hills and the Yakima Valley), only the Yakima Valley area has existing atmospheric monitoring stations, both of which are in the same general direction (i.e., west) from the PNNL Campus. However, only one existing station lies within the Yakima Valley area and one lies outside of the proposed area due to its elevation. Potential locations within the Yakima Valley and Horse Heaven Hills areas were visited and evaluated against Criterion E (wind channeling), Criterion F (power availability), Criterion G (general siting including access, obstructions, and roads), and Criterion H (co-located sampling locale). Sites considered included the following locations shown in Table 6.1 and Figure 6.1. Photos of select locations are provided in Appendix B.

Table 6.1. Potential background station locations and elevations

Area/Location Name	Latitude	Longitude	Elevation (m)[a]
Yakima Valley Area			
Kiona-Benton City High School	46.275718	-119.499132	183
Chandler Powerplant (Department of Interior, Chandler Power and Irrigation Pump Station)	46.276495	-119.570538	183 (upper) 166 (middle) 158 (lower)
Irrigated Agricultural Research and Extension Center (WSU/USDA Agricultural Research Station)	46.252268	-119.737822	262 (upper) 256 (lower)
Energy Northwest Rad. Background Station	46.303414	-119.873921	317
Prosser Water Treatment Plant	46.214232	-119.764558	191
Housel Middle School (Prosser, WA)[b]	46.206661	-119.752825	219
Horse Heaven Hills Area			
Winery (Columbia Crest)	45.956553	-119.608526	193
Crow Butte Park	45.855143	-119.851814	80
Plymouth Park Campground	45.929941	-119.35255	80
McNary Dam	45.942074	-119.30044	99
US-395 Weigh Station	45.958995	-119.34123	140

[a] PNNL Site elevation is 177 m.
[b] Former Hanford Site air monitoring and TLD station location discontinued in 1990.

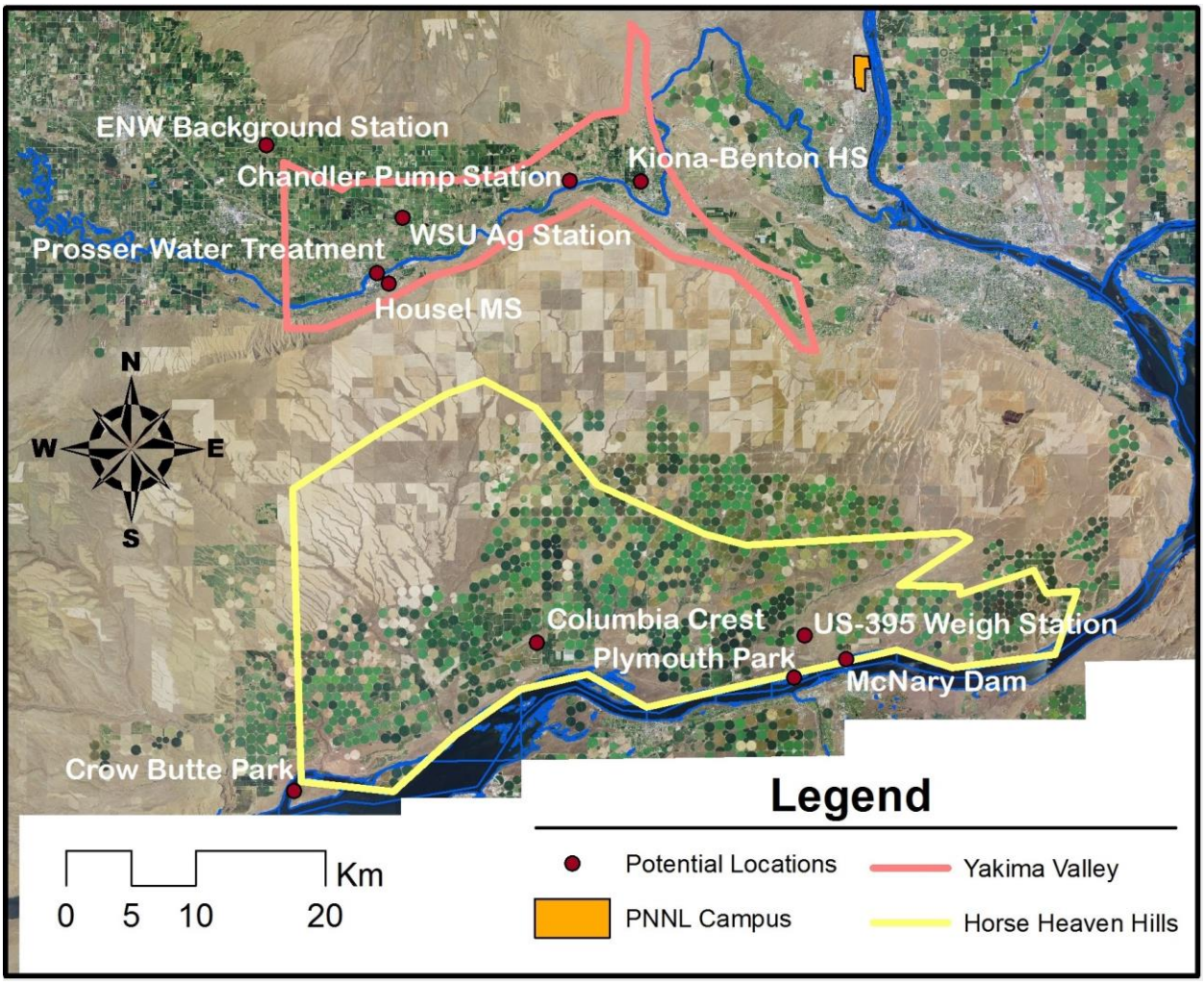

Figure 6.1. Potential background station locations relative to the PNNL Campus and either the Yakima Valley or Horse Heaven Hills area

A summary of the reconnaissance evaluation of the proposed potential background station locations is provided in Table 6.2. Based on the reconnaissance evaluation, staff identified the following four potential finalist locations:[1]

- Kiona-Benton City High School, 1205 Horne Dr., Benton City, WA, http://www.kibesd.org/site/
- Chandler Powerplant, 47415 W. Old Inland Empire Hwy., Benton City, WA, http://www.usbr.gov/projects/Powerplant.jsp?fac_Name=Chandler+Powerplant
- Irrigated Agricultural Research and Extension Center, 24106 N. Bunn Rd., Prosser, WA, http://iarec.wsu.edu/Pages/default.aspx
- Housel Middle School, 2001 Highland Dr., Prosser, WA, http://www.edline.net/pages/housel_middle_school.

[1] All finalist location websites last accessed on October 31, 2014.

Table 6.2. Reconnaissance summary of potential background station locations

Area/Site Name	Pros	Cons	Comment
Yakima Valley Area			
Kiona-Benton City High School	• Existing Hanford contractor sampling station could use to compare with PNNL data • Options for educational outreach • Could be located in the same locked area as the Hanford Site station to improve station security • Historical data potentially available		
Chandler Powerplant	• Operated by Department of the Interior • Better power access for upper and middle options • Low traffic, more secure • Due to ridge across road from pump station, upper option may be better than lower location	No convenient power at lower level location	Three possible options: upper by road, middle, and lower level. Agricultural Center may provide adequate meteorological data.
Irrigated Agricultural Research and Extension Center	• Secure and accessible • Power accessible • Ag Center has meteorological data • Option for sharing air data with Ag Center	• No obvious place to put station, but many options if away from tree line • Within hour drive, but off main arterial road	
Energy Northwest Rad. Background Station	• Existing particulate air sampling station, could use to compare with PNNL data • Historical data potentially available	• Elevation marginally too high • Location just west of the defined Yakima Valley area	Located at sub-station at the intersection of N County Line and Alexander Extension roads; however, location not actually found (no photo taken).
Prosser Water Treatment Plant	• Managed by U.S. Bureau of Reclamation • Power accessible	• Restricted U.S. government access road, could not get to treatment plant • Potential for tampering, being quite visible from side of road • Power visible, but tall poles potentially increasing line installation costs	

Table 6.2. (cont.)

Area/Site Name	Pros	Cons	Comment
		Yakima Valley Area (cont.)	
Housel Middle School	• Easy access • Power accessible (power box visible in corner of playground) • Options for educational outreach • Historical data potentially available	• Potential for tampering • Would need separate, secure gated area	.
		Horse Heaven Hills Area	
Winery	Open plateau area	• No visible power options • Air station does not fit into the aesthetics of a winery	
Crow Butte Park	Not applicable	Marginally too far	Crow Butte eliminated since outside of the 1-hr drive criterion (no photo taken).
Plymouth Park Campground	Access to power	• Limited year-round access (park typically open only April–Oct) • No ideal location on entry road	
McNary Dam	U.S. Army Corps of Engineers site	• Surrounded by steep hills • No accessible power outside of security fence (solar light on pole outside of fence line)	
US-395 Weigh Station	None identified	• Surrounded by hills • Location not ideal due to increased emissions with stop/go vehicle traffic	

These locations are evaluated against the overall criteria as shown in Table 6.3. Any one of these locations is adequate for the establishment of an environmental surveillance background station; however, the preferred location is Kiona-Benton City High School, where all of the criteria (including optional) are met. Additionally, administration officials at the Kiona-Benton City High School have indicated a willingness to support an additional environmental surveillance sampling station for the PNNL Campus, which is also a primary criterion (Criterion F).

Table 6.3. Evaluation of finalist potential background station locations against criterion

Criterion	Kiona-Benton City High School	Chandler Powerplant	Irrigated Agricultural Research and Extension Center	Housel Middle School	Comments
A. Dilution ratio of 1/50th	Yes	Yes	Yes	Yes	
B. Similar air composition	Yes. Elevation difference = 6 m	Yes. Elevation difference = 6 to 19 m	Yes. Elevation difference = 79 to 85 m	Yes. Elevation difference = 42 m	Elevation difference between PNNL Campus and background location < 200 m.
C. Similar weather conditions	Yes	Yes	Yes	Yes	Within the Lower Columbia Basin wind shed.
D. Location is reasonable distance away considering poor dispersion conditions	Yes. 25-30 min 30 km (19 mi)	Yes. 35-40 min 39 km (24 mi)	Yes. 45-50 min 60 km (38 mi)	Yes. 35-40 min 50 km (31 mi)	Not more than 1 hr drive time.
E. Terrain effects including ground cover, land use, and topography	Yes. Nearby orchard, grassy campus, and shrub steppe.	Yes. Upper site has shrub steppe, open area. Lower area includes trees and some grassy areas.	Yes. Campus area with trees, irrigation research areas, grassy areas, nearby shrub steppe.	Yes. Grassy campus and shrub steppe.	Air routes from background station toward facility much of the year. All locations within the Lower Columbia Basin.
F. Necessary infrastructure available	May need some minor electrical service added.	Would need an electrical service installed.	May need minor electrical service added.	Electrical service is already in place.	Requires electrical service of 15 amp 120 V, and cooperation with site owner.
G. Meets general siting requirements including access, minimized obstructions, and distance from other atmospheric sources.	Yes. Next to gravel and paved roads, controlled and fenced area, trees far enough away not to impede sampling.	Yes. Gravel roads. Buildings and trees far enough away. Not secured area.	Yes. Gravel and paved roads. Buildings could be far enough away. Not a secured area.	Yes. Paved road access, no trees or buildings to consider. Not a secured area, and grass watering may be an issue.	
H. Co-located sampling site.	Yes	No	No	No. Former Hanford Site sampling location.	Optional criterion not required for decision making.
I. Historic data from previous sampling program.	Yes	No	No	Yes	Optional criterion not required for decision making.
Summary	All criteria met. Shortest travel distance, smallest elevation difference. Secured area available.	All primary criteria met. optional criteria H & I not met.	All primary criteria met. optional criteria H & I not met. Farthest away and has greatest elevation differences.	All primary criteria met. optional criterion H not met.	

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Appendix A

Supporting Information

Appendix A Supporting Information

A.1 Annual Average Dilution Factor

When determining what the minimum acceptable dilution factor is between a site boundary and the background station, the primary consideration is the impact that errors in the background measurement can have on other measurements made on or near the site. If the background monitoring station is too close to the site, then site emissions could be collected by the background monitor. This would result in subtraction of unacceptably high background values from sample station measurements. Therefore, it is necessary to locate the background station sufficiently far away from the site that any errors created in the background subtraction step do not increase the total combined error above acceptable levels. For the PNNL Campus, a minimum of $1/50^{th}$ dilution, or 2%, between the PNNL Campus boundary and the background location based on annual CAP88-PC particulate dispersion modeling was selected. For the PNNL Campus Environmental Monitoring program, the acceptable error in the sample volume measurement is ±15%. For sample analysis there is no contractually required acceptable error; however, the analytical laboratory participates in the DOE MAPEP program (Meier 2011), which typically result in acceptable analytical errors on the order of 10–15%. Assuming the analytical error to be ±15%, the acceptable total combined error (calculated as the root mean square of the individual error terms) of a sample (without any background subtraction) is ~21% (Eq. A1). If the additional 2% systematic error that could be contributed by collection of site emissions at the background location is considered, the total potential combined error becomes 23% (Equation A2). Since the potential systematic error is ten times less than the acceptable error of the measurement, it might be considered acceptably small.

$$error = \sqrt{0.15^2 + 0.15^2} = 0.21 \qquad \text{Eq. A1}$$

$$error = \sqrt{0.15^2 + 0.15^2} + 0.02 = 0.23 \qquad \text{Eq. A2}$$

Therefore, if a potential background location has an annual average concentration 1/50th of the concentration estimated at the site boundary (or less), then that location might be considered acceptable for use as a background location because the small amounts of effluent collected at the background station will be indistinguishable from the random sampling error. For programs with lower tolerance for error, a lower dilution factor may be necessary.

A.2 Minimum Distance Calculation

It is also important that the background air sampler is located a minimum distance from the PNNL Campus to minimize the potential for biasing the background sample results during short time periods of poor dispersion. For example, during stable inversion conditions, a single two week sample at the background location could be influenced by PNNL Campus emissions if the background location were too close and the wind blew directly from the PNNL Campus to the background location. To calculate a minimum distance for the background sampler location, a Gaussian plume dispersion calculation is sufficient (Eqs. A3 and A4). For this case, the general form of the equation reduces to a ground-level centerline receptor. The concentration (C) along the plume centerline varies according to the horizontal

dispersion coefficient (σ_y) and the vertical dispersion coefficient (σ_z). These dispersion coefficients vary as a function of downwind distance, and were interpolated from the moderately stable Pasquill-Gifford curves (Gifford 1961; Hunter 2012). The stack emission rate (q) will be set to unity (1 g/s), and the plume height set to 38 m (current highest effective plume height for any PNNL Campus major emissions unit). The wind speed (u) chosen for this worst-case scenario is 1.3 m/s (3 mph). This wind speed is 50% of the wintertime average wind speed (Stone et al. 1983). Winter is the most common time for the occurrence of stable inversion conditions. It was decided that the minimum distance considered would be the distance where the calculated Gaussian concentration is 20% of the maximum downwind plume centerline concentration. Coupled with the infrequency that these worst-case dispersion conditions might exist, this dilution will provide a sufficient minimum distance for the placement of a background monitoring station. Under these conditions, the minimum distance that the background air sampling location should be established is 17 km from the PNNL Campus (Figure A.1). It is unlikely there would be a persistent wind direction during very stable conditions, and there would be associated meandering of the air stream.

$$C = \frac{q}{\pi u \sigma_y \sigma_z} exp\left(-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right) \qquad \text{Eq. A3}$$

$$\sigma_y = 0.0792x^{0.8852} \; ; \; \sigma_z = 17.11Ln(x) - 108.9 \qquad \text{Eq. A4}$$

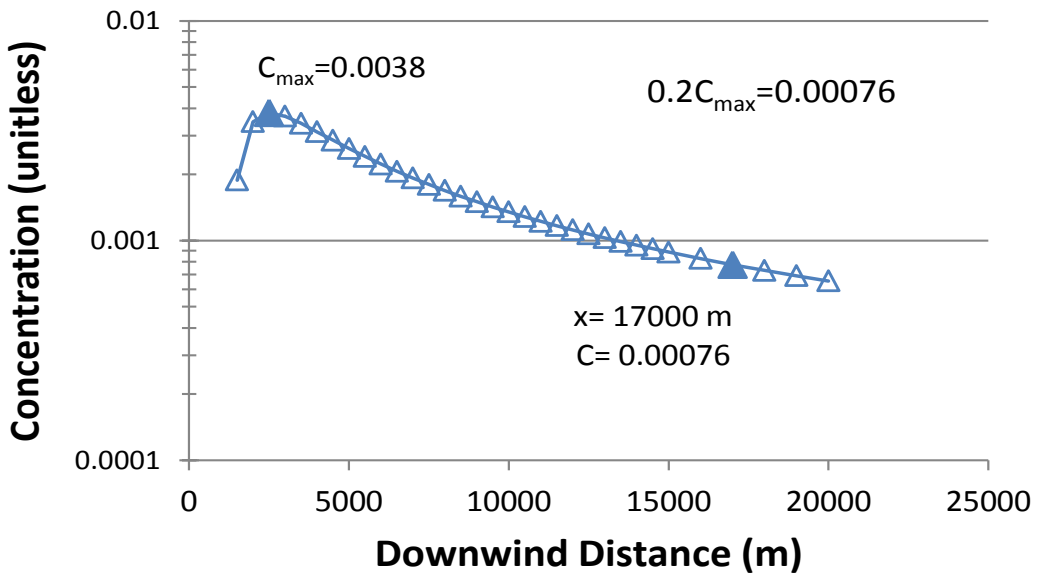

Figure A.1. Centerline concentration from a Gaussian plume model (Eq. 1) using the specified input values [u=1.3 m/s, moderately stable stability class, effective plume height 38 m)

Appendix B

Potential Background Station Locations for the PNNL Campus

Appendix B Potential Background Station Locations for the PNNL Campus

Figure B.2. Potential background air monitoring location – Yakima Valley area Kiona-Benton City High School looking NE

Figure A.3. Potential background air monitoring location – Yakima Valley area Chandler Power Plant Irrigation Pump Station (upper) looking S and looking W toward middle

Figure A.4. Potential background air monitoring location – Yakima Valley area Chandler Power Plant Irrigation Pump Station (middle) looking E toward upper

Figure A.5. Potential background air monitoring location – Yakima Valley area Chandler Power Plant Irrigation Pump Station (lower) looking NE toward middle and upper



Figure A.6. Potential background air monitoring location Yakima Valley area – WSU/USDA Agricultural Research Station with a variety of terrain/landscape types

Figure A. Error! Not a valid bookmark self-reference.Error! Not a valid bookmark self-reference.**7**. Potential background air monitoring location Yakima Valley area – Prosser Water Treatment Plant

Figure A.8. Potential background air monitoring location Yakima Valley area – Housel Middle School (Prosser, WA)

Figure A.9. Potential background air monitoring location – Horse Heaven Hills area winery location (tasting room area; public road view looking NW; public road view looking SW

Figure A.10. Potential background air monitoring location – Horse Heaven Hills area Plymouth Park Campground

Figure A.11. Potential background air monitoring location – Horse Heaven Hills area McNary Dam

Figure A.12. Potential background air monitoring location – Horse Heaven Hills area–US-395 Weigh Station, looking NNW

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