# Health Risks from Diesel Emissions in the Quincy Area

**Air Quality Program**

Washington Department of Ecology

Olympia, Washington

DEPARTMENT OF ECOLOGY
State of Washington

August 2020 | Publication 20-02-019

# Publication Information

This document is available on the Department of Ecology's website at:
https://fortress.wa.gov/ecy/publications/summarypages/2002019.html

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# Executive Summary

This document presents Ecology's assessment of health risks caused by diesel emissions in Quincy. It updates and builds on a report written for five Quincy data centers,[1] as required by the Pollution Control Hearings Board.

Ecology modeled air emissions from all diesel sources in the Quincy area to estimate how much diesel particles and nitrogen dioxide were in the air. These emissions came from data center emergency engines, locomotives, on-road vehicles, and non-road vehicles and equipment. Our goals were to:

- Determine the community locations that experience the highest exposure to diesel engine emissions.
- Estimate the health risks associated with that exposure.
- Determine the sources that most contribute to those risks.

We will use the results of this analysis and air monitoring data to inform future permitting decisions and public outreach in the Quincy area.

## Key results and conclusions

- Quincy area data centers are permitted to use their emergency engines for more hours than needed. They ask for excess hours in case they experience worst-case power outage scenarios. Because power outages are rare, they emit only a fraction of their allowable emissions.
    - In 2016, Quincy data centers emitted about 12 percent of their allowable diesel particle emissions. Emissions in years after 2016 could be higher because some data centers had not installed all permitted engines.
    - If Quincy data centers install all their permitted engines and operate at similar rates as in 2016, they will emit about 25 percent of their allowable diesel particle emissions.
    - In 2018, Quincy data centers emitted only about 3 percent of their nitrogen oxides emissions limits.
- Sources such as heavy-duty trucks, locomotives, agricultural equipment, and construction equipment contribute more than 75 percent of the total Quincy-wide actual diesel particle emissions.
    - Emissions from on- and non-road vehicles should decrease over time as they are replaced with cleaner ones. This means future data center emissions may make up a larger portion of overall diesel emissions in Quincy.
- The degree to which specific sources' emissions contribute to long-term exposure and health risk in the community depends on how close the residences are to the sources.
    - The highest exposure to long-term diesel emissions occurs at residences located near main traffic corridors.

[1] https://ecology.wa.gov/Asset-Collections/Doc-Assets/Air-quality/Data-Centers/20180806HealthDieselDataCenter

- If data centers use their engines as much as their permits allow, then emissions from clusters of data center engines may impact a few residences at levels similar to exposures along main traffic corridors in Quincy.

- The highest diesel particle level estimated at a residence in the Quincy area ranks among the lowest 25th percentile of estimated levels in Washington's communities. For comparison:
  - Moses Lake – 21st percentile
  - Clarkston and Walla Walla – 27th percentile
  - Ellensburg – 34th percentile
  - Pasco – 55th percentile
- Our estimates of nitrogen dioxide levels in Quincy, based on actual emissions in 2018, meet national air quality standards and are lower than California Office of Environmental Health Hazard Assessment's reference exposure level (health-based threshold).
- Air monitoring in Quincy during 2018 found:
  - No large contributions from data center-related emissions.
  - No violations of national air quality standards for fine particles or nitrogen dioxide.
  - Nitrogen dioxide concentrations vary throughout the day in a pattern that mirrors vehicle traffic.
  - Fine particle levels in the Quincy area are similar to other nearby sites.
  - Our previous estimates of fine particles and nitrogen dioxide background concentrations used to permit data centers in Quincy were appropriate.
- Emissions during power outages that coincide with unfavorable meteorology may cause concentrations of nitrogen dioxide that may cause some short-term temporary respiratory effects among sensitive individuals. Power appears to be stable. Grant County Public Utility District reported a system-wide average annual power availability of 99.9958 percent. Unplanned power outages at Quincy data centers occur less than one hour per year on average based on data reported by Microsoft and Oath.

## Recommendations

This analysis represents the most comprehensive look at diesel engine emissions in the Quincy area. Ecology should use the results to inform future permitting and public outreach.

We propose to:

- Update this analysis to account for changes in emissions as needed.
- Post the results of this assessment on Ecology's web site.
- Post an interactive data map that identifies sources and concentrations of diesel particles and nitrogen dioxide at different locations throughout Quincy. Future permittees would be able to use this as they prepare analyses that support their applications.[2]
- Operate the Quincy weather-monitoring site so we can use local meteorological data to model future project emissions.

[2] https://arcg.is/0SLWem

- Consider allowing fewer hours of engine use for future permits.
    - Based on engine use reported so far, data centers do not use their engines as much as they request.
- Work with data centers to improve methods for estimating ambient impacts from existing data center emissions.
    - These analyses partly define the existing background levels of pollutants in the area. Current methods require significant effort and may overestimate background levels.
    - Air quality analyses that support permits should reasonably reflect data centers' intermittent emissions instead of treating them as continuous sources.
- Raise awareness among local planners about emissions from data centers. Local planners may help reduce exposure to data center emissions by avoiding residential zoning near current and future clusters of data centers in Quincy.
- Write a letter that recommends data centers develop plans to reduce generator use in the event of lengthy electric power outages.

# Introduction

This document presents Ecology's analysis of health risks posed by diesel engine exhaust in Quincy. It builds on and enhances a similar analysis submitted on behalf of five companies that own and operate data centers in Quincy. The goals of this analysis were to:

- Determine the community locations that experience the highest exposure to diesel engine emissions.
- Estimate the health risks associated with that exposure.
- Determine the sources that most contribute to those risks.

The results will be used to inform future decisions.

More specifically, this document provides:

- A background on data center permitting in Quincy.
- A description of a citizen group's appeals of past data center permits.
- Estimates of diesel engine emissions in the Quincy area.
- Estimates of the maximum cancer risk attributable to actual and potential diesel emissions in Quincy and the source contribution of these risks.
- A description of potential non-cancer hazards related to diesel engine emissions in Quincy.
- A discussion of uncertainties related to assessment of health risks.
- A summary of Quincy air monitoring results.

## Permitting data centers in Quincy

Quincy has become a favored place for data center expansion and construction, mostly because its power supply is a good value and very dependable. According to Grant County Public Utility District (Grant County PUD), power outages in Quincy are rare, with a 99.9958 percent annual average reliability from 2006 through 2016 (Grant County PUD, 2017). Reports of unplanned outages at Quincy area data centers through 2017 support PUD's reliability figures.[3]

To plan for an electrical power outage, companies build each data center with enough backup generators to operate their systems when electrical line power goes out. Ecology is involved in permitting data center construction because backup generators use diesel fuel. Diesel engine exhaust contains regulated criteria and toxic air pollutants (TAPs) including nitrogen dioxide ($NO_2$), carbon monoxide, organic compounds, and small particles.

When reviewing increases in emissions from a new or modified source of air pollutants, Ecology must determine that the proposed new source complies with existing performance and emission standards, and uses best available control technology (WAC 173-400-113).

[3] Microsoft Columbia Data Center reported 2.6 hours of total unplanned outage from 2008-2017. Oath Data Center reported 2.5 hours of total unplanned outages from 2011-2017.

In addition, estimated emissions from the proposed new source must not cause ambient impacts that:

- Violate National Ambient Air Quality Standards (NAAQS) – This process involves estimating the ambient impacts of the project's criteria pollutant emissions added to an assumed background (existing) concentration of pollutants.
- Result in unacceptable health risk from exposure to TAPs (Chapter 173-460 WAC) – This process involves estimating ambient impacts of the project's TAP emissions compared to acceptable source impact levels or other acceptable risk criteria.

In 2007, Ecology permitted construction of the first three data centers in Quincy. When we permitted these facilities, diesel engine exhaust particulate (diesel particles) was not regulated as a TAP under Chapter 173-460 WAC. As a result, those data center permits allowed more hours of operation (and diesel fuel use) than would likely be permitted under the revised toxics rule in effect since June 2009.

Since 2010, several companies proposed either expansions or new data center projects in Quincy (Table 1). Each of these projects considered ambient impacts of diesel particles and $NO_2$ because the updated rule (Controls for New Sources of Toxic Air Pollutants, Chapter 173-460 WAC) included these pollutants as TAPs. Under this rule, applicants must determine the ambient impact of their emissions. If their emissions cause an ambient impact greater than acceptable source impact levels (ASILs), they must assess the health impact of their increased emissions. If the risks meet acceptability criteria according to WAC 173-460-090, Ecology may issue a permit. As of June 2020, Ecology has permitted over 300 emergency engines at eight data centers in Quincy (Table 1).

**Table 1**. Data Center Companies Diesel-Powered Emergency Generators Permitted by Ecology in Quincy

| Year Permitted | Company | Facility/Project Name | Number of Engines | Generating Capacity (per generator) | EPA Tier Rating[a] |
|---|---|---|---|---|---|
| 2007 | Microsoft Corporation | Columbia Data Center – CO1 & CO2 | 24 | 2.5 MW | II |
| 2007 | Oath (formerly Yahoo) | Phases 1-3 | 13 | 2.0 MW | II |
| 2007 (revised 2018) | H5 (formerly Intuit) | H5 Quincy Data Center | 9 | 2.5 MW | II |
| 2010 (revised 2020) | Microsoft Corporation | Columbia Data Center – CO3, CO4, & CO5 | 11[b] | 2.5 MW | II |
| 2011 | Oath (formerly Yahoo) | Phase 5 | 10 | 2.0 MW | II |
| 2011 (revised 2017) | NTT Data Services (formerly Dell) | --- | 5[c] | 3.0 MW | II |
| 2011 (revised 2016) | Sabey | Intergate-Quincy | 44 | Up to 2.0 MW[d] | II |

| Year Permitted | Company | Facility/Project Name | Number of Engines | Generating Capacity (per generator) | EPA Tier Rating[a] |
|---|---|---|---|---|---|
| 2012 (revised 2017 and 2019) | Vantage | --- | 17 | 5 @ 3.0 MW<br>10@ 2.75 MW<br>2 @ 0.5 MW | II |
| 2014 (revised 2017) | Microsoft Corporation | MWH – 01-02 | 45 | 40 @ 2.5 MW<br>4 @ 2.0 MW<br>1 @ 0.75 MW | IV |
| 2018 (revised 2019 and 2020) | Microsoft Corporation | MWH – 03-04-05-06[e] | 60[f] | 56 @ 3.0 MW<br>2 @ 1.5 MW<br>1 @ 1.0 MW<br>1 @ 0.5 MW | IV |
| 2019 | CyrusOne | Quincy Data Center [g] | 42 | 40 @ 2.25 MW<br>2 @ 0.75 MW | II |
| 2020 | Microsoft Corporation | Columbia Data Center – CO6[g] | 5 | 2.5 MW | II |

a – Tier rating relates to the level of emission controls
b – 13 engines originally permitted
c – 28 engines originally permitted
d – Engines may be smaller as long as they meet appropriate emission limits
e – Originally permitted October 23, 2018. Emissions from these engines not included in the ambient impact analysis
f – 72 engines originally permitted
g – permit issued after Ecology conducted this ambient impact analysis

## Community-wide approach to permitting data centers in Quincy

Washington's air toxics rule allows an increased cancer risk of up to 10 cases of cancer per million people for each new source or project (WAC 173-460-090(7)). State law does not currently define an upper limit for acceptable cancer risk related to cumulative air toxics.

In 2010, when we recognized that Quincy was becoming a preferred location for data centers, Ecology considered a community-wide approach to data center permitting. We intended for this approach to consider the impacts of emissions from clusters of new emergency engines on individuals in Quincy. This approach included requirements for the permittees to:

- Coordinate with other area data centers about maintenance and testing of their engines to minimize periods of overlapping plumes and impacts on the community.
- Quantify the health risk from cumulative exposure to diesel particles.

## Data center air permits appealed to PCHB

With Ecology's 2010 approval order (permit) to expand the Microsoft Columbia Data Center (CO3, CO4, and CO5), a group of Quincy residents formed Microsoft Yes, Toxic Air Pollution No (MYTAPN). This community group appealed Microsoft's permit and several Quincy data center permits after that to the Pollution Control Hearings Board (PCHB). In the Microsoft Columbia

Data Center appeal, MYTAPN raised several issues. Two of these issues proceeded to a two-day hearing in February 2012. These issues centered on whether:

- Emissions controls represented best available control technology (BACT).
- Emissions estimates used in ambient impact and health impact analyses were flawed to the point of invalidating the 2010 approval order.

After hearing the group's appeal, the PCHB concluded that although appellants failed to show that the ambient impact analysis (i.e., modeling) was incorrect, the process contained significant uncertainties. To address this, the PCHB inserted a condition in the permit to require:

> ". . . a health risk assessment that analyzes the public health risk to Quincy residents from DEEP [diesel particle] emissions in the Quincy area, including emissions from data center engines, highways, locomotives, and other source categories. . . . The study shall model the locations in the community that experience the highest exposure to DEEP [diesel particle] emissions, estimate the health risks associated with that exposure, and apportion the health risks among contributing source categories. In preparing the study, Microsoft may collaborate with other owners of diesel engines in or near Quincy. Ecology shall review the assessment and take appropriate action based on the results (PCHB 2012)."

Yahoo (now Oath) also agreed to help prepare a health risk assessment. The Board ordered Dell (now NTT) and Sabey to "cooperate with Microsoft and Yahoo as they complete the 2017 Health Risk Assessment as required by the Board in Microsoft and Yahoo." Although not required by the Board, Vantage contributed to the preparation of a health risk assessment (HRA).

## Data center companies' health risk assessment (HRA)

The data center companies – Microsoft Corporation, Oath Holdings (formerly Yahoo), Sabey Data Centers, Vantage Data Centers, and NTT DATA Services (formerly Dell) – hired Landau Associates to prepare an assessment of health risk caused by diesel particles. Before submitting an HRA, the Board specified that a protocol be submitted to Ecology before July 1, 2017. The protocol describes how emissions, impacts, and health risks will be determined.

Landau Associates worked with Ecology as they prepared a protocol for the HRA. Landau submitted the protocol on June 30, 2017, and Ecology approved it on November 14, 2017. Landau submitted the final HRA on August 6, 2018.[4]

After reviewing the HRA submitted by Landau Associates (for the data centers), Ecology determined that it followed the modeling protocol and it satisfied the Board's requirement.

[4] https://ecology.wa.gov/Asset-Collections/Doc-Assets/Air-quality/Data-Centers/20180806HealthDieselDataCenter

Still, Ecology identified the following issues:

- The characterization and modeling approach for estimating impacts from area sources (local roadways and agricultural areas) likely resulted in overestimates of ambient impacts.[5]
- Shortly after Landau Associates submitted the HRA, EPA released new tools to improve diesel particle emissions estimates from on-road highway vehicles.
- Incorrect geographic coordinates for portions of the rail line led to errors in the location of locomotive-related ambient impacts.

Ecology fixed the issues listed above and conducted additional analyses that extended beyond the scope of the Board's order. These included:

- Corrected the misaligned railroad track emission location (Figure 1).
- Updated the emissions estimates from on-road heavy-duty vehicles based on 2019 projected emissions instead of 2015 emissions estimates.
- Corrected some slightly misaligned road segments.
- Improved the technique for estimating ambient impacts from local (area) sources such as side street traffic and agricultural equipment.
- Analyzed short-term $NO_2$ impacts based on actual 2018 emissions profiles from Quincy data centers and mobile sources.
- Evaluated 2018 Quincy air pollutant monitoring data.

# Ecology's Analysis of Ambient Impacts and Health Risks of Diesel Engine Exhaust Emissions in the Quincy Area

Ecology modeled diesel engine emissions to determine short- and long-term health risks in Quincy. In many ways, the analysis resembled that conducted by Landau Associates, except Ecology made corrections, updated emissions estimates, and used alternate techniques as shown in Table 2. Generally, the health risk analysis involved:

- Estimating diesel engine emissions from sources in and around Quincy.
- Identifying the routes of diesel engine emissions exposure (i.e., inhalation, ingestion, or absorption through skin).
- Modeling the dispersion of pollutants in the atmosphere.
- Estimating long-term (chronic) and short-term (acute) exposure concentrations.
- Identifying concentration-response information (how exposure to varying concentrations result in health effects in a population) for use in quantifying risk and hazards.
- Calculating and characterizing risks from exposure to diesel engine emissions.
- Discussing the uncertainty related to assessing risks.

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[5] Landau Associates used a modeling approach specified by Ecology.

**Table 2**. Key Diesel Particulate Emissions Methodology Differences between Landau Associates HRA and Ecology Re-analysis

| Sources of Emissions | Landau HRA | Ecology Re-analysis |
|---|---|---|
| SR 28 and SR 281 | Emissions based on MOVES 2015 VMT | Emissions based on updated MOVES 2019 projected emissions |
| Locomotives | Some emission points for railroad were not correctly aligned | Corrected misaligned railroad track emission locations |
| Local roads, area source, background, agricultural background | Used AERMOD to estimate emissions from 1.33 km x 1.33 km gridded area sources | Used the 99th percentile of Quincy-area gridded emission rate in AERSCREEN modeled as a volume source with a 3 m release height and a 1.4 m initial vertical dimension. The maximum impact was conservatively chosen to represent "background" across the entire modeling domain. |

# Emissions and source data

Ecology gathered the best available data on emissions and emissions release parameters. Ecology first determined the diesel particle and nitrogen oxides ($NO_x$) emission rates from emergency diesel engines permitted at data centers before October 23, 2018, as well as mobile sources and other sources in the Quincy area. We also identified the emissions release characteristics of these emission points (e.g., stack height, exhaust temperature, exhaust flow rate).

As part of the diesel emissions health risk analysis, Ecology considered emissions from:

- On-road highway traffic (SR 28 and SR 281) – Ecology relied on EPA's Motor Vehicle Emission Simulator (MOVES) model and projected vehicle miles travelled (VMT) information to estimate emissions projected for 2019.
- Locomotives (BNSF rail line) – Ecology used Burlington Northern Santa Fe (BNSF) 2015 activity data to estimate locomotive emissions.
- Agricultural equipment, construction equipment, local (non-highway) roads, and other diesel equipment – Based on countywide totals, we allocated emissions to the local area based on spatial surrogates such as population and land use.
- Emergency engines at Quincy data centers (Figure 2).
    - Actual 2016 emissions from Quincy data centers – These emissions are estimated based on the actual use of engines at each data center during 2016.
    - Projected actual emissions from Quincy data centers – Because 2016 actual emissions are based on data centers that have not achieved full build-out, the projected actuals represent a scaled-up estimate of emissions based on the fraction of unbuilt (i.e., engines are not present on-site) to the total number of permitted engines before October 23, 2018.
    - Potential emissions from Quincy data centers assuming each of the facilities uses all of their engines at the maximum allowable rate every year (as of October 23, 2018).

Since October 23, 2018, Ecology modified some facilities' existing permits to make requested changes in permit conditions, and issued new permits to install and operate additional engines at Quincy-area data centers. These new and modified permits for Quincy-area data centers result in a net additional 105 engines and 612 lb/yr of allowable diesel particulate emissions that were not incorporated in this ambient impact analysis.

- Microsoft MWH permitted to install an additional 60 engines (net allowable diesel particle emissions increase in 312 lb/yr).
- CyrusOne permitted to install 42 engines (allowable diesel particle emissions 1240 lb/yr).
- Microsoft Columbia permitted to install a net additional three engines (net decrease in allowable facility-wide diesel particle emissions of 860 lb/yr due to additional restrictions on existing engines).
- Vantage modified their permit resulting in a net decrease in allowable diesel particle emissions of 80 lb/yr.

Table 3 shows each general source's contribution to the total amount of diesel particle emissions within a 15 km x 15 km area around Quincy (Figure 3). Emissions from the data center emergency engines reflect:

- Actual emissions in 2016.
- Projected actual emissions assuming all permitted engines are installed and operate similarly to 2016.
- Emissions based on allowable limits in permits (i.e., potential to emit).

We assumed no year-to-year variations in on- and non-road sources' emissions. Figure 4 shows the estimated annual diesel particle emissions from each of the sources considered within this same area encompassing Quincy.

**Table 3**. Diesel Particle Emissions Estimates from Quincy-area Sources (within 15 km x 15 km area encompassing Quincy)

| Source | Emissions in 2016 (lb/yr) | Projected Actual Emissions (lb/yr) | Potential to Emit (lb/yr) |
|---|---|---|---|
| All Quincy data centers | 1170 | 2490 | 10020 |
| H5 Data Center | 94 | 141 | 1200 |
| Microsoft Columbia Data Center | 154 | 163 | 2060 |
| Microsoft MWH Data Center | 618 | 1379 | 1628 |
| NTT | 34 | 34 | 254 |
| Sabey | 76 | 224 | 816 |
| Vantage | 124 | 422 | 458 |
| Yahoo | 66 | 123 | 3600 |
| SR 28 | 1190 | 1190 | 1190 |
| SR 281 | 310 | 310 | 310 |
| BNSF – locomotive | 2450 | 2450 | 2450 |
| Other sources – agricultural equipment, local roads, construction and other diesel equipment | 4200 | 4200 | 4200 |
| **All Quincy-area sources** | **9320** | **10640** | **18170** |

- SR 28 and SR 281 emissions based on 2019 vehicle miles traveled.
- Locomotive emissions based on 2015 data.
- Other (area) source emissions based on 2014 county-wide totals adjusted by spatial surrogates such as land use and population.

## Identifying routes of exposure

Human exposure to chemicals in the environment occurs through inhalation, ingestion, or absorption through skin. The primary route of exposure to most air pollutants is inhalation; however, some air pollutants may be absorbed through ingestion or skin/eye contact. Ecology uses guidance provided in California's "Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments" to determine which routes and pathways of exposure to assess for the chemicals emitted to the air (CalEPA, 2015). This guidance does not indicate the need to consider multi-pathway exposures for diesel particles and $NO_2$.

It is possible that levels of polycyclic aromatic hydrocarbons (PAHs) and the few other persistent chemicals in diesel particles will build up in food crops, soil, and drinking water sources near roadways and facilities. However, given the relatively low amounts of PAHs and other multi-exposure route type chemicals emitted from these sources, quantifying exposures via pathways other than inhalation is very unlikely to yield significant concerns. Further, inhalation is the only route of exposure to diesel particles that has received sufficient scientific study to be useful in human health risk assessments. In the case of the Quincy-area diesel emissions, Ecology will evaluate only inhalation exposure to diesel particles and $NO_2$.

## Dispersion modeling for inhalation exposure assessment

For Ecology's health risk analysis related to diesel emissions in Quincy, we estimated long-term inhalation exposure concentrations for diesel particles and short-term inhalation exposure concentrations for $NO_2$. We used dispersion models that rely on meteorological, geographical, and emissions data to estimate ambient impacts at predefined spatial locations.

For modeling average annual diesel particle emissions, we used:

- AERSCREEN to estimate a regional background concentration based on the median emission rate of all 1.33 km grids (i.e., 1.33 km by 1.33 km emission areas) with diesel particle emissions less than or equal to 0.06 tons per year. This regional background estimate considers that diesel particles move into the Quincy area from outside areas.
- AERSCREEN to estimate impacts throughout the modeling domain from "area sources" or diffuse emissions from places such as local roadways (i.e., side streets) and agricultural land (Appendix A).
- American Meteorological Society/EPA Regulatory Model (AERMOD, Version 16216r) to model emissions from data center emergency engines, locomotives, and heavy-duty on-road (i.e., diesel trucks on main highway) sources. AERMOD is EPA's preferred Gaussian plume dispersion model.
- The data center building dimensions and the Plume Rise Model Enhancements (PRIME) algorithm to account for building downwash.
- Five years of sequential hourly meteorological data from Moses Lake Airport (2012–2016) for diesel particle impacts.
- Twice-daily upper air data from Spokane International Airport (2012–2016) to define mixing heights.

- Quincy area digital elevation model (DEM) files, which describe local topography and terrain.
- Quincy area digital land classification files, which describe surface characteristics.
- Emission release parameters
    - Source-specific stack heights as specified in permits and engine-specific exhaust gas temperature and velocity.
    - Locomotive exhaust at five meters and an initial vertical dimension of 2.3 meters.
    - Highway vehicles release at three meters and an initial vertical dimension of 1.4 meters.
- The receptor grid for the AERMOD modeling domain used 33,395 discrete Cartesian receptors, with defined nested grid spacing of 50 meters and 500 meters. The grid included residential, commercial, and sensitive receptors within the community and on-site receptors within facility boundaries. Sensitive receptor locations include places with vulnerable populations such as schools and health care facilities.

We modeled $NO_2$ using similar techniques except we used:

- Measured $NO_2$ concentrations in Quincy from August 2017 to August 2018 when wind speeds were greater than 2 mph and from a northerly direction between 9 a.m. and 4 p.m. to determine "background" $NO_2$ levels. This was to exclude obvious influences from roads and rail, which were explicitly modeled, and the typical buildup of $NO_2$ during nighttime stagnation.
- Quincy-specific 2-meter temperatures and 10-meter wind speed and direction during 2018.
- 2018 Automated Surface Observation System data from Moses Lake to fill in the remaining meteorological parameters, such as pressure, relative humidity, precipitation, and cloud cover.
- Ambient Ratio Method (ARM2) option, which models the conversion of nitrogen oxides ($NO_x$) to $NO_2$. For purposes of modeling $NO_2$ impacts, we assumed primary $NO_x$ emissions were 10 percent $NO_2$ and 90 percent nitric oxide by mass. The ARM2 method is more appropriate when modeling low level, continuous sources like roads mixed with point sources. Permit modeling, however, used a different $NO_x$ to $NO_2$ conversion method to model the relatively isolated data center plumes, since roads were not considered in those analyses.

The results of the model produced average annual concentration of diesel particles and hourly concentrations of $NO_2$. The highest annual average concentrations of diesel particle vary depending on which emissions scenario was modeled:

- For the scenarios based on 2016 actual emissions and projected actual emissions, the highest diesel particle concentration of 0.35 microgram per cubic meter ($\mu g/m^3$) occurred at a location about 700 meters south of the center of Quincy along SR 281 (Figures 5 and 6).
- For the scenario based on allowable emissions or potential to emit (PTE), the highest diesel particle concentration of 0.88 $\mu g/m^3$ occurred within the boundary of H5 Data Center (Figure 7).

The highest 1-hour maximum $NO_2$ concentration based on 2018 actual emissions (210 µg/$m^3$) occurred within the boundary of H5 Data Center (Figure 8). Generally, we estimated higher concentrations near key diesel emission sources. Levels tapered off with distance from these sources.

## Estimating chronic human inhalation exposure

The long-term average exposure to pollutants emitted from diesel engines in the Quincy area depends on local wind patterns (meteorology), diesel engine emission rates, and the amount of time people spend in the immediate area. As discussed previously, the air dispersion model uses emissions and meteorology information (and other assumptions) to determine ambient diesel particle and $NO_2$ concentrations in the Quincy area. We use EPA's guidance (EPA, 2009) to determine long-term exposure to diesel particles based on the modeling results through the following equation:

**EC = (CA x ET x EF x ED)/AT**

Where:

EC (EC (µg/$m^3$) = exposure concentration

CA (µg/$m^3$) = contaminant concentration in air (based on annual average modeled concertation)

ET (hours/day) = exposure time

EF (days/year) = exposure frequency

ED (years) = exposure duration

AT (70 years [lifetime cancer increase] or ED in years [for non-cancer hazards] x 365 days/year x 24 hours/day) = averaging time

We identified key receptor locations based on land use. Ecology considered the land use information in the Quincy area to estimate exposure frequency and duration at a given location. For example, frequent and longer duration exposures to diesel emissions in the Quincy area are more likely to occur at residential locations because people spend much of their time at home. A worker's exposure to diesel emissions in commercial areas likely occurs only during their working hours.

Ecology typically made simplified assumptions about receptors' exposure frequency and duration. For exposures occurring at residential locations in Quincy, we used the estimated annual average ambient air concentration of diesel particles at each receptor located on residential parcels as a surrogate for lifetime exposure concentration. We did not address short-term human activity, including indoor air concentrations or people's movement from place to place in and around a given community. Instead, we assumed that each person's predicted exposure is constant over the course of their lifetime, which is assumed to be 70 years. We did this to ensure we were estimating the highest potential exposures to diesel emissions originating in the Quincy area.

We also considered workplace and other non-residential exposures, but made adjustments because people predictably spend less time at these locations than at their homes. We presented examples of exposure adjustments for various receptor types in Table 4.

**Table 4.** Exposure Factors

| Exposure Parameter | Residential | Commercial Worker | Boundary Receptor – Bystander | Elementary School Student | Middle – Jr. High School Student | High School Student | Hospital |
|---|---|---|---|---|---|---|---|
| ET (hours/day) | 24 | 8 | 2 | 8 | 8 | 8 | 24 |
| EF (days/year) | 365 | 250 | 250 | 180 | 180 | 180 | 365 |
| ED (years) | 70 | 40 | 30 | 6 | 3 | 4 | 1 |
| ET = exposure time; ED = exposure duration; EF = exposure frequency | | | | | | | |

## Estimating acute human inhalation exposure

For short-term exposures, we used the modeled short-term $NO_2$ concentration to determine the exposure concentration.

**EC = CA**

Where:

EC (µg/m$^3$) = exposure concentration

CA (µg/m$^3$) = short-term (i.e., 1-hr average) concentration in air

## Dose response assessment

To determine how a toxic air pollutant may affect exposed individuals or populations, agencies determine the relationship between dose or concentration, and incidence of effects in humans. Using information from human epidemiological and animal exposure studies, agencies develop toxicity values for use in quantifying risks and hazards of exposures to chemicals in the environment. For this assessment, Ecology considered available toxicity values for diesel particles and $NO_2$.

### Diesel particle toxicity values

Ecology identified toxicity values for diesel particles from two agencies: EPA (EPA, 2002; EPA, 2003), and California EPA's Office of Environmental Health Hazard Assessment (OEHHA) (CalEPA, 1998). These agencies derived toxicity values from studies of animals exposed to a known amount (concentration) of diesel particles or from epidemiological studies of exposed humans. They represent a level at or below which we do not expect adverse non-cancer health effects and a metric by which to quantify increased risk from exposure to a carcinogen. Table 5 shows the diesel particle non-cancer and cancer toxicity values used in this assessment.

EPA derived a reference concentration (RfC) and OEHHA derived reference exposure level (REL) for diesel engine exhaust (measured as diesel particles) from dose-response data on inflammation and changes in the lung from rat inhalation studies. Each agency established a level of 5 µg/m$^3$ as the concentration of diesel particles in air at which long-term exposure is not likely to cause adverse non-cancer health effects.

EPA published National Ambient Air Quality Standards (NAAQS) and other regulatory toxicological values for short- and intermediate-term exposure to particulate matter, but values specifically for diesel particle exposure at these intervals do not currently exist.

OEHHA derived a unit risk factor (URF) for estimating cancer risk from exposure to diesel particles. They based the URF on several epidemiological studies of humans occupationally exposed to diesel particles. In these studies, researchers estimated diesel particle exposure from measurements of elemental carbon and respirable particulate representing fresh diesel exhaust. Therefore, we define diesel particles as the filterable fraction of particulate emitted by diesel engines. The URF is the upper limit probability of developing cancer, assuming continuous lifetime exposure to a substance at a concentration of one microgram per cubic meter (1 µg/m$^3$), and is expressed in units of inverse concentration [i.e., (µg/m$^3$)$^{-1}$]. OEHHA's URF for diesel particles is 0.0003 per µg/m$^3$ meaning that a lifetime of exposure to one microgram of diesel particles per cubic meter of air results in an increased individual cancer risk of 0.03 percent or a population cancer risk of 300 excess cancer cases per million people exposed.

## Nitrogen dioxide toxicity values

OEHHA developed an acute reference exposure level for $NO_2$ based on inhalation studies of asthmatics exposed to $NO_2$. These studies found that some asthmatics exposed to about 0.25 ppm (i.e., 470 µg/m$^3$) experienced increased airway reactivity following inhalation exposure to $NO_2$ (CalEPA, 2008). Not all exposed subjects experienced an effect.

The acute REL derived for $NO_2$ does not contain any uncertainty factor adjustment, and therefore does not provide any additional buffer between the derived value and the exposure concentration at observed effects among sensitive populations. This implies that exposure to $NO_2$ at levels equivalent to the acute REL (which is also the same as Ecology's ASIL could result in increased airway reactivity in a subset of asthmatics. People without asthma or other respiratory disease are less likely to experience effects at $NO_2$ levels equal to or less than the REL. OEHHA intended acute RELs to be "for infrequent one-hour exposures that occur no more than once every two weeks in a given year" (CalEPA, 2015).

EPA published NAAQS for short- and long-term exposure to $NO_2$. For decades, EPA only regulated ambient $NO_2$ levels based on the annual standard of 53 ppb (100 µg/m$^3$). Beginning in 2010, EPA set a new 1-hour standard at a level of 100 ppb (188 µg/m$^3$). EPA determined the form of the new short-term standard as the 98th percentile of the daily maximum one-hour average $NO_2$ concentration. They evaluated other options for the form of the standard (e.g., the highest, second highest, or 99th percentile hourly concentration) but they determined that the 98th percentile provided appropriate public health protection and greater regulatory stability (EPA, 2010).

**Table 5**. Toxicity Values or Comparison Values Considered in Assessing and Quantifying Non-cancer Hazard and Cancer Risk

| Pollutant | Agency | Non-cancer | Cancer |
|---|---|---|---|
| Diesel particles | EPA | RfC[1] = 5 µg/m$^3$ | NA[2] |
| Diesel particles | California EPA Office of Environmental Health Hazard Assessment | Chronic REL[3] = 5 µg/m$^3$ | URF[4] = 0.0003 per µg/m$^3$ |
| $NO_2$ | EPA | Annual NAAQS[5] = 100 µg/m$^3$<br>1-hr NAAQS = 188 µg/m$^3$ | NA |
| $NO_2$ | California EPA Office of Environmental Health Hazard Assessment | Acute REL = 470 µg/m$^3$ | NA |

1. Reference Concentration
2. EPA considers diesel particles to be a probable human carcinogen, but has not established a cancer slope factor or unit risk factor.
3. Reference Exposure Level
4. Unit Risk Factor
5. National Ambient Air Quality Standard

## Quantifying/characterizing health risks

Risk characterization involves integrating the information from the previous steps to synthesize an overall conclusion about risk and provide information to decision makers. Generally, we characterize risks differently depending on whether the chemical(s) cause(s) cancer versus non-cancer effects.

To calculate cancer risk from diesel particle exposure, we multiply the corresponding lifetime average exposure estimate by the appropriate unit risk factor (URF).

**Cancer risk = EC x URF**

Where:

EC = exposure concentration (µg/m$^3$)

URF = Unit Risk Factor (µg/m$^3$)$^{-1}$

This calculated cancer risk is defined as the upper limit probability of developing cancer over a 70-year period (i.e., the assumed human lifespan) at that exposure. Because the URF for diesel particles is an upper limit estimate, actual risks at a given exposure level may be lower than predicted.

Unlike linear dose-response assessments for cancer, non-cancer health hazards generally are expressed by comparing an exposure to a reference level as a ratio. We derive a hazard quotient (HQ) as the estimated exposure divided by a reference level (e.g., the REL). Exposures at or below the reference level (HQ less than or equal to 1) are not likely to cause adverse health effects. As exposures increase above the reference level (HQs increasingly greater than 1), the potential for adverse effects increases.

**Non-cancer hazard quotient = EC / RfC or REL**

Where:

EC = exposure concentration (µg/m$^3$)

RfC = EPA's reference concentration (µg/m$^3$)

REL = California OEHHA's reference exposure level (µg/m$^3$)

## Chronic cancer risk based on 2016 actual emissions

Table 6 summarizes the chronic inhalation risk results attributable to cumulative and source-specific exposures at various key residential receptor locations in Quincy. We focus on residential receptors because we expect higher exposures and highest risks related to Quincy-area emissions compared to intermittently exposed receptors.

The highest estimated cumulative risk in 2016 of 67 in one million occurred at the maximally impacted residence east of the center of Quincy (Figure 9). The bulk of the estimated cumulative risk at this location results from mobile source emissions. Only a small amount of estimated exposure to data center emissions occurred at this location.

The highest estimated exposure to data center emissions occurred at a residence east of the center of Quincy on a parcel nearly surrounded by four data centers. Actual data center emergency engine emissions in 2016 contributed to a chronic inhalation cancer risk of about 11 in one million at this location.

**Table 6.** Estimated Lifetime Increase of Cancer Risk (Reported as Number per Million) at Maximally Impacted Residential Receptors Related to Diesel Particle Emissions from Sources in the Quincy area

| Key Receptor | All Sources (risk per million) | Data Centers (risk per million) | Locomotives (risk per million) | SR 28 (risk per million) | SR 281 (risk per million) | Area Sources (risk per million) | Regional Background (risk per million) |
|---|---|---|---|---|---|---|---|
| Residence (East) – Maximum cumulative impact | 67 | 0.5 | 9.0 | 30 | 1.3 | 16 | 9 |
| Residence (West) – Maximum cumulative impact | 59 | 0.8 | 8.7 | 19 | 5.3 | 16 | 9 |
| Residence (East) – Maximally impacted by data centers | 42 | 11 | 4.7 | 1.2 | 0.2 | 16 | 9 |
| Residence (West) – Maximally impacted by data centers | 39 | 3.9 | 7.1 | 2.5 | 0.6 | 16 | 9 |
| Note: Data center risks based on 2016 actual emissions. | | | | | | | |

## Chronic cancer risk based on projected future actual emissions

Table 7 summarizes the chronic inhalation risk results attributable to cumulative and source-specific exposures at various key residential receptor locations in Quincy.

The highest estimated cumulative risk based on projected data center emissions occurred at the maximally impacted residence east of the center of Quincy (Figure 9). The bulk of the cumulative risk at this location results from mobile source emissions. Only a small amount of exposure to data center emissions occurred at this location.

The highest estimated exposure to data center emissions based on projected emissions occurred at a residence east of the center of Quincy on a parcel nearly surrounded by four data centers. Projected actual data center emergency engine emissions contributed to a chronic inhalation cancer risk of about 19 in one million at this location.

**Table 7**. Estimated Lifetime Increase of Cancer Risk (Reported as Number per Million) at Maximally Impacted Residential Receptors Related to Diesel Particle Emissions from Sources in the Quincy area

| Key Receptor | All Sources (risk per million) | Data Centers in 2016 (risk per million) | Locomotives (risk per million) | SR 28 (risk per million) | SR 281 (risk per million) | Area Sources (risk per million) | Regional Background (risk per million) |
|---|---|---|---|---|---|---|---|
| Residence (East) – Maximum cumulative impact | 67 | 0.7 | 9.0 | 30 | 1.3 | 16 | 9 |
| Residence (West) – Maximum cumulative impact | 59 | 1.1 | 8.7 | 19 | 5.3 | 16 | 9 |
| Residence (East) – Maximally impacted by data centers | 51 | 19 | 4.7 | 1.2 | 0.2 | 16 | 9 |
| Residence (West) – Maximally impacted by data centers | 41 | 5.6 | 7.1 | 2.5 | 0.6 | 16 | 9 |
| **Note**: Data center risks based on projected actual emissions. | | | | | | | |

## Chronic cancer risk based on PTE emissions

Table 8 summarizes the chronic inhalation risk results attributable to cumulative and source-specific exposures at various key residential receptor locations in Quincy.

The highest estimated cumulative risk (79 in one million) based on allowable (i.e., potential to emit) data center emissions occurred at a residentially-zoned parcel west of the center of Quincy near NTT and Microsoft Columbia Data Centers (Figure 9). More than half of the estimated cumulative risk at this location results from potential data center emissions. The parcel is not currently developed. Only a fraction of the potential emissions was released in 2016.

**Table 8**. Estimated Lifetime Increase of Cancer Risk (Reported as Number per Million) at Maximally-Impacted Residential Receptors Related to Diesel Particle Emissions from Sources in the Quincy-area

| Key Receptor | All Sources (risk per million) | Data Centers in 2016 (risk per million) | Locomotives (risk per million) | SR 28 (risk per million) | SR 281 (risk per million) | Area Sources (risk per million) | Regional Background (risk per million) |
|---|---|---|---|---|---|---|---|
| Residence (East) – Maximum cumulative impact | 71 | 4.7 | 9.0 | 30 | 1.3 | 16 | 9 |
| Residence (West) – Maximum cumulative impact | 69 | 10 | 8.7 | 19 | 5.3 | 16 | 9 |
| Residence (East) – Maximally impacted by DC | 72 | 40 | 4.7 | 1.2 | 0.2 | 16 | 9 |
| Residence (West) – Maximally impacted by DC | 79 | 44 | 7.1 | 2.5 | 0.6 | 16 | 9 |
| Note: Data center risks based on allowable emissions (PTE). | | | | | | | |

## Chronic non-cancer hazards

Because the maximum estimated diesel particle concentration in Quincy (0.35 $\mu g/m^3$) is expected to be much lower than the RfC (5 $\mu g/m^3$), we expect hazard quotients to be substantially less than unity (i.e., 1.0). Therefore, we do not anticipate long-term non-cancer (chronic) hazards attributable to diesel particles in Quincy.

Diesel particles make up part of the total fine particle ($PM_{2.5}$) mass in Quincy. Given that, EPA has not determined a concentration threshold of $PM_{2.5}$ below which adverse effects do not occur in a population (EPA, 2019); diesel particles may contribute in some ways to health effects among some individuals in the Quincy area.

### Acute hazards

For short-term (acute) hazards, Ecology evaluated $NO_x$ emissions based on estimates of on-and non-road sources and actual 2018 emergency engine use by Quincy data centers. The analysis (described in Appendix B) determined that no violations of national standard for $NO_2$ occurred, and the maximum estimated 1-hour concentration (about 210 $\mu g/m^3$) within the modeling domain did not exceed the REL (470 $\mu g/m^3$).

During past data center permitting in Quincy, Ecology noted that potential short-term respiratory hazards may happen when numerous data center emergency engines run during unplanned power interruptions (Ecology, 2019). So far, unplanned outages at Quincy data centers appear to be infrequent.

## Uncertainties

Uncertainties in the Quincy diesel emissions cumulative risk assessment occur in the following areas:

- Exposure – Uncertainties in emission estimates, air quality models, and human activity patterns lead to uncertainty in air concentrations and exposure concentrations.
- Dose-response relationships – Uncertainty in the relationship between exposure and effects, the URF and the RfC also contribute to uncertainties in the risk assessment.

### Emissions uncertainties

Uncertainty in the emissions data set stems from data gaps, default assumptions, and the emission models used to develop emissions inventory estimates.

Ecology developed emissions estimates based on various sources of data. For data center emissions, estimates were based on hours of engine use and load-specific emission factors from manufacturer emission specification sheets. Other tools were used to develop emissions estimates from on-road, locomotive, and other (area source) diesel engine emissions. While the accuracy of these estimates is not known, we used the best available information at the time of the analysis.

### Air modeling uncertainties

EPA has evaluated AERMOD extensively to determine how well it performs under a variety of conditions. EPA also periodically improves the model as needed. Still, air modeling is not perfect and depends on quality emissions estimates and meteorological data. Even if we knew the exact input parameters (e.g., emission rate, stack velocity, etc.) to an air dispersion model, random effects found in the real atmosphere will introduce uncertainty. EPA developed the AERMOD dispersion model to avoid underestimating the modeled impacts.

Since $NO_2$ was measured in Quincy, Ecology compared the performance of AERMOD at the location of the monitor and found that AERMOD was within 10 percent of the measured $NO_2$ 98th percentile.

## Human activity pattern uncertainties

The assessment evaluated the cancer inhalation risks associated with pollutant exposures over a 70-year period, which is the assumed lifetime of an individual. Other factors will influence future risks caused by a given source in the Quincy area:

- The length of time that data center emergency engines actually operate (i.e., more or less than 70 years).
- The growth or decline of the data center industry (i.e., the increase or decrease in the number and size of data center facilities).
- The number and fleet characteristics of on- and non-road vehicles.

Depending on the characteristics of emissions in the future, risks estimated in this analysis may be overestimated or underestimated.

We did not include the effects of short- and long-term human mobility on exposures in the assessment. Short-term mobility is movement from one microenvironment to another over the course of hours or days. Long-term mobility is movement from one residence to another over the course of a lifetime. Because we did not consider mobility, our estimate of individual risk was probably overestimated.

## Dose-response relationship uncertainties

One of the largest sources of uncertainty in any risk evaluation is associated with the scientific community's limited understanding of the toxicity of most chemicals in humans following exposure to the low concentrations generally encountered in the environment. To account for uncertainty when developing toxicity values (e.g., RfCs or RELs), EPA and other agencies apply "uncertainty" factors to the doses or concentrations observed to cause adverse non-cancer effects in animals or humans. Agencies apply these uncertainty factors so that they derive a toxicity value considered protective of humans including susceptible populations. In the case of diesel particle exposure, agencies developed the non-cancer reference values used in this assessment from animal studies. These reference values are probably protective of the majority of the population including sensitive individuals, but in the case of EPA's diesel particle RfC, EPA acknowledges:

> "…the actual spectrum of the population that may have a greater susceptibility to diesel exhaust (DE) is unknown and cannot be better characterized until more information is available regarding the adverse effects of diesel particulate matter (DPM) in humans." (EPA, 2002)

Quantifying cancer risk related to diesel particle exposure is also uncertain. Although EPA classifies diesel engine exhaust as probably carcinogenic to humans, they have not established a URF for quantifying cancer risk. In their health assessment document, EPA determined that "human exposure-response data are too uncertain to derive a confident quantitative estimate of cancer unit risk based on existing studies."[6] However, EPA suggested that a URF based on existing diesel exhaust toxicity studies would range from $1 \times 10^{-5}$ to $1 \times 10^{-3}$ per µg/m$^3$. OEHHA's diesel particle URF ($3 \times 10^{-4}$ per µg/m$^3$) falls within this range. Regarding the range of URFs, EPA states in their health assessment document for diesel exhaust:

> "Lower risks are possible and one cannot rule out zero risk. The risks could be zero because (a) some individuals within the population may have a high tolerance to exposure from [diesel exhaust] and therefore not be susceptible to the cancer risk from environmental exposure, and (b) although evidence of this has not been seen, there could be a threshold of exposure below which there is no cancer risk." (EPA, 2002)

Other sources of uncertainty cited in EPA's health assessment document for diesel exhaust are:

- Lack of knowledge about the underlying mechanisms of diesel exhaust toxicity;
- Whether toxicity studies of diesel particles based on older engines is relevant to current diesel engines.

## Air monitoring in Quincy 2018

Ecology established an air monitoring site in Quincy in August 2017. Monitors collected data on $NO_x$, $PM_{2.5}$, black carbon, wind direction, and wind speed. Based on monitoring data through December 31, 2018, no exceedances of $PM_{2.5}$ or $NO_2$ national ambient air quality standards occurred. Ecology was not able to identify individual sources of diesel exhaust emissions. Furthermore, known power outage situations did not show any distinct impact on monitored concentration.

Appendix C provides more details about the analysis of air monitoring data in Quincy.

# Discussion and Conclusions

We evaluated diesel particle and $NO_2$ emissions in Quincy to determine the relative contribution to health risk from sources in the community.

Data centers have the potential to emit about half of the total diesel particle emissions in the 15 km x 15 km area around Quincy. Data centers' potential emissions were much less than their actual emissions. The projected actual emissions accounted for less than one quarter of the total diesel particle emissions in this same area.

While the data centers potentially represent a sizable portion of the total diesel emissions in the Quincy area, the risks from these emergency engines is somewhat offset by:

- Lower engine use than permitted.

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[6] The Health Effects Institute reports that more recent epidemiology studies may be useful for deriving quantitative risk assessments of exposures, but they caution that uncertainty still exists especially related to effects from exposures to newer technology diesel engine emissions. https://www.healtheffects.org/system/files/SR19-Diesel-Epidemiology-2015_0.pdf

- Higher stacks (release points) than other diesel sources (i.e., farm equipment, trucks, locomotives, etc.) so emissions disperse before they enter the breathing zone.
- Lower population density in areas immediately surrounding data centers.

While data centers are not typically located in dense residential areas of Quincy, their emissions potentially, affect a few residential locations.

- The highest increase in cancer risk attributable to data center-related estimates of projected actual diesel emissions in Quincy (19 per million) occurs at a residential location surrounded by four Quincy data centers. Assuming each data center emits their allowable (i.e., potential to emit) emissions each year for the next 70 years, a data center-related risk of 40 per million would occur at this same location.
- The highest increase in cancer risk attributable to cumulative estimates of potential diesel emissions in Quincy (79 per million) occurs at a residential location about 400 feet north of Microsoft Columbia Data Center and 100 feet east of NTT Data Center on a residentially-zoned parcel that is currently undeveloped. Projected actual emissions at this location result in much lower cumulative risks (about 41 per million) where the bulk of diesel exposure is attributable to non-data center sources.

Non-data center sources contribute to the highest diesel emission ambient impacts (based on actual emissions).

- The highest increase in cancer risk attributable to cumulative estimates of projected actual diesel emissions in Quincy (67 per million) occurs at a residential location along SR 28 about 600 meters east of the center of Quincy. About one percent of the total diesel engine emissions exposure comes from data center emergency engine emissions at this location.
- Regional background and other area emissions from diffuse sources such as agricultural equipment, construction equipment, and local roads contribute a uniform risk of about 25 per million at residential locations throughout the modeling domain.

In spite of the emissions from data center emergency engines, Quincy-area diesel particle concentrations appear to be relatively low compared to other areas of Washington. The concentration at the maximum cumulatively impacted residence (0.236 $\mu g/m^3$) in Quincy ranks among the lower 25th percentile of estimates from EPA's NATA 2014 (Figure 10). When this analysis was done, exposure to diesel particles in Quincy represented a relatively low risk when compared to many other areas of the state. As older on- and non-road vehicles are replaced with newer ones, diesel engine emissions should continue to decrease in Washington, but continued development and use of emergency engines in Quincy may offset some of these decreases.[7]

Currently, the overall risk in the community from clustered data center development is low. Future risks may eventually exceed a risk level of 100 in one million at some locations in the

[7] The analysis considered emissions from engines permitted before October 23, 2018. Since then, new permits have been issued and others modified, resulting in a net additional 105 permitted emergency engines totaling a net additional 612 pounds of diesel particle allowable emissions each year from Quincy-area data centers.

Quincy-area, depending on the number and location of new data centers, their continued use of diesel engines for backup power, and changing emission characteristics from other sources.

Estimated short-term $NO_2$ impacts based on actual emissions in 2018 met National Ambient Air Quality Standards. No areas within the modeling domain experienced estimated maximum 1-hour $NO_2$ levels that exceeded a reference exposure level (i.e., level of potential short-term health concern).

In 2018, air monitoring in Quincy found no data center-related $NO_x$ or diesel particles. Quincy air monitoring also found:

- Daily patterns of $NO_x$ indicated temporal variations related to traffic patterns.
- $PM_{2.5}$ and $NO_2$ did not exceed national air quality standards.
- Quincy-area $PM_{2.5}$ levels are similar to other nearby sites.
- The $PM_{2.5}$ and $NO_2$ background concentrations used so far in permitting actions were adequately representative.

Emissions during power outages that coincide with unfavorable meteorology may cause ambient concentrations of $NO_2$ that exceed a reference exposure level of concern. Power appears to be stable. Grant County PUD reported a system-wide average annual power availability of 99.9958 percent. Unplanned power outages at Quincy data centers occur less than one hour per year on average based on data reported by Microsoft and Oath.

# Recommendations

This analysis represents the most comprehensive look at diesel engine emissions in Quincy area. Ecology and other local agencies should use the modeling and air monitoring results to inform future permitting, and public outreach and communications as follows:

- Update this analysis to account for changes in emissions as needed.
- Post the results of this assessment on Ecology's web site.
- Post an interactive data map that identifies sources and concentrations of diesel particles and $NO_2$ at different locations throughout Quincy. Future permittees would be able to use this as they prepare analyses that support their applications.[8]
- Operate the Quincy weather monitoring site so we can use local meteorological data to model future project emissions
- Consider allowing fewer hours of engine use for future permits.
    - Based on reported use, data centers do not need their engines as much as they request.
- Work with data centers to improve methods for estimating ambient impacts from existing data center emissions.
    - These analyses partly define the existing background levels of pollutants in the area. Current methods require significant effort and may overestimate background levels.

[8] https://arcg.is/0SLWem

    - Air quality analyses that support permits should reasonably reflect data centers' intermittent emissions instead of treating them as continuous sources.
- Raise awareness among local planners about emissions from data centers. Local planners may help reduce exposure to data center emissions by avoiding residential zoning near current and future clusters of data centers in Quincy.
- Write a letter that recommends data centers develop plans to reduce generator use in the event of lengthy electric power outages.

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Pollution Control Hearings Board State of Washington, Findings of Fact, Conclusions of Law, and Order, PCHB No. 10-162, <http://www.eluho.wa.gov/Global/RenderPDF?source=casedocument&id=60>.

# Figures

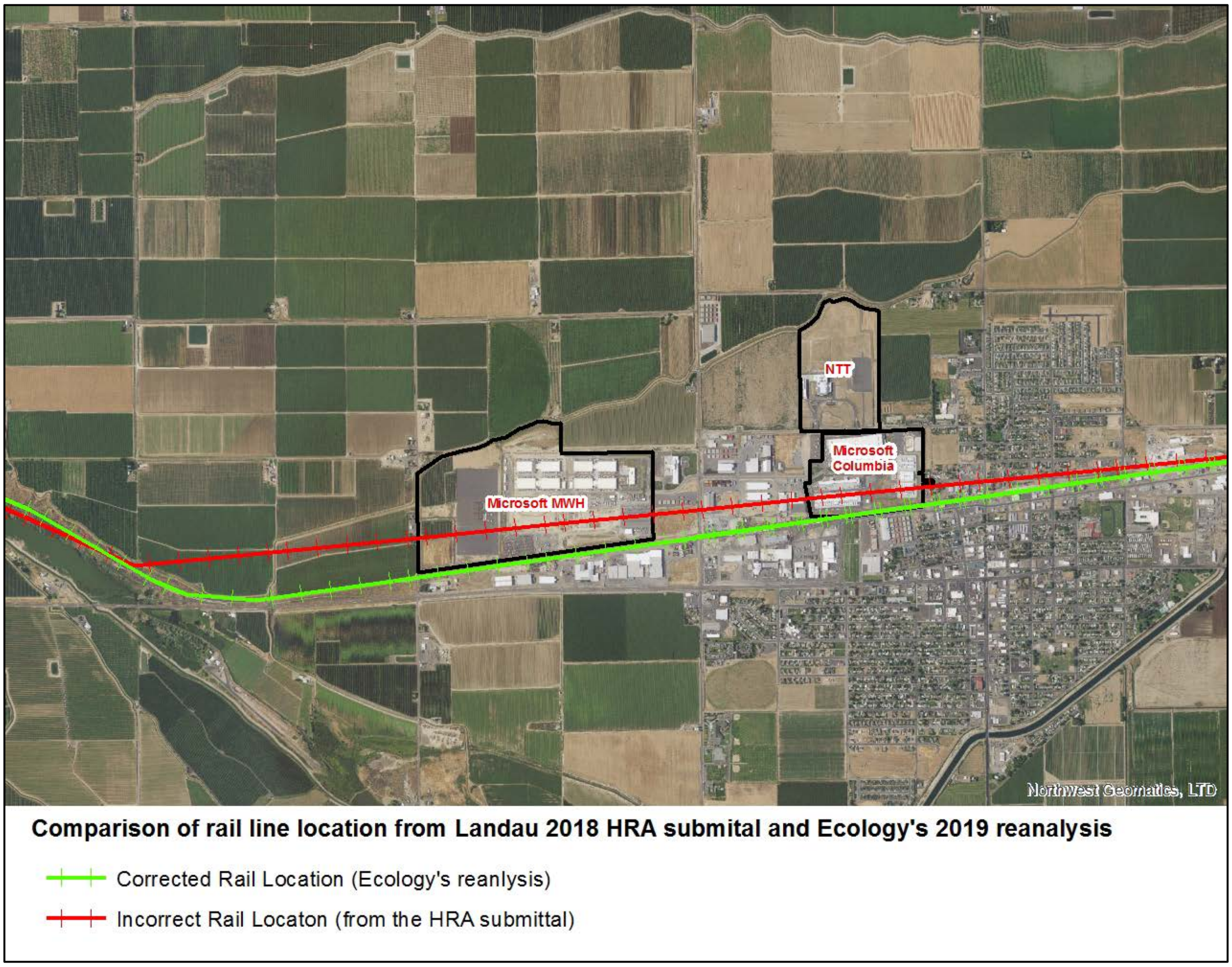



**Figure 1**. Illustration of changes made to rail line location from Landau Associated HRA vs. Ecology’s cumulative analysis

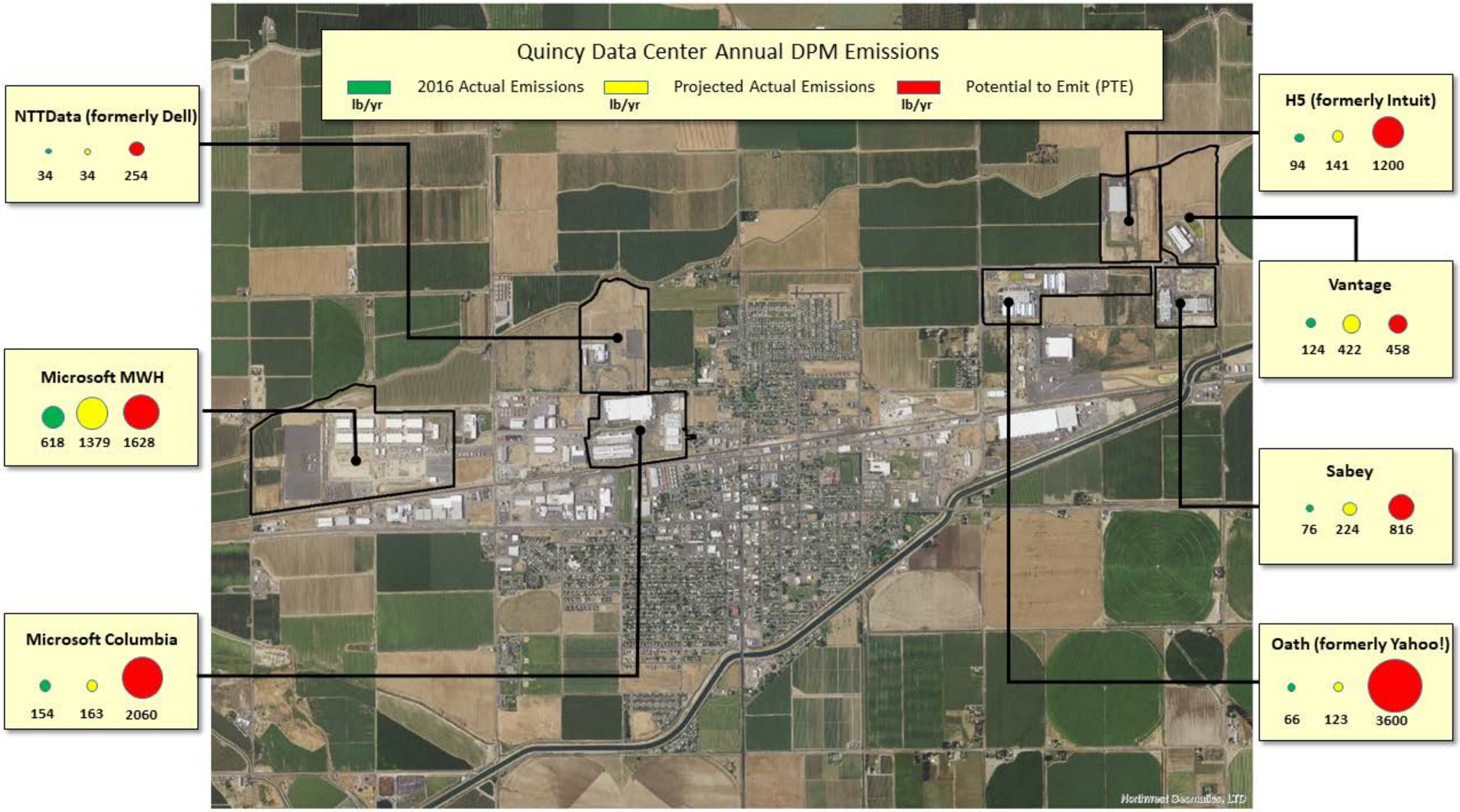



**Figure 2**. Quincy data center diesel particle emissions for three emissions scenarios (2016 actual emissions, projected actual emissions, and allowable emissions)

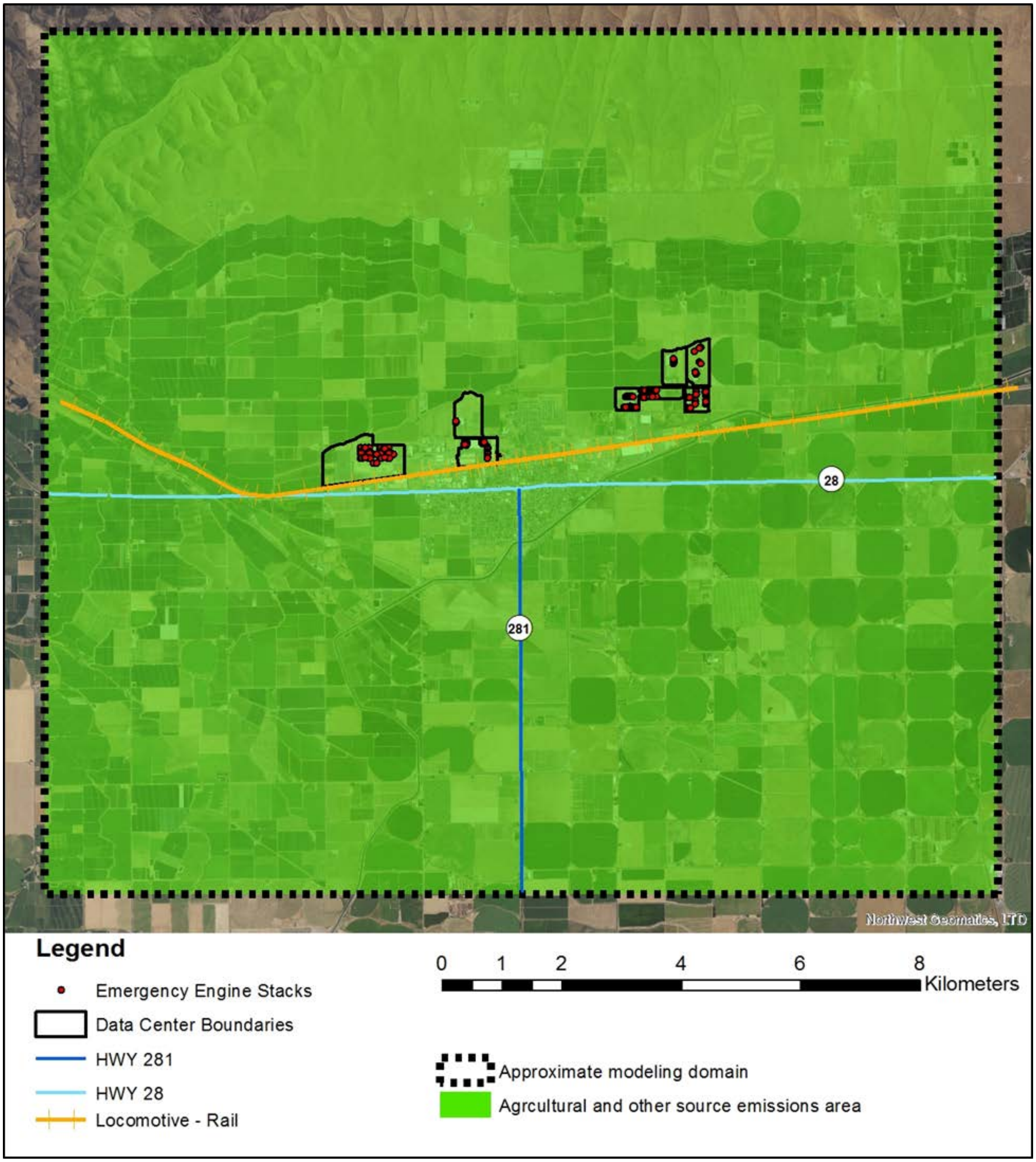
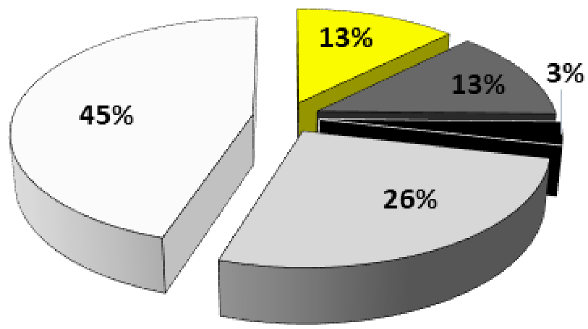
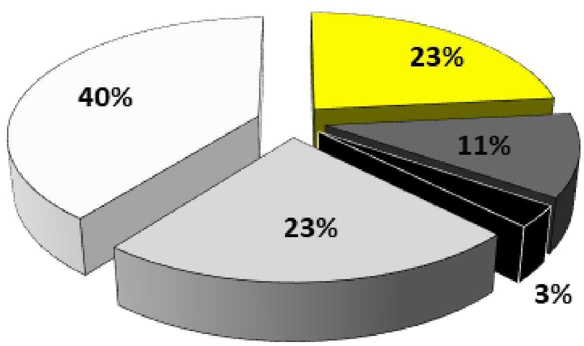
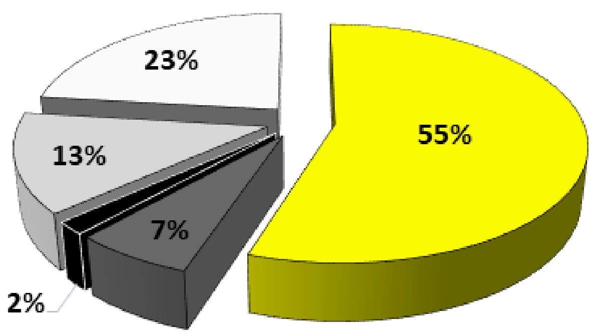



**Figure 3**. Quincy-area modeling domain and diesel emissions sources

| Source contribution to diesel particle emissions - Quincy | Total diesel particle emissions (lb/yr) | Data Center Emissions Scenario |
|---|---|---|
|  | 9,300 | Actual emission in 2016 |
|  | 10,600 | Projected actual emission assuming full installation of all permitted engines |
|  | 18,200 | Potential data center emissions if each data center emits their permitted total diesel particles |

**Emission Source**

| | | |
|---|---|---|
| Locomotives | State Route 281 | Data Centers |
| Other area sources | State Route 28 | |

**Figure 4**. Estimated annual diesel particle emissions from sources in and around Quincy

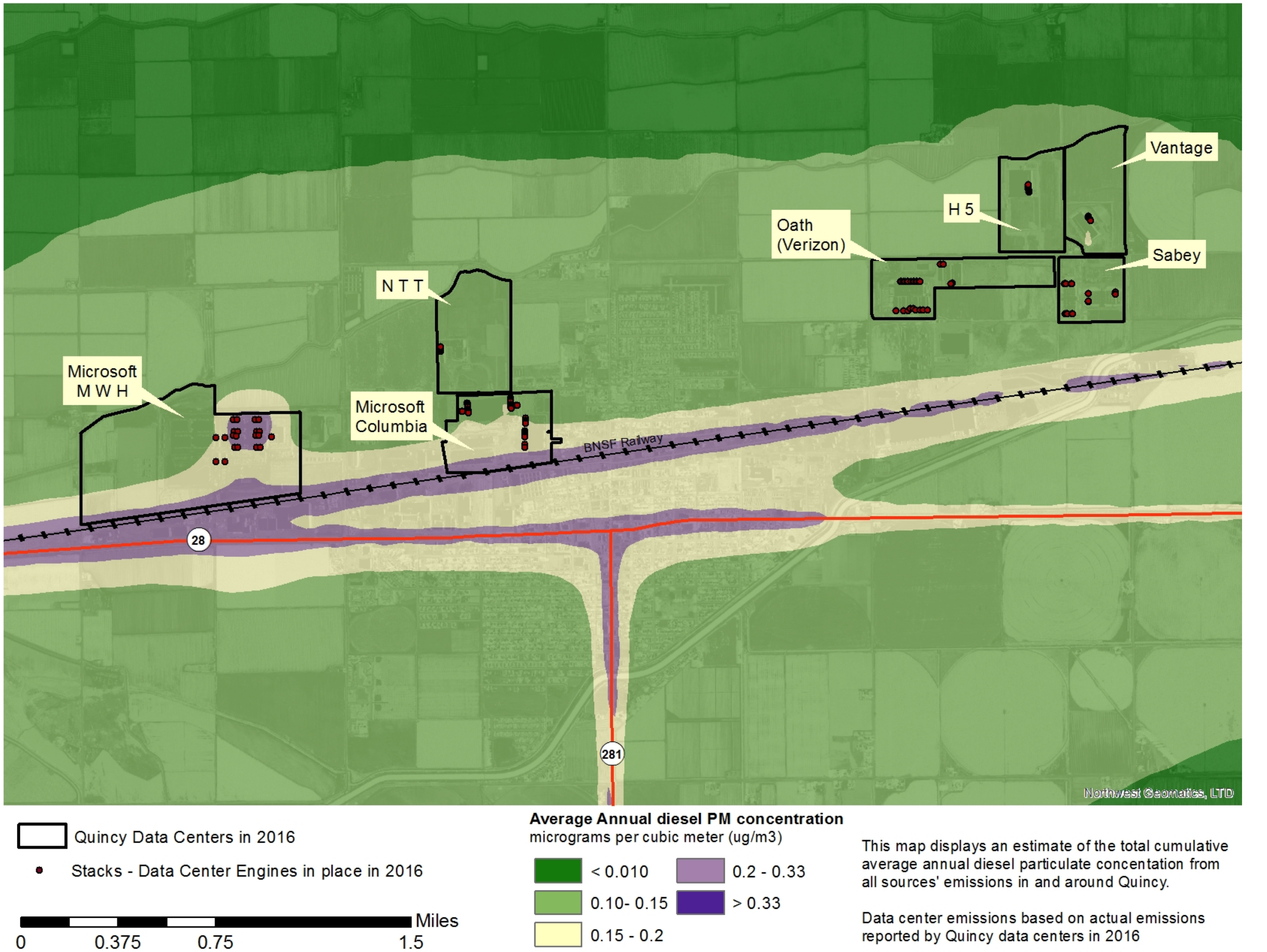



**Figure 5**. Estimated average annual diesel particulate concentration – cumulative impacts from all sources in and around Quincy (based on actual emissions reported by Quincy data centers in 2016)

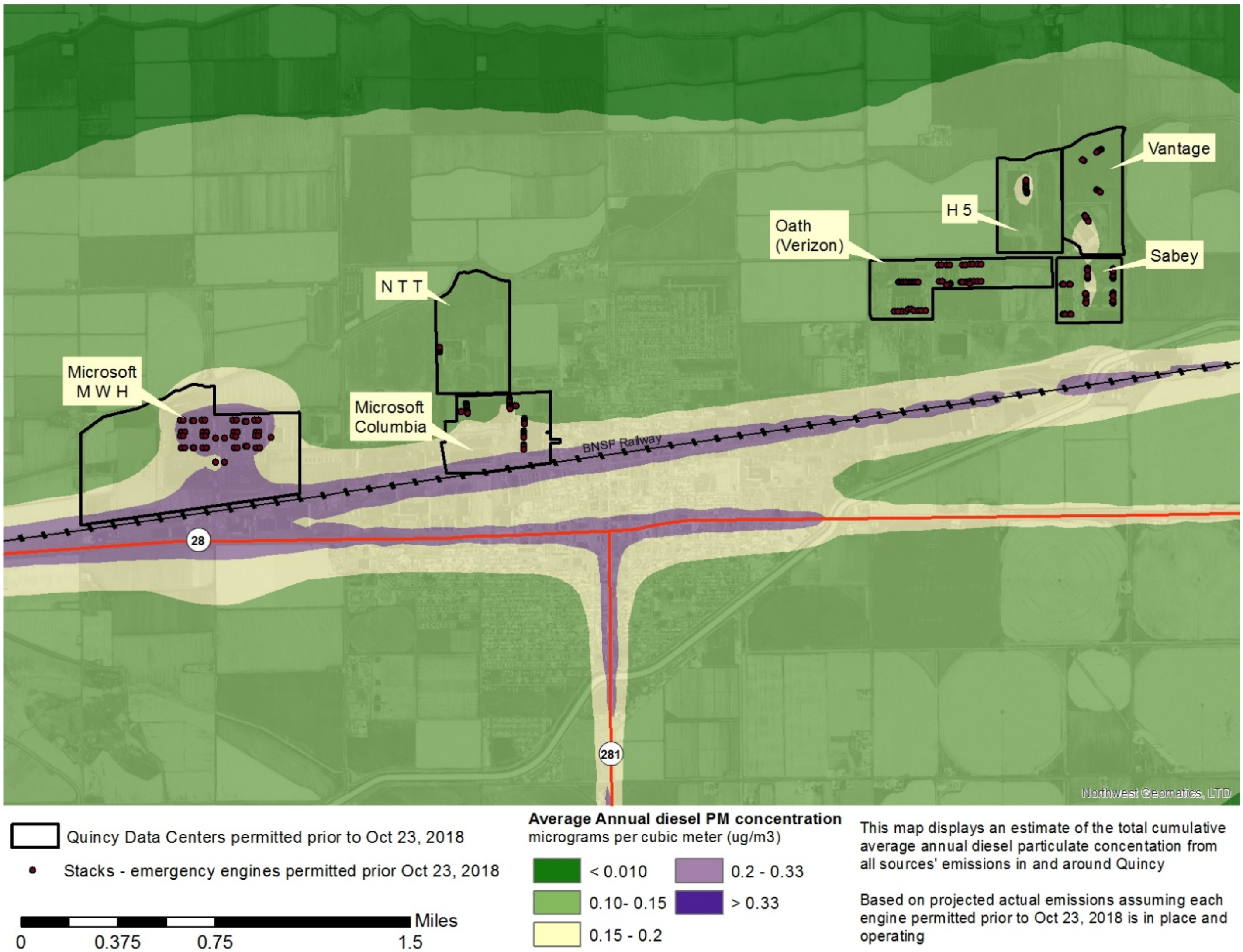



**Figure 6**. Estimated average annual diesel particulate concentration – cumulative impacts from all sources in and around Quincy (based on projected actual emissions assuming each data center emergency engine permitted before Oct. 23, 2020 is in place and operating)

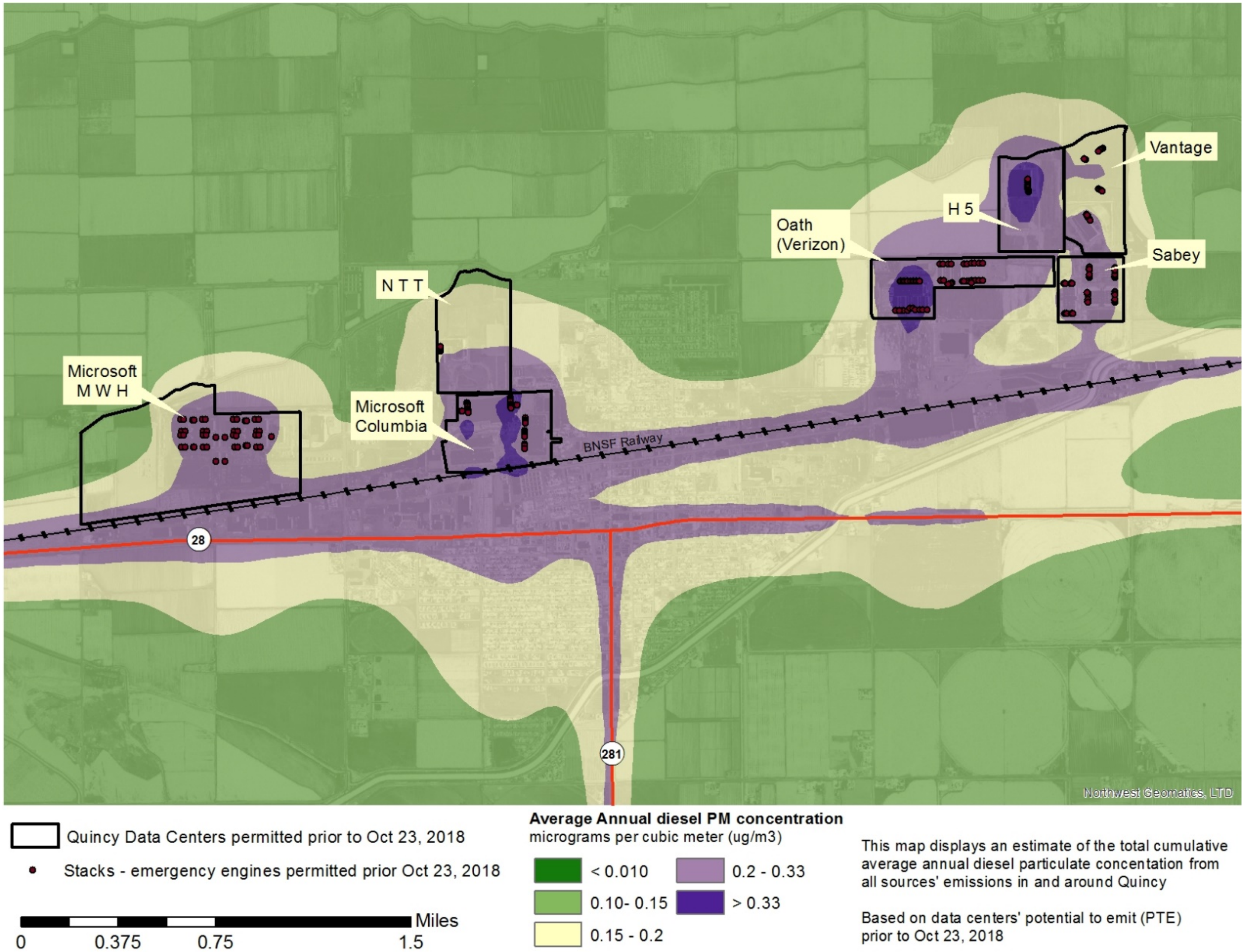



**Figure 7**. Estimated average annual diesel particulate concentration – cumulative impacts from all sources in and around Quincy (based on the assumption that each data engine permitted before Oct. 23, 2018 operates at their maximum allowable rate every year for the next 70 years)

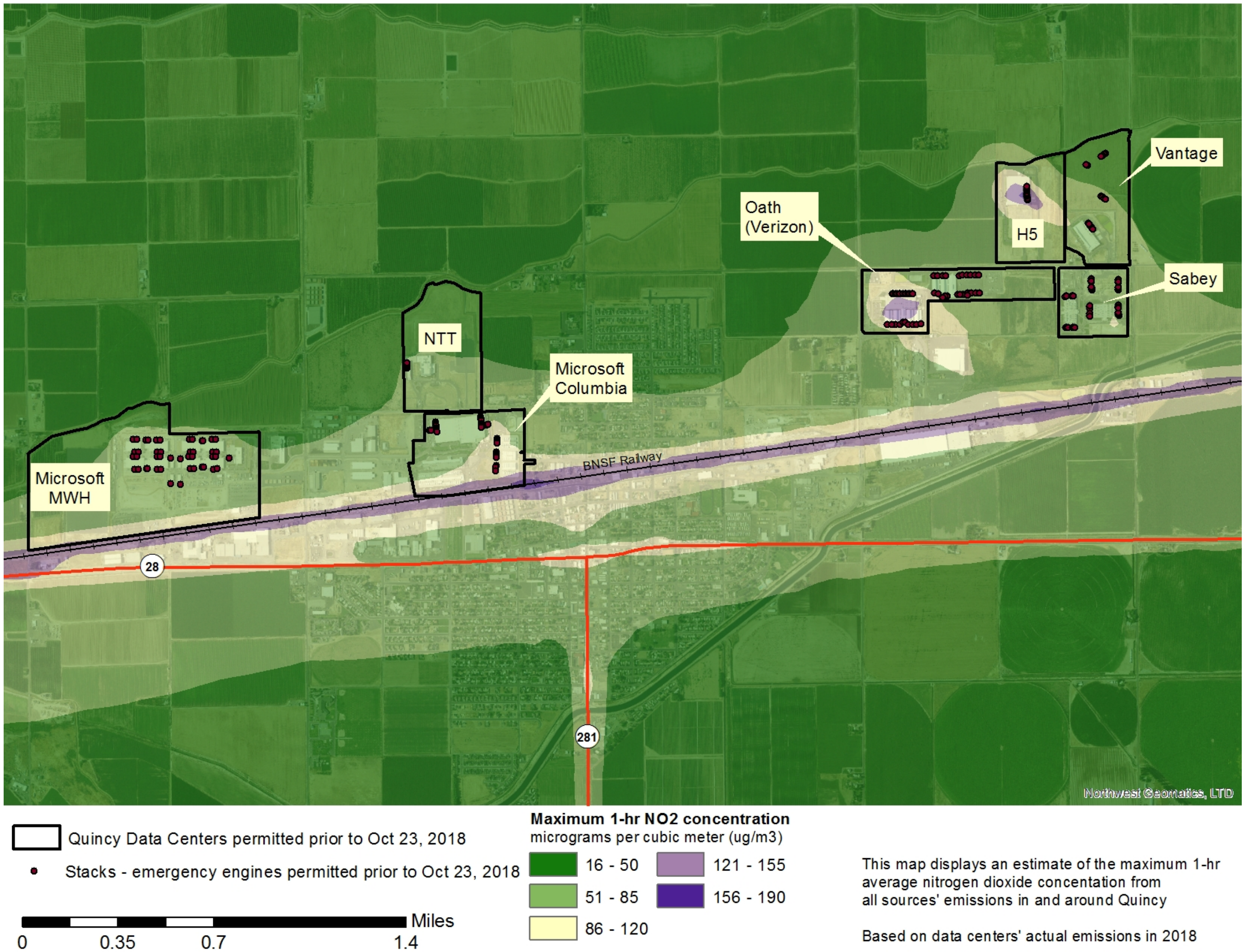
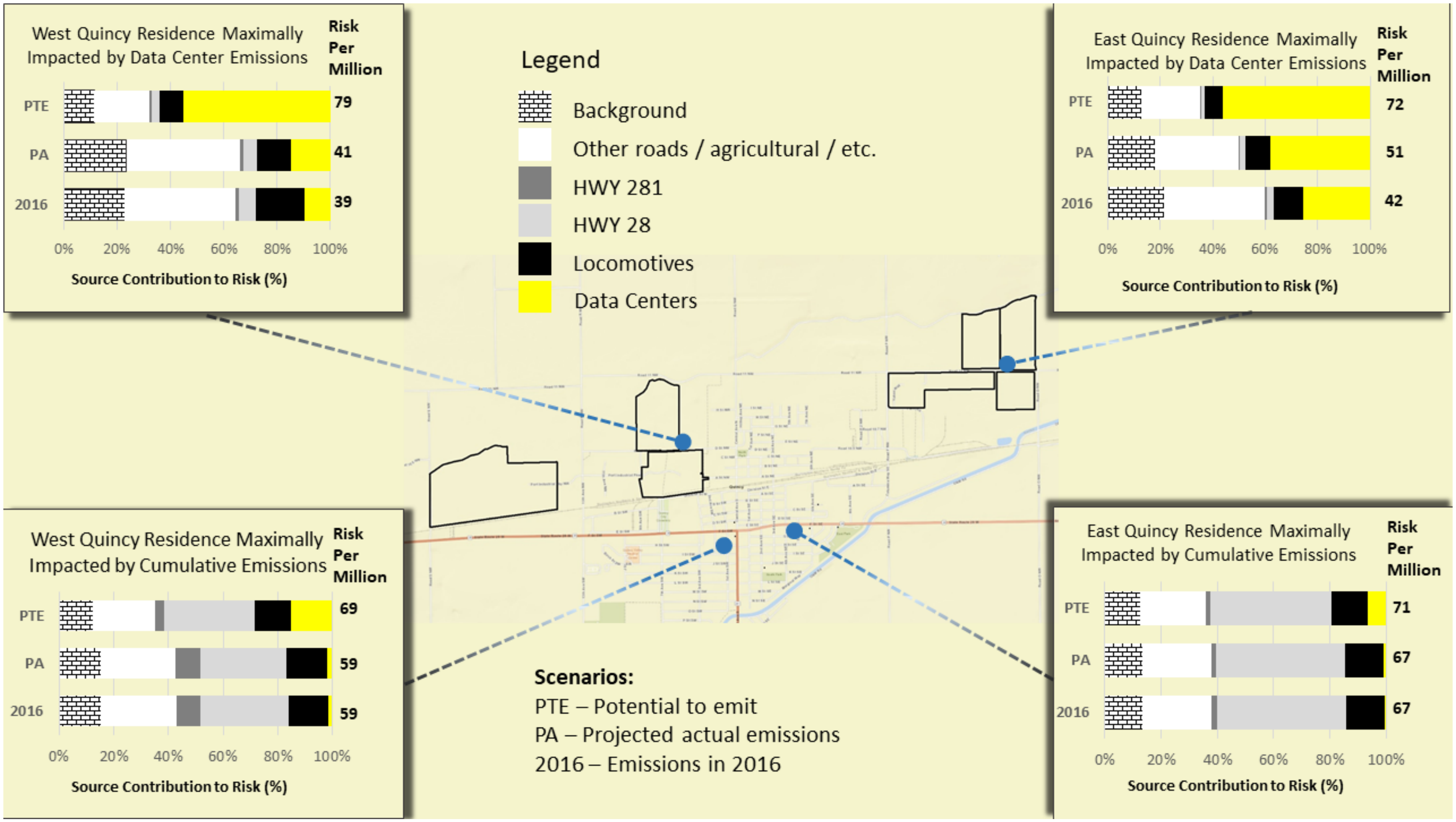



**Figure 8**. Estimated maximum 1-hour $NO_2$ concentration (based on actual emission estimates from 2018)




**Note**: To improve readability, this figure uses a different color scheme than in supporting documents.

**Figure 9.** Estimated contribution of diesel emission sources to increased cancer risk at key residential receptor areas in Quincy. The number to the right of the colored bar graphs represents the total cumulative increased risk per million at each location.

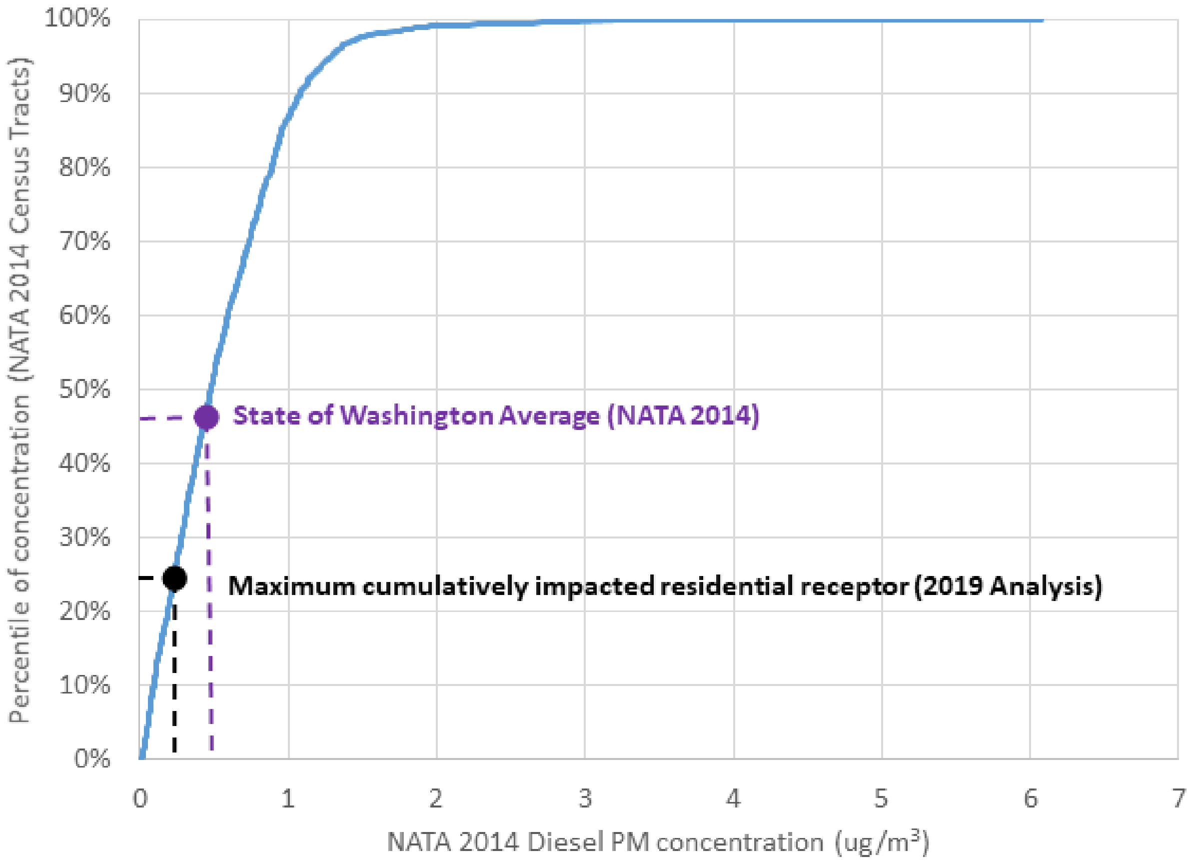



**Figure 10**. Cumulative distribution of estimated diesel particle levels at Washington census tracts

For comparison purposes, we display the estimated concentration at the maximum cumulatively impacted residential receptor.

# Appendix A. Addendum to August 6, 2018 Landau Report on Quincy-Wide Health Risk Assessment Attributable to Diesel Particulate Matter

**Addendum to Landau Inc. Report of 8/6/2018 on Quincy-wide Health Risk Assessment attributable to Diesel Particulate Matter**

**Background**

After Ecology received the Quincy-wide cumulative Health Risk Assessment (HRA) from Landau[9], a few deficiencies in some of the input data were noted. These had to do with data Ecology provided Landau. Ecology undertook to address these shortcomings and merge the results with Landau's findings. This technical addendum outlines the deficiencies and corrective steps taken in early 2019.

To remain consistent with the HRA, Landau- supplied meteorological and terrain files were used. Data center emissions and model results were not adjusted in any way.

**Rail emissions**

Modeled emission points (rail tracks) were not correctly aligned with the map especially at the west end of the modeling domain, resulting in some mis-located high concentrations. The emission rate and source parameters were not altered.

**Highway 28 and 281 emissions**

Emissions data supplied to Landau was based on the 2015 Vehicle Miles Travelled (VMT). A newer version of the Motor Vehicle Emissions Simulator (MOVES) model was released shortly afterward and this enabled Ecology to project on- road emissions to 2019.

We assumed a VMT growth rate of 8.3% from 2015 to 2019 based on the growth rate calculated from WSDOT 2015-2017 VMT estimates for Grant County. Emissions were calculated using EPA's MOVES model version 2014a with database movesdb20161117 using a combination of default and local inputs. MOVES emission rates were calculated for 2019, though mainly using 2014 inputs from Ecology's comprehensive 2014 inventory. Emissions are much lower than the 2015 estimates, primarily due to fleet turnover.

Some slight misalignments of road segments were also corrected.

**DPM from non-road engines such as farm equipment, and local roads**

The treatment of these sources as 1.33km x 1.33km gridded area sources clearly resulted in excessive ground level concentrations, causing the "Other Roadways" category of sources to pose more of a DPM health risk than the major highways and locomotives combined. Therefore, the 99$^{th}$ percentile of the gridded emission rate was modeled as a volume source with a 3m release height and a 1.4m initial vertical dimension. The ADJ_U* option was used to remain consistent with the HRA. The AERSCREEN output plot in Figure A1 shows a maximum impact of 0.0542 $\mu g/m^3$ (AERSCREEN only outputs 1-hr concentrations and these need to be divided by a factor of 10 to estimate annual means). This domain-wide estimate was added to all the receptors when estimating cumulative risk.

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[9] https://ecology.wa.gov/Asset-Collections/Doc-Assets/Air-quality/Data-Centers/20180806HealthDieselDataCenter

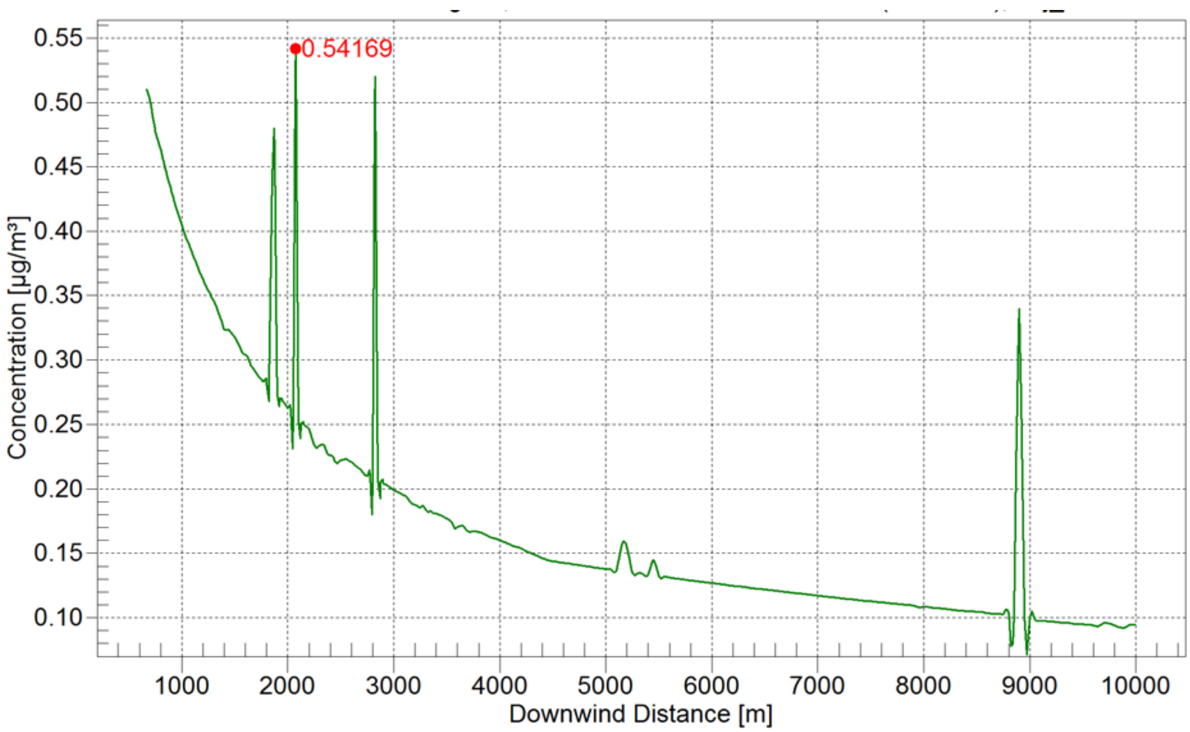


**Figure A1.** AERSCREEN modeling of non-road and local road emissions. Titled "other roads" in Figure A2.

The cumulative health risks at each sensitive receptor identified by Landau in Figures 8 and 9 of the original report were re-calculated using the updated data, and are shown in Figure A2. The same site-specific Unit Risk Factors were used, and the numbers on the right of each bar are the cumulative DPM health risks per million people exposed.

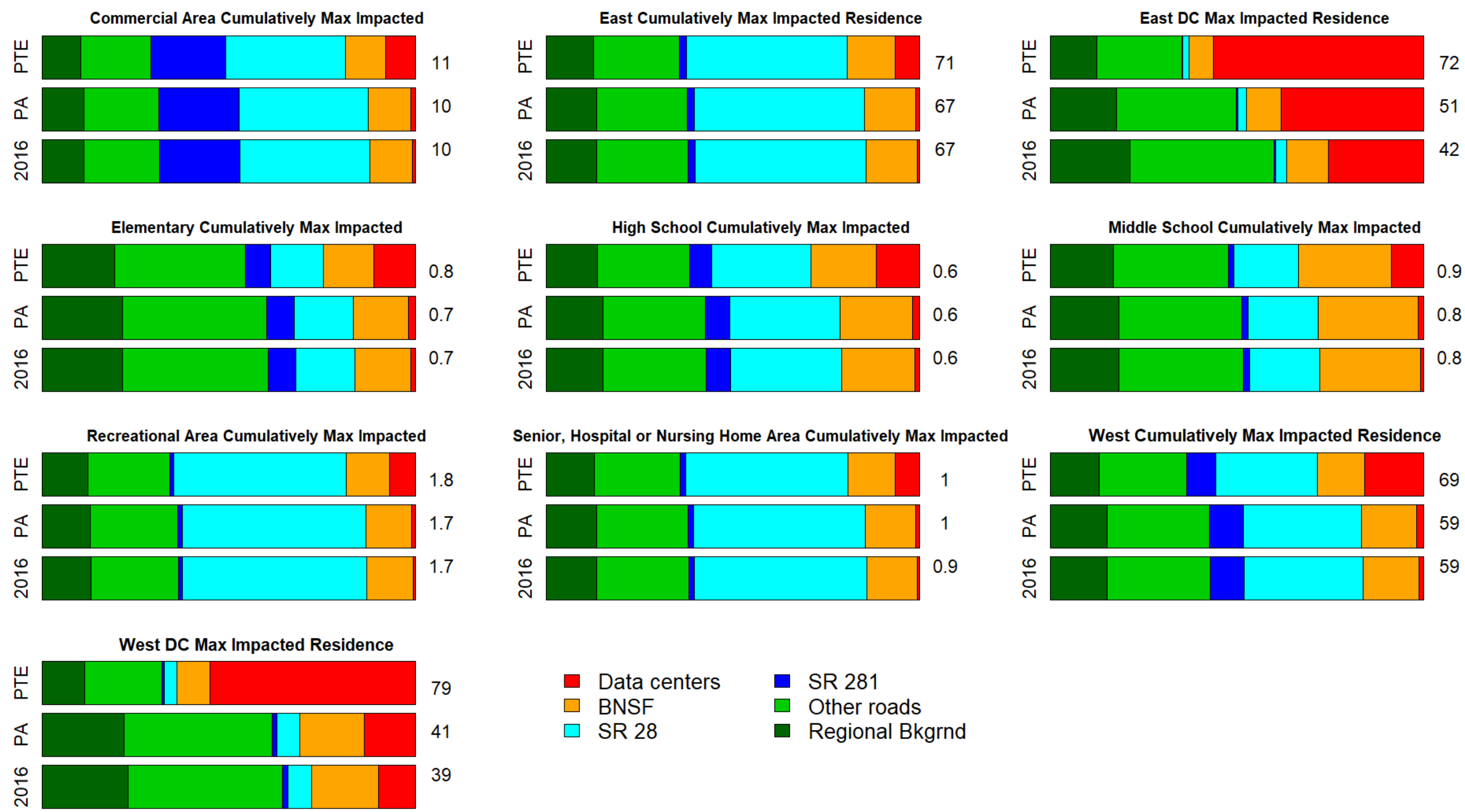


**Figure A2**. Recalculated cumulative DPM health risks at sensitive receptors in Quincy

# Appendix B. Modeling Actual Nitrogen Dioxide Concentrations from Quincy Data Centers in 2018

**Modeling actual $NO_2$ concentrations from Quincy Data Centers in 2018**

## Background

With the expansion of Data Centers (DCs) in Quincy, Ecology has been particularly concerned about health risks to the public from exposure to Diesel Particulate Matter (DPM) and $NO_2$. Other air pollutants are not released in sufficient amounts to threaten the NAAQS or ASILs. While a recent cumulative Health Risks Assessment (HRA) for DPM was conducted by the data centers for all of Quincy, Ecology felt it was appropriate to include an assessment of $NO_2$-related health risks in the community.

The availability of meteorological data and $NO_2$ measurements in Quincy in 2018 facilitates the assessment of actual conditions during that year. Seven DCs in Quincy reported monthly $NO_x$ emissions in 2018. Other major $NO_x$ sources in the area are highways 28 and 281, and the BNSF railroad. This report outlines community-wide $NO_2$ modeling conducted by Ecology, for the purposes of:

- Updating the cumulative $NO_2$ health risks posed to the community. This was last conducted in 2014, and used permitted emissions, not actual emissions data.
- Understanding the spatial pattern of present- day $NO_2$ pollution in Quincy
- Leveraging the availability of monitoring data from Quincy to assess model accuracy

Table B1 shows the seven DCs & their number/type of generators.

**Table B1**. Quincy Data Centers and their emergency generators

| | | Emergency Generators in Power Units of Mega Watts (MW) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Data Centers | **Total** | **0.75MW** | **1.5MW** | **2.0MW** | **2.5MW** | **2.75MW** | **3.0MW** |
| 1. | Intuit (H5) | 6 | | | | 6 | | |
| 2. | IGQ (Sabey) | 44 | | 6 | 38 | | | |
| 3. | Microsoft Columbia | 35 | | | | 35 | | |
| 4. | MWH | 45 | 1 | | 4 | 40 | | |
| 5. | NTT (Dell) | 5 | | | | | | 5 |
| 6. | Vantage | 5 | | | | | | 5 |
| 7. | Yahoo! (Oath) | 26 | | | 24 | | 2 | |
| | Total Generators | **166** | | | | | | |

## Data Preparation

The 2018 $NO_x$ emissions data reported from each of the 166 DC engines were used as input into the AERMOD modeling system. Six of the seven DCs reported monthly emissions data for each engine. For Intuit (H5), the annual total emissions of each generator had to be divided evenly across all months, since their permit did not require recordkeeping of monthly data. Intuit's total $NO_x$ emissions were anomalously high and were divided by 10 after discussion with the facility. It appeared that the reported number was inadvertently multiplied by the default $NO_2$ → $NO_x$ conversion factor of 10.

Emission reports also indicated the number of hours each engine was operated each month. This allowed the computation of an hourly average emission rate on a per-generator basis.

Most DC permits require testing and maintenance activities to be coordinated with nearby facilities. This is to control the number of generators emitting pollutants simultaneously. Since it is very difficult to identify the exact dates and times when each individual engine operated throughout the year, an attempt was made to mimic the testing schedule by defining twenty separate source groups such that emissions from two or more nearby engines are unlikely to overlap. Figure B1 shows the locations of the 166 point sources in Quincy and Table B2 lists the source groups. Downwash from DC buildings was considered using building dimensions identical to those in the DPM HRA. $NO_x$ from highways (WA-28 and WA-281) and the BNSF railroad were modeled as segmented line sources, similar to the HRA.

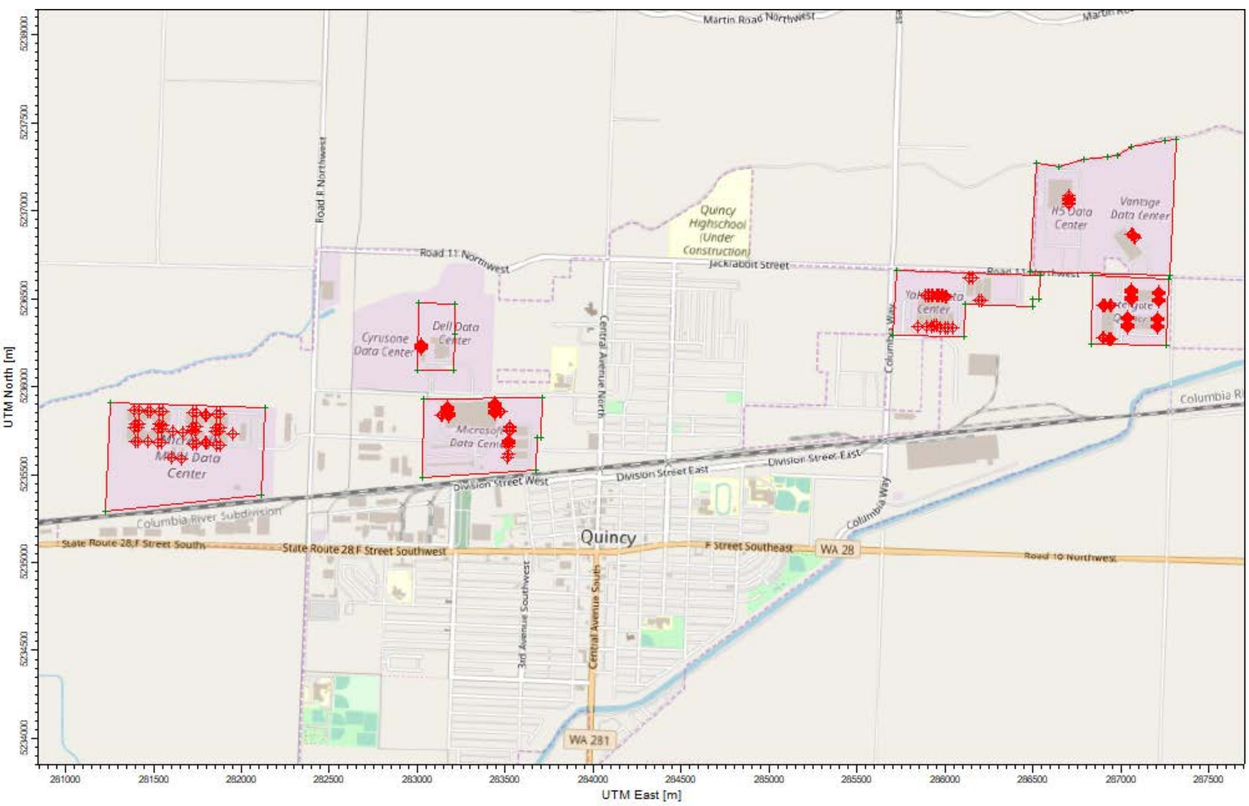


**Figure B1**. Point sources (166 red crosses) of the seven Data Centers in Quincy

**Table B2**. Source groups for AERMOD input, randomly selected from West/East DCs in Quincy (see Figure B1).

| Src. Grp | W | W | W | W | E | E | E | E | W/E |
|---|---|---|---|---|---|---|---|---|---|
| 1. | MWH02 | MWH22 | COL01 | COL21 | SAB01 | SAB20 | YAH01 | YAH21 | SAB40 |
| 2. | MWH03 | MWH23 | COL02 | COL22 | SAB02 | SAB21 | YAH02 | YAH22 | SAB41 |
| 3. | MWH04 | MWH24 | COL03 | COL23 | SAB03 | SAB22 | YAH03 | YAH23 | SAB42 |
| 4. | MWH05 | MWH25 | COL04 | COL24 | SAB04 | SAB23 | YAH04 | YAH24 | SAB43 |
| 5. | MWH06 | MWH26 | COL05 | COL25 | SAB05 | SAB24 | YAH05 | YAH25 | SAB44 |
| 6. | MWH07 | MWH27 | COL06 | COL26 | SAB06 | SAB25 | YAH06 | YAH26 | MWH01 |
| 7. | MWH08 | MWH28 | COL07 | COL27 | SAB07 | SAB26 | YAH07 | | MWH42 |
| 8. | MWH09 | MWH29 | COL08 | COL28 | SAB08 | SAB27 | YAH08 | | MWH43 |
| 9. | MWH10 | MWH30 | COL09 | COL29 | SAB09 | SAB28 | YAH09 | | MWH44 |
| 10. | MWH11 | MWH31 | COL10 | COL30 | SAB10 | SAB29 | YAH10 | | MWH45 |
| 11. | MWH12 | MWH32 | COL11 | COL31 | SAB11 | SAB30 | YAH11 | VAN01 | |
| 12. | MWH13 | MWH33 | COL12 | COL32 | SAB12 | SAB31 | YAH12 | VAN02 | |
| 13. | MWH14 | MWH34 | COL13 | COL33 | SAB13 | SAB32 | YAH13 | VAN03 | |
| 14. | MWH15 | MWH35 | COL14 | COL34 | SAB14 | SAB33 | YAH14 | VAN04 | |
| 15. | MWH16 | MWH36 | COL15 | COL35 | SAB15 | SAB34 | YAH15 | INT01 | |
| 16. | MWH17 | MWH37 | COL16 | NTT01 | SAB16 | SAB35 | YAH16 | INT02 | |
| 17. | MWH18 | MWH38 | COL17 | NTT02 | SAB17 | SAB36 | YAH17 | INT03 | |
| 18. | MWH19 | MWH39 | COL18 | NTT03 | SAB18 | SAB37 | YAH18 | INT04 | |
| 19. | MWH20 | MWH40 | COL19 | NTT04 | SAB19 | SAB38 | YAH18 | INT05 | |
| 20. | MWH21 | MWH41 | COL20 | NTT05 | VAN05 | SAB39 | YAH20 | INT06 | |

### Meteorological Data

The same meteorological data sources and configuration used in the cumulative Health Risk Assessment (HRA) of DPM were used, with one important difference: on- site 2m temperatures and 10m wind speed and direction measured at 330 3rd Ave NE in Quincy (47.24126N, 119.84595W) during 2018 were used to drive the AERMET model. In summary, the data inputs were:

- 2018 Automated Surface Observation System (ASOS) data from Grant County International Airport in Moses Lake, located approximately 25 miles from Quincy. AERMINUTE v15272 was run to reduce the instance of “calms.”
- NWS twice-daily upper air soundings from Spokane in 2018

- Surface characteristics were estimated for both surface meteorological stations using the AERSURFACE v13016 model, supplied with 1992 National Land Cover Data. Default seasonal categories were used to represent the four seasonal categories as follows:
  - midsummer with lush vegetation;
  - autumn with unharvested cropland;
  - late autumn after frost and harvest, or winter with no continuous snow; and
  - transitional spring with partial green coverage or short annuals.

**Receptors**

As with the HRA, a total of 33,395 discrete Cartesian receptors used, with defined nested grid spacing of 50m and 500m. These receptors include sensitive and on-site receptors within facility boundaries.

**Emission Sources**

Highways “WA-28” and “WA-281” were defined as “Highway” and the railroad as “Line” source groups. 166 emergency generators were modeled as point sources with the same stack parameters as used in the DPM HRA. The following steps were set up to prepare emission sources to run AERMOD.

1. Each DC engine’s monthly average $NO_x$ emission rate was assumed to persist from 9:00AM to 4:00PM local standard time. This is a slightly narrower operating window than the permitted 7AM to 7PM, and was arrived at to keep testing activities to well within normal business hours. Also, persisting the average emission rate for approximately 240 hours each month allows the consideration of all meteorological conditions encountered during the month. In reality, the generator runtimes averaged 2 hours/month (maximum 34 hours). As such, this is a very conservative estimate.
2. The line sources were assumed to emit each hour of each day throughout the year.
3. AERMOD’s Ambient Ratio Method (ARM2) was used to establish the conversion from $NO_x \rightarrow NO_2$. The ARM2 method is a Tier II regulatory default method for use in AERMOD and differs from the Tier III Plume Volume Mixing Ratio Method (PVMRM) method used in most Quincy DC permits as follows:
   a. PVMRM is mostly applicable to relatively isolated and elevated plumes. While this was deemed acceptable for modeling DC-only plumes, the presence of $NO_x$ from ground level sources (roads and rail) in the model run makes the technique less applicable.
   b. ARM2 is more applicable to handling a mixture of source types like this.
   c. The use of ARM2 does not require consultation with the EPA Regional office, unlike PVMRM.
4. Using a Tier II or Tier III $NO_2$ conversion method in AERMOD requires the total $NO_x$ in the model to approximately mimic reality. There cannot be large amounts of hypothetical emissions in the model, as it results in under-estimated $NO_2$ levels. Therefore separate

AERMOD runs was setup for each of the twenty source groups, where only the respective source group and line sources were actually emitting. Only daily mean concentrations from the DC source group was written out into unformatted POST files (twenty files of 95 MB each). The rationale behind daily averaging of DC contributions is explained in the section on Monte Carlo processing.

5. A slightly conservative approach was followed by conducting a separate run with roads and rail emissions only (the presence of other emissions would lower the $NO_2$/ $NO_x$ ratio slightly). Hourly concentrations written into POST files (two files of 2.2GB each).
6. Monthly variations in emissions and the 9AM- 4PM restriction were implemented using the EMISFACT keyword in AERMOD's source groups.
7. The $NO_2$ background was computed from hourly concentrations measured in Quincy between August 2017 and August 2018, meeting the following criteria:
    a. winds speeds were over 2 mph (no stagnant conditions).
    b. winds had a northerly component (excludes built up area to the south of town).
    c. conditions 7a and 7b were met between 9AM and 4PM (to avoid counting evening/ nighttime hours when low mixing heights trap pollution from all sources).
8. This background $NO_2$ concentration of 14 µg/m³ (7.2 ppb) is comparable to concentrations provided by the NW-AIRQUEST background lookup tool, for areas outside of Quincy. It is assumed that contributions from non-road engines such as farm equipment, construction activities and local roads are captured therein.

**Highway and rail emissions**

Ecology ran EPA's Motor Vehicle Emissions Simulator (MOVES) model to estimate 2014 on-road $NO_x$ emissions, and projected these emissions to 2019. We assumed a Vehicle Miles Travelled (VMT) growth rate of 8.3% from 2015 to 2019 based on the growth rate calculated from WSDOT 2015-2017 VMT estimates for Grant County. The main reason to project emissions to 2019 was the recent release of a newer version of MOVES with substantially lower emissions factors.

Rail emissions were calculated from 2014 fuel use and unlike highway emissions, they were not projected out to 2019 because there were no compelling reasons to believe the data would be substantially different.

**Terrain Heights**

AERMAP was used to obtain a height scale and the base elevation for receptors, sources and buildings, and to develop receptor grids with terrain effects. Digital topographical data from the Shuttle Radar Topography Mission data was used for this project, and has a resolution of approximately 30 m (1 arc-second).

**Monte Carlo post processing**

Since mimicking actual conditions rather than conservatism is the objective of this modeling exercise, the conservative assumptions made about DC emissions were offset as follows:

- AERMOD's hourly output files were used to compute daily *mean* $NO_2$ concentrations at each receptor from each DC- source group.
- Ecology's stochastic post-processing Monte Carlo simulation tool was used to obtain a probabilistic estimate of the $NO_2$ impacts from DCs, since the exact times of actual generator operations are unknown. Each generator source group was treated as if it were operating on one randomly selected day each month. However if the Monte Carlo method randomly selected the same day for different DC source groups (resulting in an overlap of DC plumes), concentrations were summed instead of using the maxima. This step retains a measure of conservatism in the Monte Carlo technique.
- Since each of the 20 source groups are treated as if emitting one day per month, there are about 10 random days each month where no data center emissions are present.
- The median of 1000 random iterations is expected to provide a robust estimate of the "real" $NO_2$ impacts from Quincy DCs in 2018.
- $NO_2$ hourly concentrations from all line sources were used to calculate the daily 1hr maximum concentrations, and their 98$^{th}$ percentiles at each receptor. These "design values" were added to the Monte Carlo output and the static background of 14 µg/m³.

**Results**

**Comparison against the $NO_2$ monitor**

The procedure described above yielded 98$^{th}$ percentiles that were within ±10% of measured data, which is considered an acceptable benchmark for air quality models. 98$^{th}$ percentiles of DC contributions (from the MC method) + rail + highway + background within a 3 x 3 grid of receptors centered on the monitor, was 38.9 µg/m³, whereas the monitor recorded a 98$^{th}$ percentile concentration of 42.4 µg/m³.

The Monte Carlo method only yields design values (DV) and not hourly or daily concentrations for comparing with measured values. Nevertheless, a time-varying breakdown of the modeled sources at the location of the monitor is desirable, even though hourly or daily AERMOD outputs are not expected to correspond with paired-in-time and paired-in-space measurements. For creating such a visualization, a randomly chosen DC source group was deemed operational on a given day, and its contribution at the location of the monitor was combined with corresponding concentrations from rail and highways. A single background concentration is not appropriate year-round, so the procedure described in #7 of the "Emission Sources" section was employed on a weekly basis to create a varying background. Figure B2 shows the breakdown of these modeled sources at the monitor on 3$^{rd}$ Avenue. The measured $NO_2$ concentration is also overlaid for comparison. It can be seen that rail and background often account for a large fraction of the total.

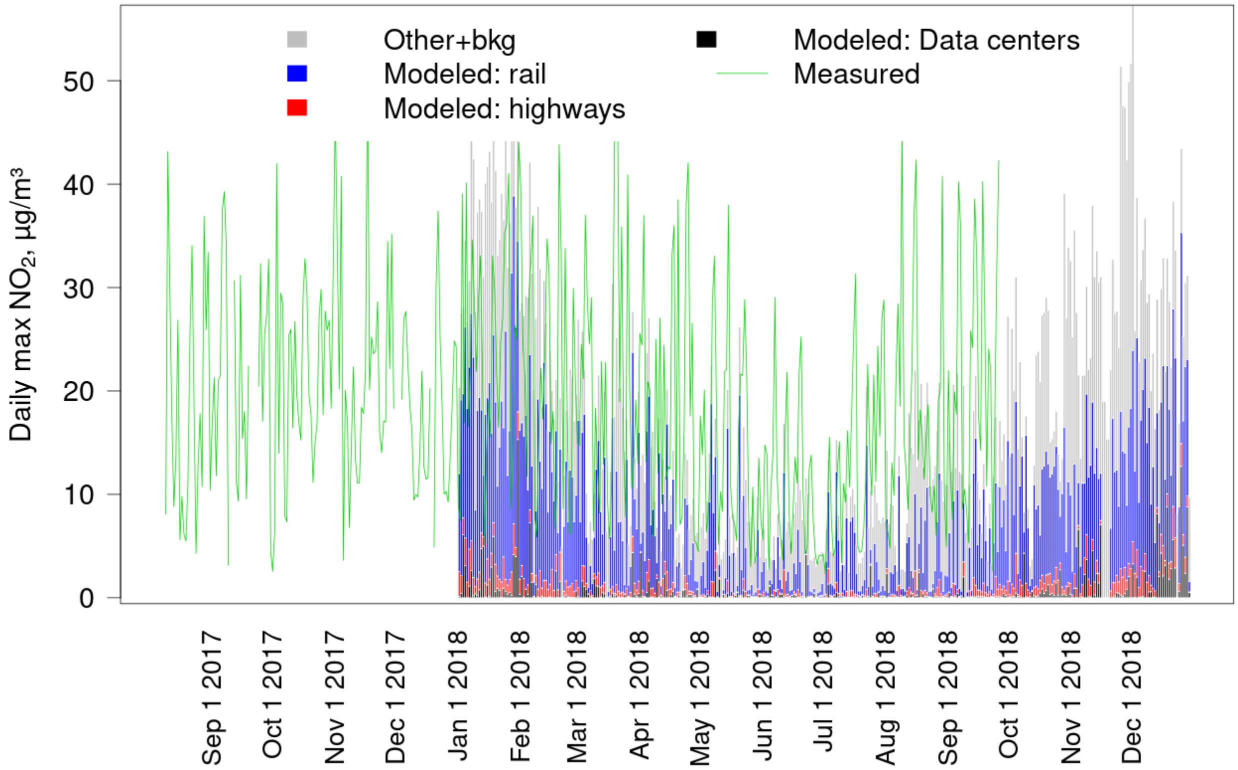


**Figure B2**. Breakdown of modeled daily 1-hr maximum $NO_2$ impacts at the 3rd Avenue monitor. Measured $NO_2$ levels are also overlaid. The hourly Federal Standard of 188 µg/m³ is never threatened.

A more appropriate model- monitor comparison can be made with a quantile-quantile plot, or Q-Q plot, where data are paired in space, but not paired in time. Q-Q plots rank dependent and independent variables and plot the values of a given percentile against each other. This allows the detection systematic biases more easily. The modeled daily maximum $NO_2$ is compared against the 3rd Avenue monitor data in the Q-Q plot shown in Figure B3. A reasonably close correspondence between the two data series (within 10% of the 1:1 line) suggests that the modeling is not consistently biased toward large over or under-predictions of $NO_2$. This lends confidence to the spatial estimates of cumulative DVs.

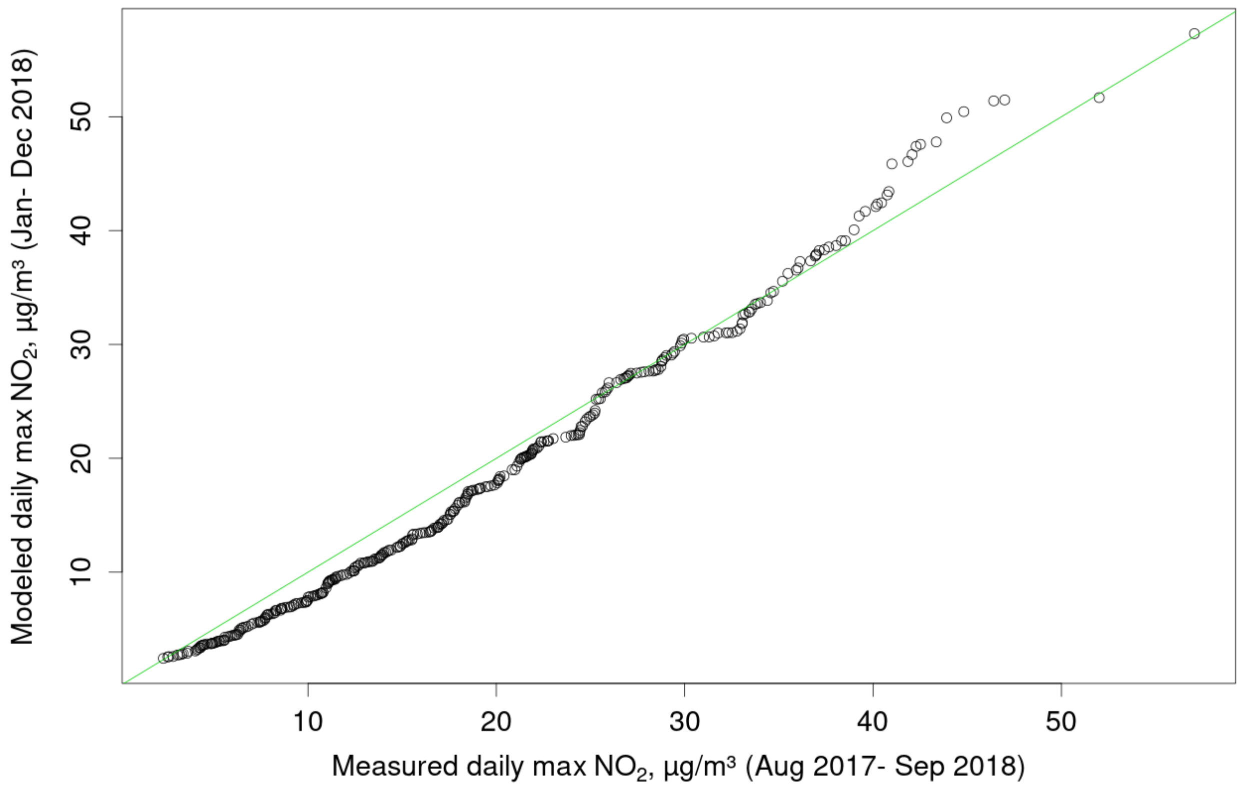


**Figure B3**. Q-Q plot of modeled vs measured daily 1-hr maximum $NO_2$ concentrations at the 3rd Avenue monitor.

**Map of $NO_2$ design values**

Figure B4 shows how the $NO_2$ design values vary spatially across Quincy. The highest values are along the rail line and isolated hotspots are present at buildings within Sabey's and Intuit's property boundaries. No exceedances of the $NO_2$ standard are projected anywhere. An interactive version of Figure B4 is available in the interactive data map.[10] The interactive data map also contains popup graphics of the $NO_2$ attributions at 31 sensitive receptors, each of which was identified when permitting different DCs.


**Figure B4.** Map of $NO_2$ DVs in Quincy. Source attribution at each receptor can be seen in the interactive data map.

[10] https://arcg.is/0SLWem

**Conclusions and Recommendations**

- Not all permitted data center capacity is used as yet. Modeling $NO_2$ levels in Quincy from all major source categories' emissions in 2018 suggests the community comfortably meets the federal standard.

Future permitting could utilize the gridded 2018 background concentrations to account for the highly localized impacts from data centers, highways and rail in lieu if a spatially static background concentration from the NW-AIRQUEST lookup tool. Currently, this value is mostly driven by the DV of the monitor (22.5 ppb or 42.4 $\mu g/m^3$). This will speed up permitting decisions as applicants will not need to quantify emissions from neighboring facilities. However, such a product will become outdated as anthropogenic emissions change, underscoring the need to repeat the exercise every few years.

# Appendix C. Quincy Air Monitoring

**Executive Summary**

A monitoring site in Quincy, WA was established in August 2017 to measure components present in diesel exhaust emissions, including particles less than 2.5 micrometers in diameter ($PM_{2.5}$), black carbon, and oxides of nitrogen ($NO_x$). Meteorological parameters including wind speed, wind direction, and ambient air temperature were also monitored. The measurement campaign lasted until December 2018, although $PM_{2.5}$ and meteorological measurements are still ongoing.

There were no exceedances of the $PM_{2.5}$ or $NO_2$ National Ambient Air Quality Standards during the measurement campaign. $PM_{2.5}$ concentrations were similar to nearby sites, and $NO_x$ concentrations were lower than those at near-road sites in the state. Diurnal and weekly patterns showed increased pollutant concentrations consistent with traffic emissions.

While components of diesel exhaust are present in the airshed, analysis could not resolve individual sources of diesel exhaust emissions. No distinct source directions of measured compounds common in diesel exhaust emissions were present. Known power outages did not show distinct influence at the monitoring site from diesel exhaust emissions, and a source apportionment analysis did not identify an individual source of diesel exhaust emissions.

**Methods: Site and instruments**

Located at 330 3rd Ave NE, the Quincy air monitoring site (longitude = -119.84595, latitude = 47.24126) consisted of a meteorological tower and a trailer housing $NO_x$, black carbon, and $PM_{2.5}$ instrumentation. The trailer was sited following standard Ecology procedures. Local pollution sources include rail traffic (freight and passenger), local transit and vehicle emissions, residential wood combustion, and data centers that use diesel generators. Measurements began in August 2017. $NO_x$ and black carbon measurements ended in December 2018, while $PM_{2.5}$ and meteorological measurements are still ongoing.

**Figure C1.** Quincy monitoring site trailer and meteorological tower


**Figure C2**. Map of Quincy identifying the monitoring site location

Instruments used to measure nitrogen oxides, $PM_{2.5}$, black carbon, wind speed, wind direction, and ambient air temperature are outlined in Table C1. Quality control, quality assurance, and data validation were conducted following Ecology's Standard Operating Procedures. Data were collected at one minute intervals. To isolate only impacts from local emissions (including potential diesel generator emissions), hourly data impacted by wildfires (denoted as days in July through September that observed daily $PM_{2.5}$ concentrations greater than 15 µg $m^{-3}$) were removed from the dataset.

**Table C1**. Measurements at the Quincy monitoring site and associated instruments

| **Measurement** | **Instrument** | **Start Date** | **End Date** |
|---|---|---|---|
| $NO_x$ ($NO + NO_2$) | Teledyne API M200EU chemiluminescence monitor | 08-08-2017 | 12-31-2018 |
| $PM_{2.5}$ | M903 Nephelometer | 08-08-2017 | ongoing |
| Particulate Black Carbon (BC) | Met One BC 1054 Black Carbon monitor | 08-08-2017 | 12-31-2018 |
| Wind speed, wind direction | Ultrasonic anemometer | 08-08-2017 | ongoing |

| Measurement | Instrument | Start Date | End Date |
|---|---|---|---|
| Ambient Air Temperature | Thermometer | 08-08-2017 | ongoing |

## Results

### Ambient concentrations

Hourly and daily averages of $PM_{2.5}$ and black carbon concentrations are shown in Figure C3. Average 24-hour $PM_{2.5}$ concentrations are much lower than the National Ambient Air Quality Standard of 35 μg $m^{-3}$; the maximum 24-hour PM2.5 concentration observed at Quincy was 21 μg $m^{-3}$. Daily averages of black carbon concentrations peaked at 0.96 μg $m^{-3}$. Observed maximum hourly concentrations of $PM_{2.5}$ and black carbon were 25.6 μg $m^{-3}$ and 3.3 μg $m^{-3}$, respectively.

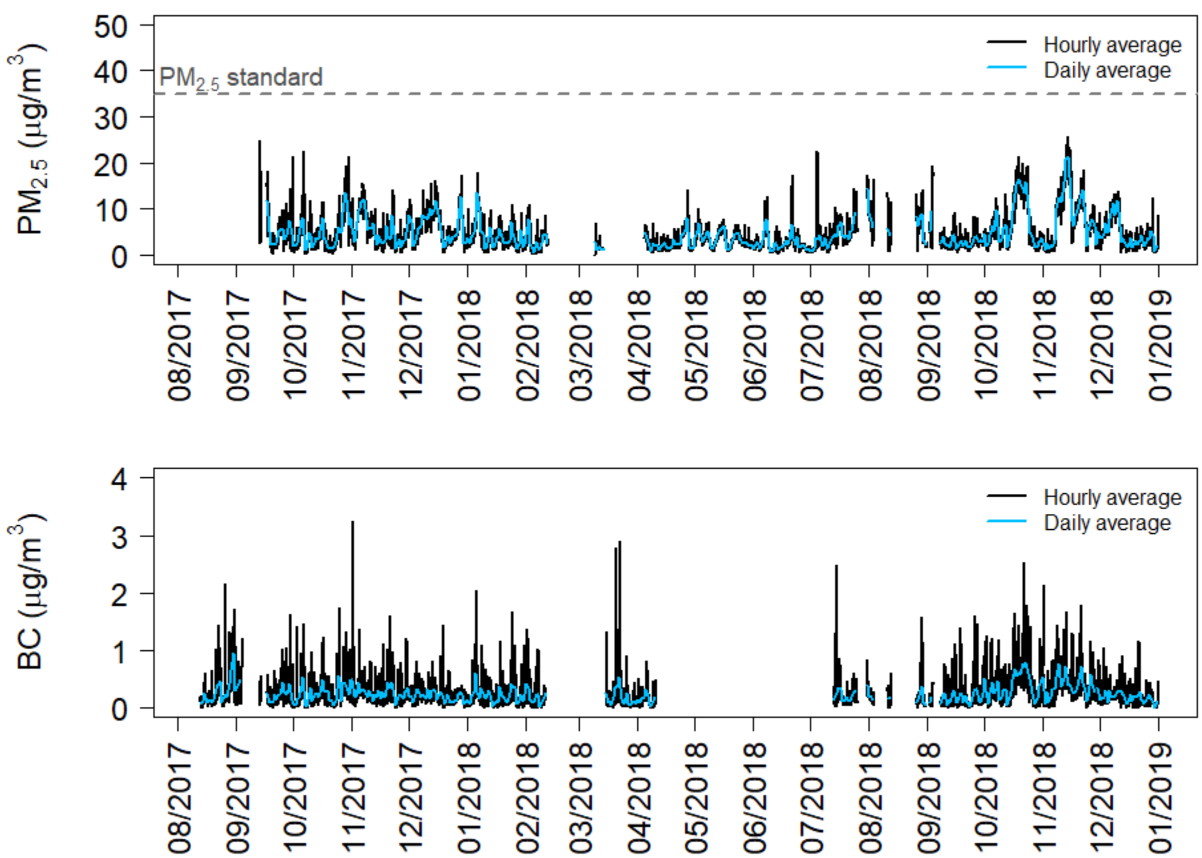


**Figure C3.** Hourly average concentrations of $PM_{2.5}$ (upper panel) and black carbon (lower panel), overlaid with daily averages (blue lines). The 24-hour $PM_{2.5}$ standard of 35 μg $m^{-3}$ is denoted by the dashed grey line in the upper panel. Days and hours impacted by wildfire smoke have been removed from the dataset.

Hourly average $NO_x$ concentrations are shown in Figure C4. The National Ambient Air Quality $NO_2$ Standard is a one hour daily maximum concentration of 100 ppb; the observed maximum one hour daily maximum $NO_2$ concentration was 30.3 ppb. Figure C4 also shows the $NO_2$ to $NO_x$ ratio as a function of $NO_x$ concentrations. Especially at low $NO_x$ concentrations, the majority of $NO_x$ is in the form of $NO_2$. The median $NO_2$ to $NO_x$ ratio observed at Quincy is 0.89. Ecology's near-road site in Seattle routinely measures contributions from diesel exhaust emissions; an average $NO_2$ to $NO_x$ ratio of 0.55 was determined at the near-road site for the same time period as the Quincy measurements.

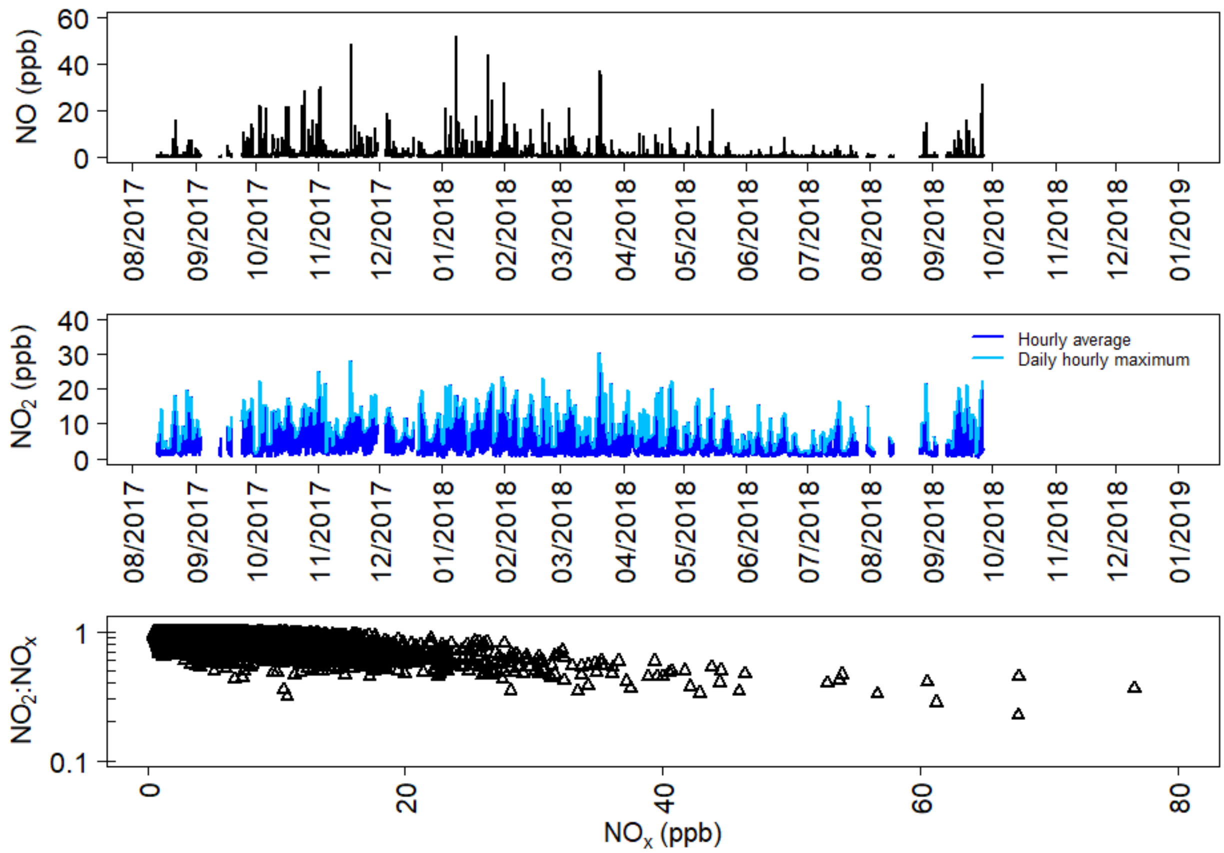


**Figure C4**. Hourly concentrations of NO (upper panel) and $NO_2$ (middle panel) as a function of time. The lower panel describes hourly $NO_2$ to $NO_x$ ratios as a function of $NO_x$ concentrations. Hours impacted by wildfire smoke have been removed from the dataset.

**Comparison to Nearby Sites**

$PM_{2.5}$ concentrations measured at Quincy are similar to those measured at nearby regional sites. Comparison of the distribution of daily $PM_{2.5}$ concentration at Quincy to nearby sites Wenatchee and Moses Lake is shown in Figure C5. The range of $PM_{2.5}$ concentrations and the mean values are similar for all three sites.

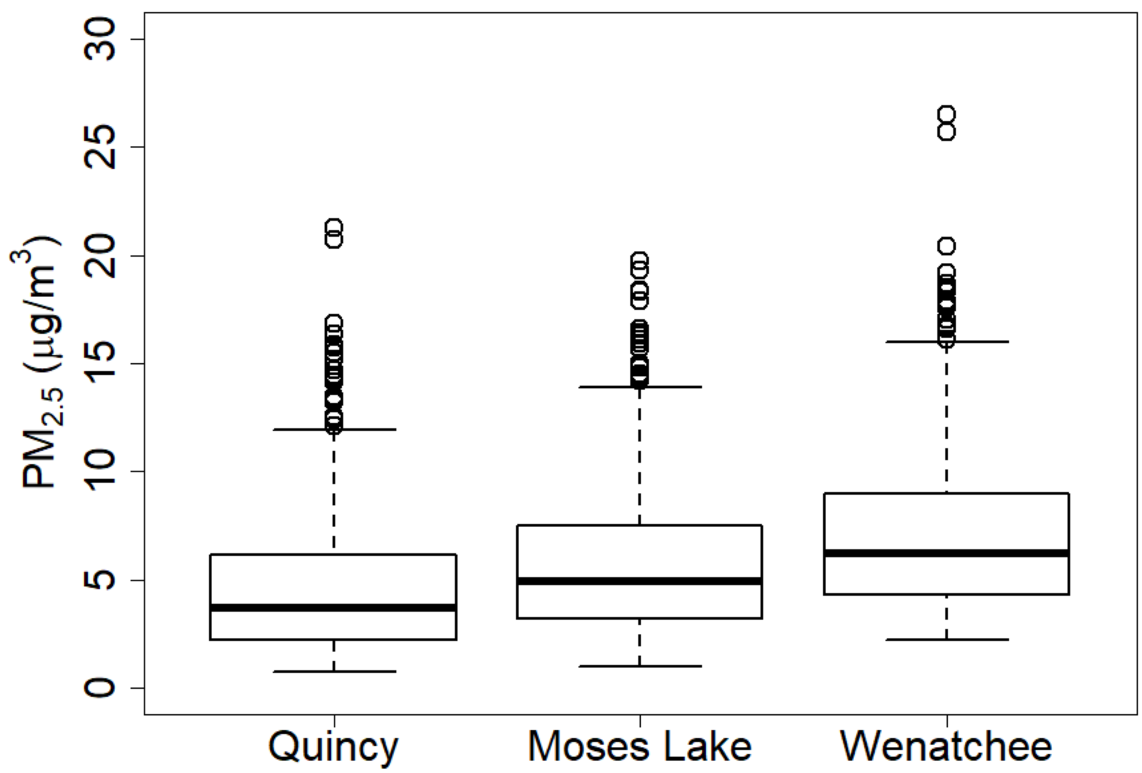


**Figure C5**. Comparison of $PM_{2.5}$ measurements at Quincy, Moses Lake, and Wenatchee during the same time period.

The Washington monitoring network also measures $NO_x$ concentrations at urban near-road monitoring sites in Tacoma and Seattle. These near-road monitoring sites routinely observe pollution from on-road diesel sources. Average NO concentrations at the Seattle and Tacoma near-road sites during the same 2017-2018 measurement time period at Quincy are 22-28x higher than the average concentration of NO observed at Quincy. Average $NO_2$ concentrations at the Seattle and Tacoma near-road sites are 5x higher than the average $NO_2$ concentration observed at Quincy.

Table C2 includes 95th percentiles of NO and $NO_2$ concentrations for the Seattle and Tacoma near-road monitoring sites, as well as Seattle's urban background site and the rural Cheeka Peak site, which is located at the northwest point of Washington. Pollution sources at Seattle's urban background site include local traffic emissions and home heating. The rural Cheeka Peak site observes few direct pollution sources; ships, wood burning, sea salt, and dust are the main sources of pollution (*Hadley, 2017*). Quincy $NO_x$ concentrations are lower than Seattle's urban background site, but higher than the rural Cheeka Peak site. Boxplots of hourly $NO_x$ concentrations at Quincy and the rural, urban, and near-road sites in Washington further shows the lower observed $NO_x$ concentrations at Quincy as compared to more urban monitoring sites. (Figure C6).

**Table C2**. Comparison of 95th percentile $NO_x$ concentrations at Quincy to $NO_x$ concentrations at other $NO_x$ measurements across the state from August 2017-December 2018. Wildfire impacts have been removed. *$NO_2$ at Cheeka Peak is inferred based on the difference between $NO_x$ and NO.

| **Monitoring Site** | **NO (ppb)** | **$NO_2$ (ppb)** |
|---|---|---|
| Seattle near-road | 85.3 | 37.3 |
| Tacoma near-road | 77.9 | 30.5 |
| Seattle urban | 29.5 | 26.7 |
| Cheeka Peak (rural) | 0.300 | 2.80* |
| Quincy | 3.40 | 10.9 |

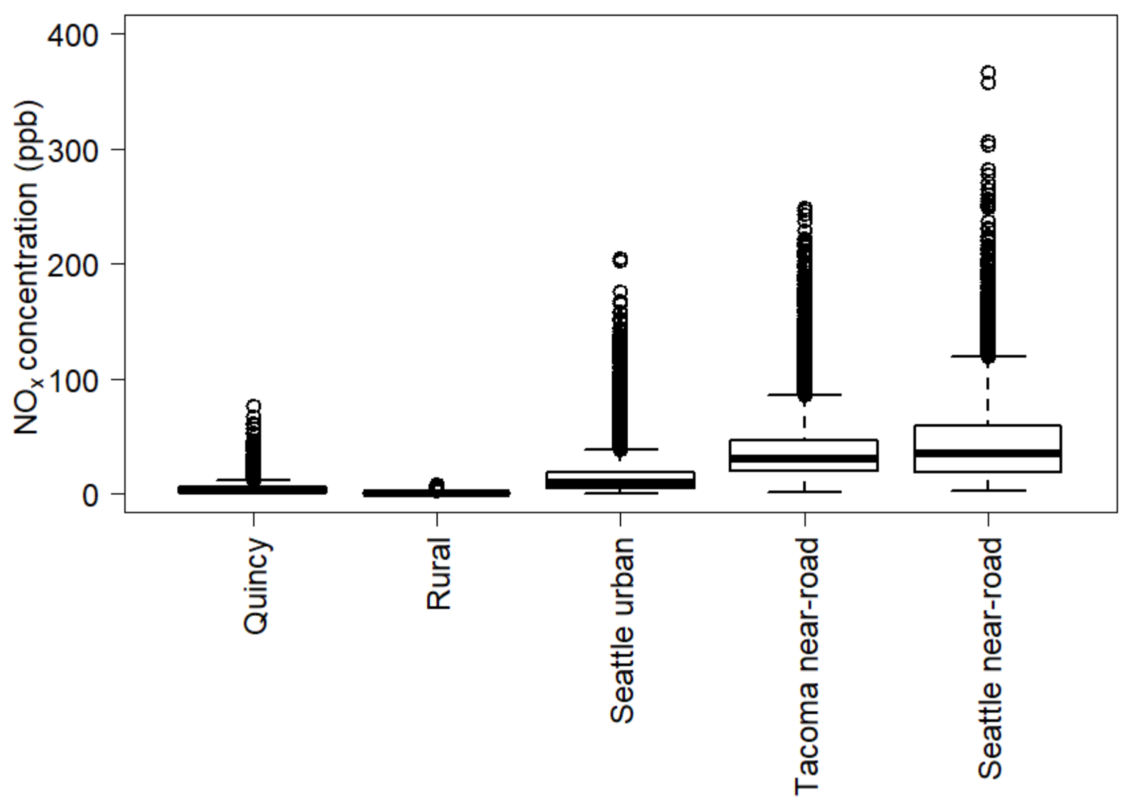


**Figure C6**. Comparison of hourly $NO_x$ concentrations between Quincy and other monitoring sites in Washington.

**Concentrations as a function of time of day and day of week**

Pollutant concentrations throughout the day provide insight about the pollutant's source, as many activities are conducted routinely (such as driving to work or train schedules). Any variation of a pollutant's diurnal cycle may indicate point source emissions or a source that is not as routinely observed (such as diesel generator emissions). Diurnal cycles of $PM_{2.5}$, black carbon, and $NO_x$ are shown in Figure C7. All pollutants show primary peak concentrations in the morning hours (6-8am) and secondary peak concentrations in the afternoon hours (5-7pm). These peak concentrations correspond to traditional rush hour timing, suggesting that $PM_{2.5}$, black carbon, and $NO_x$ concentrations observed in Quincy are largely due to local traffic emissions. The variation in each pollutant's diurnal cycle is small—$PM_{2.5}$, black carbon, and $NO_x$ vary at most by 1%, 3%, and 2%, respectively, suggesting any substantial changes to emission sources should be measureable.

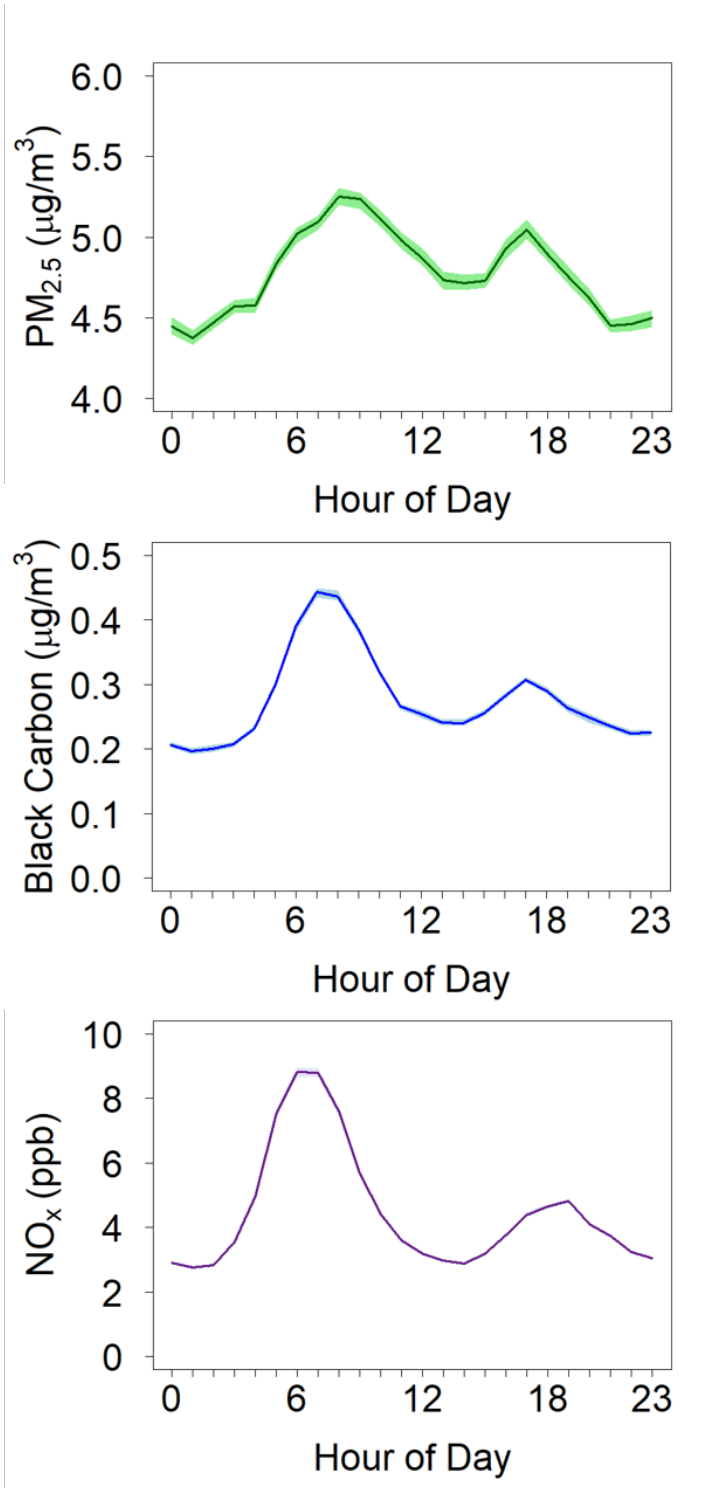


**Figure C7**. Concentrations of $PM_{2.5}$ (upper), black carbon (middle), and $NO_x$ (lower) as a function of hour of day. Solid line is the average, and shaded areas represent the 95th percent confidence interval in the mean.

$PM_{2.5}$, black carbon, and $NO_2$ concentrations are also higher during the weekdays as opposed to the weekend (Figures C8-10). The range of concentrations for each pollutant is similar across all weekdays. However, the median concentrations of black carbon and $NO_2$ are slightly lower during the weekend than during the week. Higher pollutant concentrations during the weekdays as opposed to the weekend are also indicative of local traffic emissions, as more people tend to drive routinely during the week.

Ratios of black carbon to $NO_x$ and $NO_2$ to $NO_x$ were also examined as a function of time of day and day of week. Results did not add any new information about sources of pollutants in Quincy.

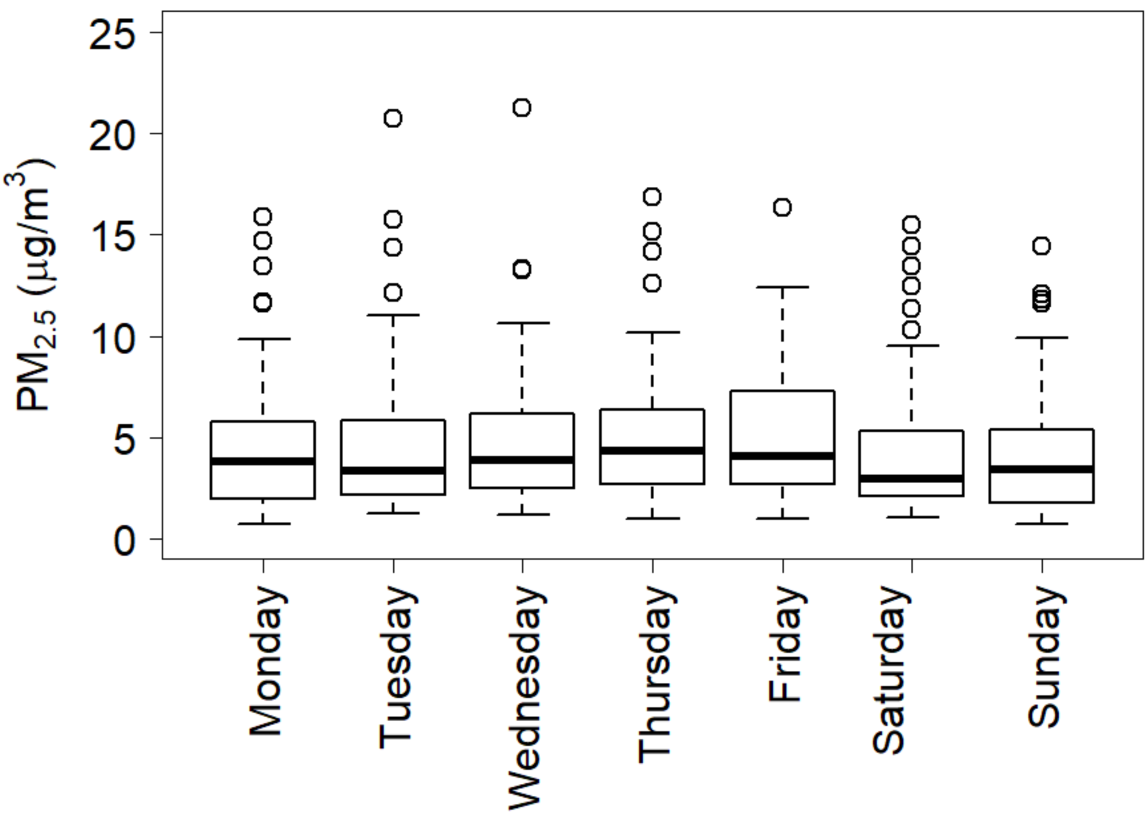


**Figure C8**. $PM_{2.5}$ concentrations as a function of day of the week

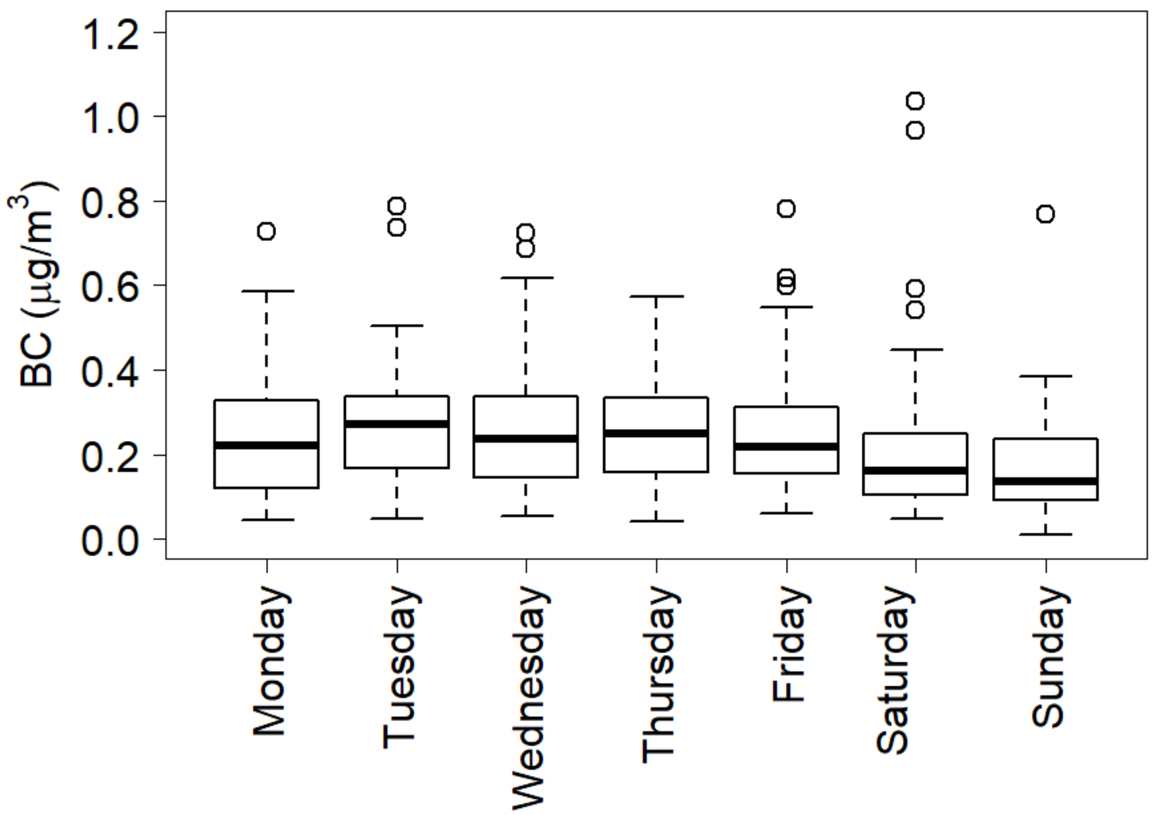


**Figure C9**. Black carbon concentrations as a function of day of the week

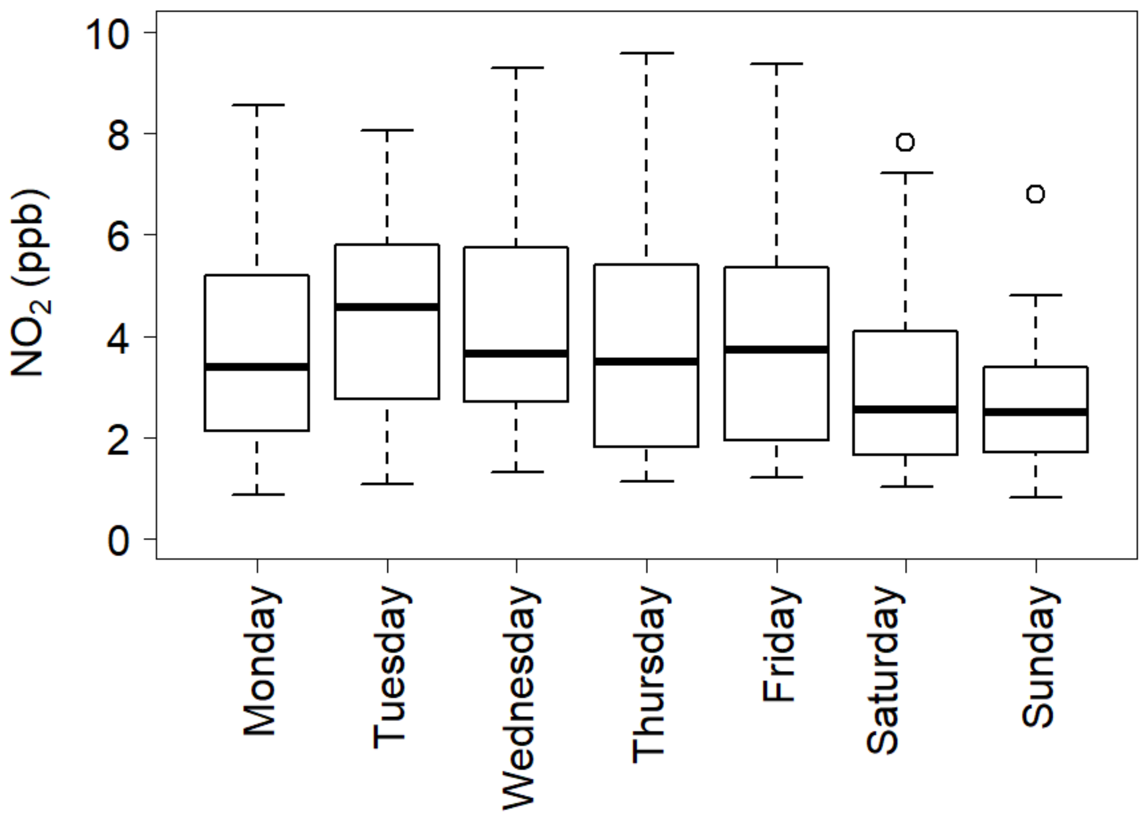


**Figure C10**. $NO_2$ concentrations as a function of day of the week

## Meteorological data and pollutant source directions

The wind profile for the monitoring site is shown in Figure C11, and describes the wind speed and wind direction data from the entire measurement period. Wind at the Quincy monitoring site comes from all directions, with more occurrences as well as higher wind speeds from the northwest direction.

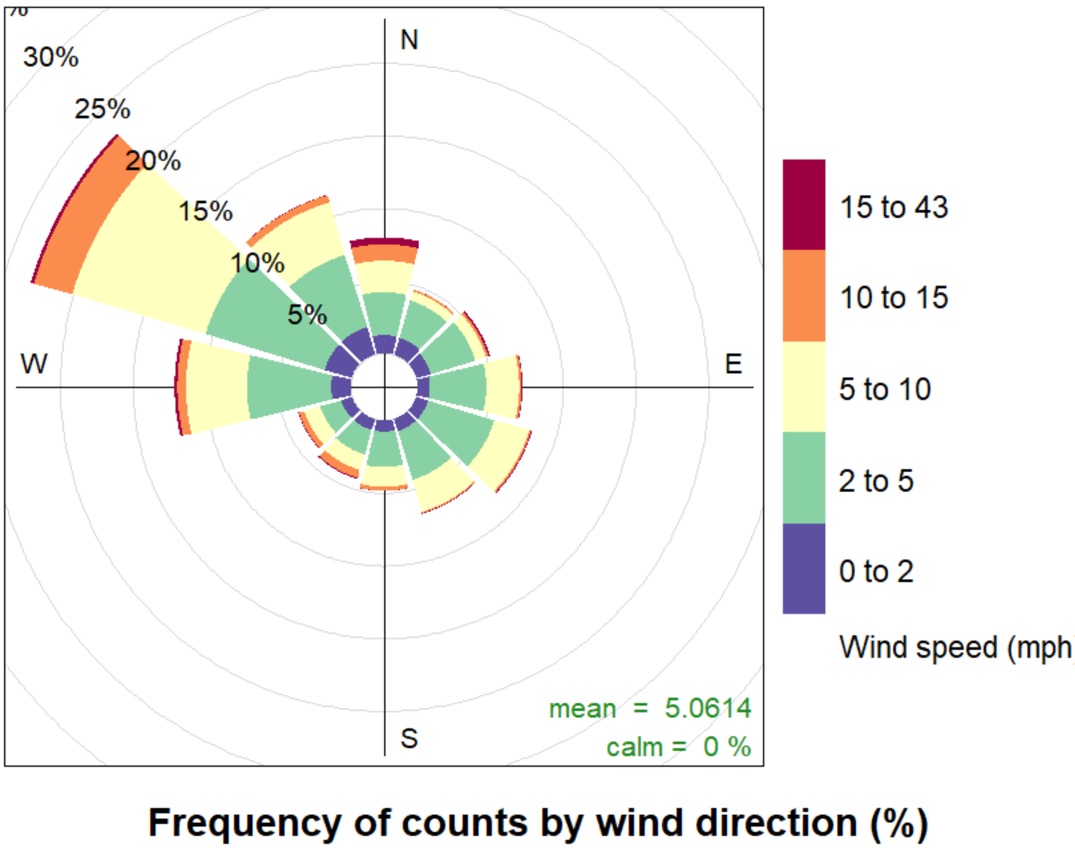


**Figure C11**. Wind rose for the entire measurement period at the Quincy monitoring site. The length of each paddle around the circle is related to the frequency of time that the wind blows from that particular direction. Colors indicate the wind speed (mph).

Combining meteorological data with pollutant concentrations allows identification of how much each pollutant comes from a given wind direction. Pollution roses are shown in Figures C12, 13, and 14, and utilize hourly wind and pollutant data. Sources of $PM_{2.5}$, black carbon, and $NO_x$ are not significantly different from the overall wind profile, indicating that no pollutant can be isolated to a single source or source direction. Concentrations of $PM_{2.5}$, black carbon, and $NO_x$ come from all directions, with higher occurrences from the northwest, similar to the higher wind frequencies in the overall wind profile in Figure C11.

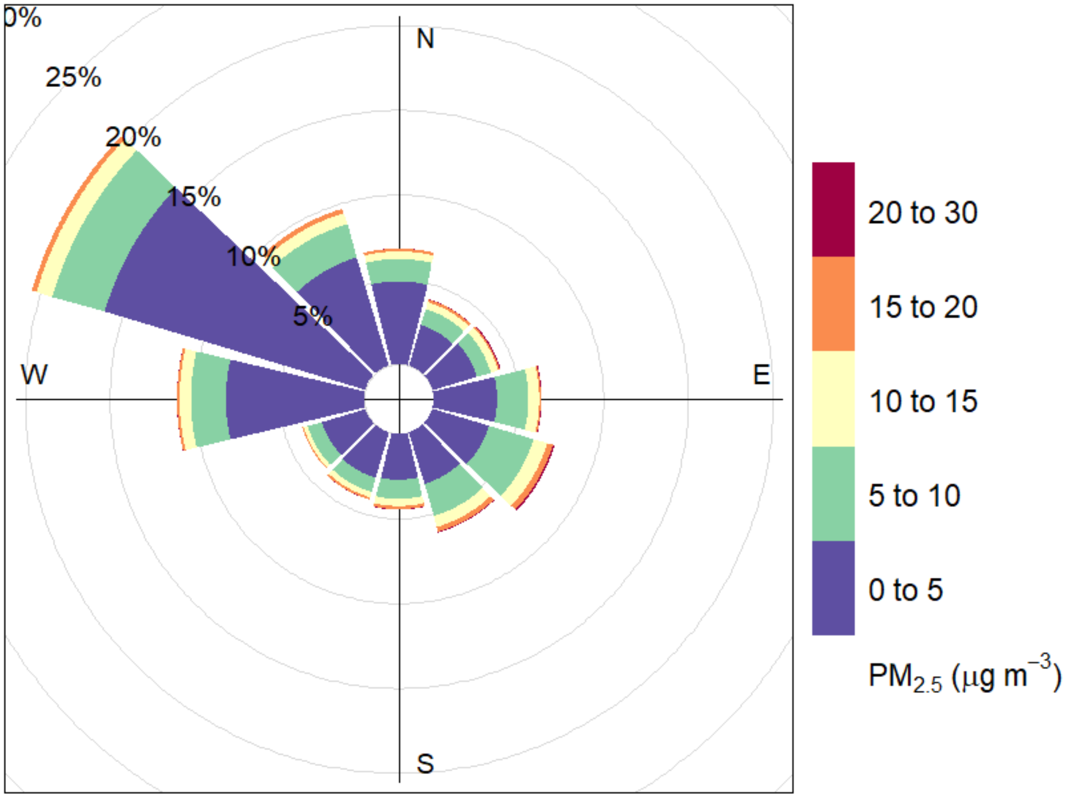


**Figure C12**. Pollution rose of $PM_{2.5}$ concentrations. Colorbar indicates $PM_{2.5}$ concentration, and the length of the paddle indicates the frequency of time the wind is blowing from a given direction.

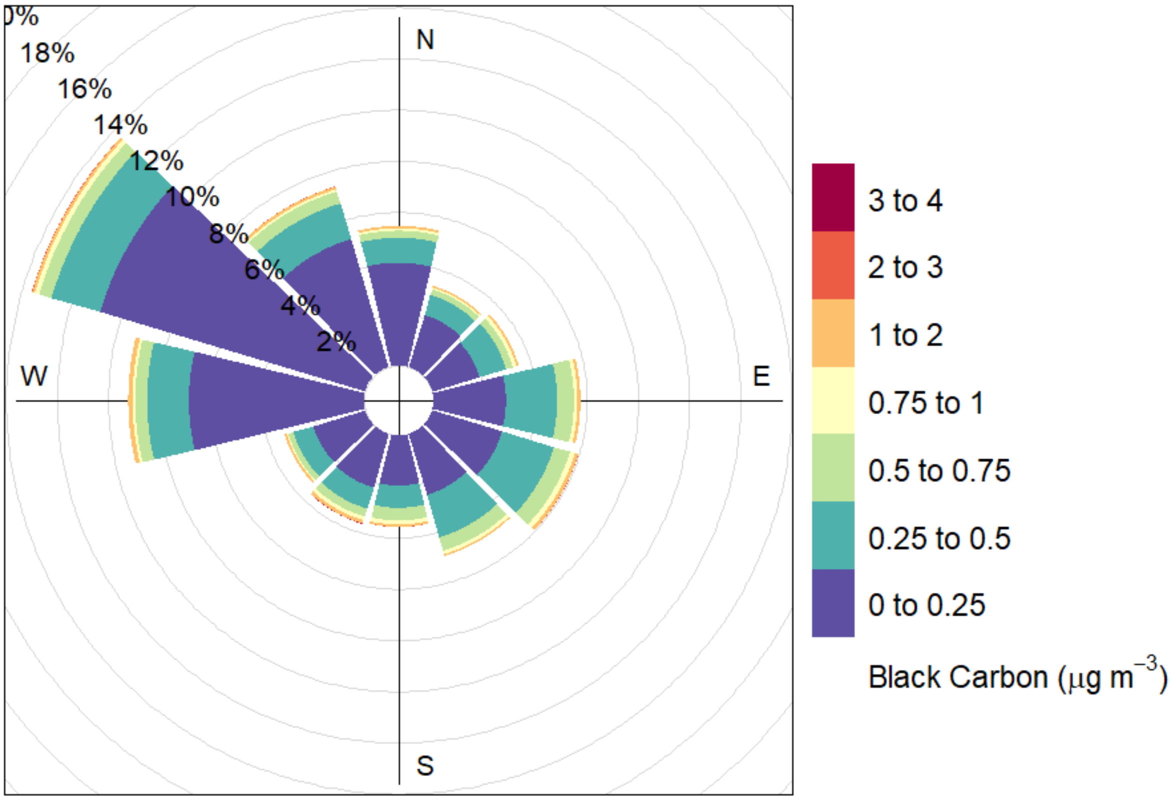


**Figure C13**. Pollution rose of black carbon concentrations. Colorbar represents black carbon concentrations.

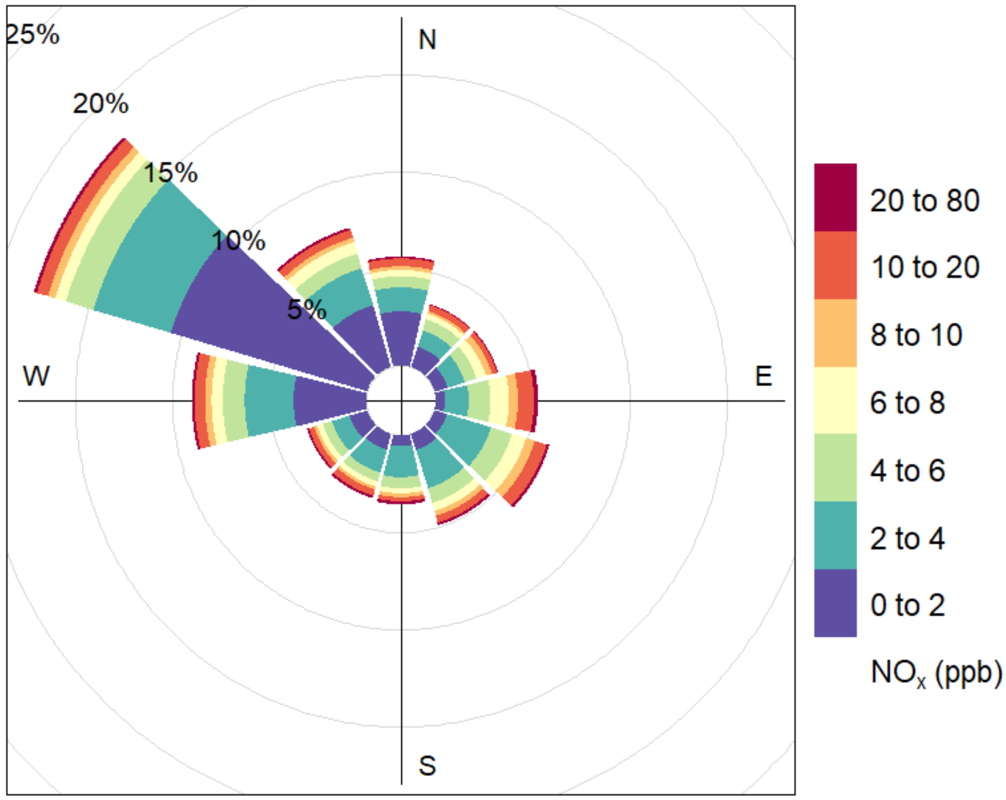


**Figure C14**. Pollution rose of $NO_x$. Colorbar represents $NO_x$ concentrations.

To isolate the source direction of only the highest concentrations of pollutants present in diesel exhaust, $PM_{2.5}$, black carbon, and $NO_2$ concentrations were separated into percentiles and plotted as a function of wind direction (Figures C15-17). No clear direction or a source pointing to the highest concentrations of $PM_{2.5}$, black carbon and $NO_2$ is observed.

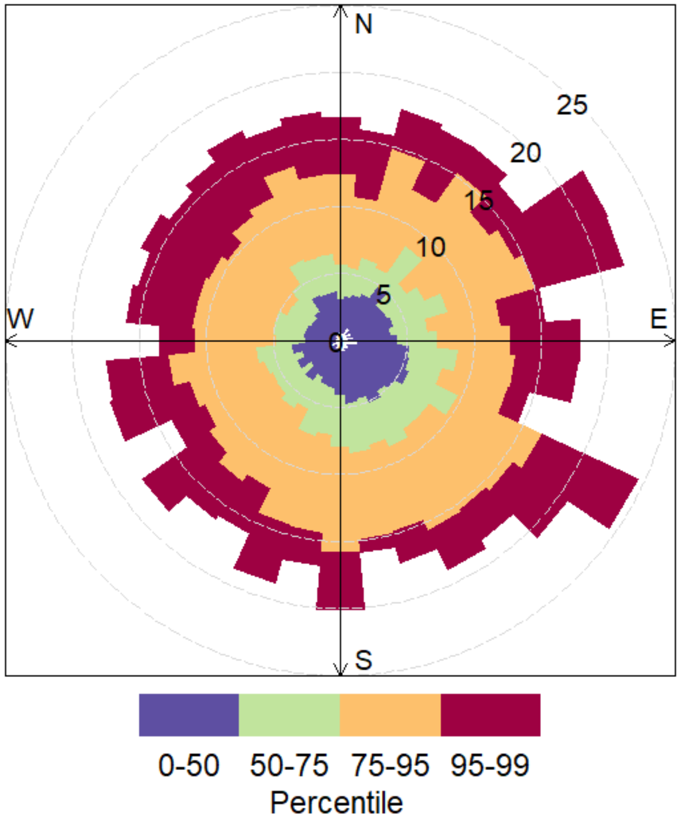


**Figure C15**. $PM_{2.5}$ concentrations as a function of wind direction, colored by percentile

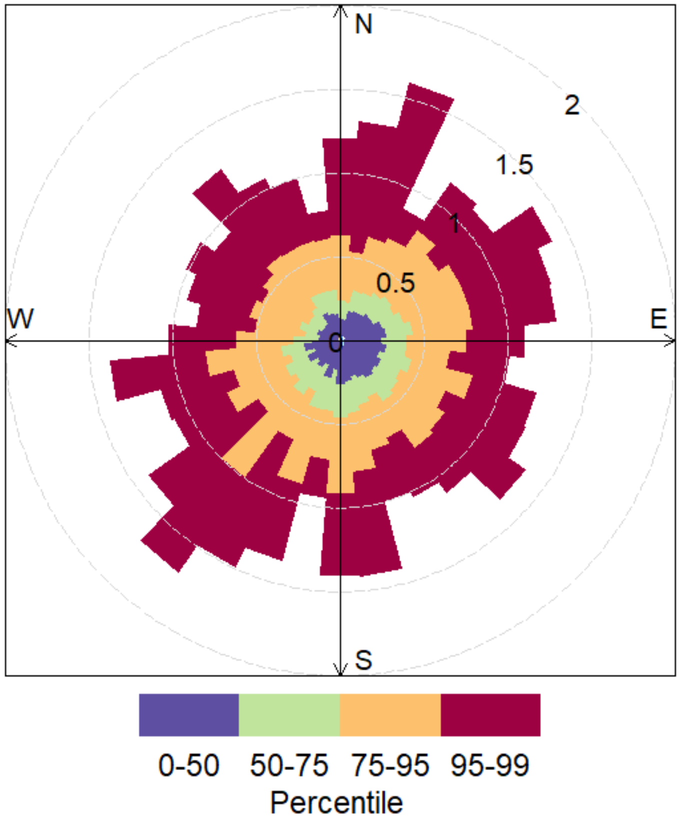


**Figure C16**. Black carbon concentrations as a function of wind direction, colored by percentile

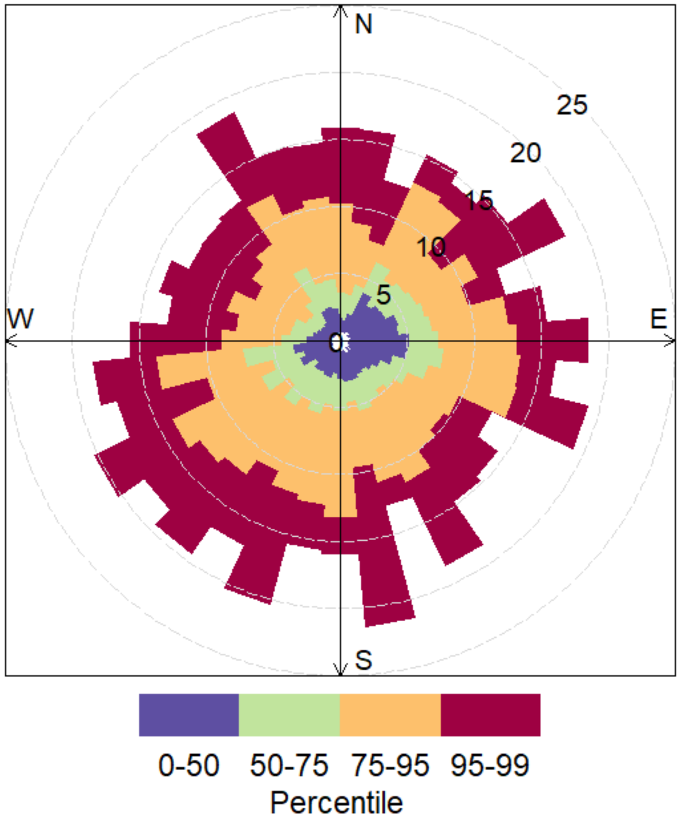


**Figure C17**. $NO_2$ concentrations as a function of wind direction, colored by percentile

### Impact of power outages on ambient concentrations

Known power outages at data centers include outages at the Microsoft facilities 11/17/17 and 2/9/18, and an outage at the Yahoo facility 2/7/18. These power outages generally occurred for about two hours, providing an opportunity to observe changes in ambient concentrations when the backup diesel generators are running. Table C3 details each outage and $PM_{2.5}$, black carbon, and $NO_x$ concentrations observed during the power outage compared to the day of the outage.

Figure C18 shows black carbon and $NO_x$ concentrations for November 17, 2017, the day of an outage at the Microsoft Columbia facility. The dashed red lines denote the start and end of the power outage. Based on the distance from the facility to the monitoring site and the average wind speed during the outage, there is an approximate lag time of 6-8 minutes between the time of the power outage and when the monitoring site intercepted any impacts. Black carbon, $PM_{2.5}$, and $NO_x$ concentrations during the power outage are much lower than the average concentrations observed that day. Wind direction (denoted in the plot by the arrows) show the winds intercepted at the monitoring site during the power outage were coming from the west and northwest. The Microsoft Columbia facility is located to the west of the monitoring site. However, concentrations of black carbon and $NO_x$ do not show a clear sustained increase in concentrations that can be attributed to diesel generator emissions.

The Yahoo power outage on February 7, 2018 is shown in Figure C19. The lag time between the Yahoo facility and the monitoring site is approximately 17-33 minutes. $PM_{2.5}$ and $NO_x$ concentrations are higher during the outage, while black carbon concentrations are similar. However, during the power outage the Yahoo facility was downwind of the monitor and unlikely contributing to these increases.

The Microsoft Oxford outage on February 9, 2018 does not show a distinct increase in ambient concentrations of $NO_x$, black carbon, and $PM_{2.5}$ that would be expected with observed emissions from diesel generators (Figure 20). The lag time between the Microsoft Oxford facility and the monitoring site is approximately 9-12 minutes. Observed $PM_{2.5,}$ and black carbon concentrations are similar during the outage compared to the day of the outage, while average concentrations of $NO_x$ are lower during the outage compared to the day of the outage. However, wind data shows emissions coming from the north, whereas the Microsoft Oxford facility is to the west of the monitoring site.

**Table C3**. Details of the known power outages at the data centers, including concentrations of PM2.5, black carbon, and $NO_x$ during the outage and during the day of the outage

| Facility | Day | Time | Mean $PM_{2.5}$, outage ($\mu g\ m^{-3}$) | Mean $PM_{2.5}$, day of outage ($\mu g\ m^{-3}$) | Mean black carbon, outage ($\mu g\ m^{-3}$) | Mean black carbon, day of outage ($\mu g\ m^{-3}$) | Mean $NO_x$, outage (ppb) | Mean $NO_x$, day of outage (ppb) |
|---|---|---|---|---|---|---|---|---|
| Microsoft Columbia | 11/17/2017 | 13:00-15:00 PST | 0.70 | 2.6 | 0.080 | 0.27 | 4.1 | 13 |

| Facility | Day | Time | Mean $PM_{2.5}$, outage ($\mu g\ m^{-3}$) | Mean $PM_{2.5}$, day of outage ($\mu g\ m^{-3}$) | Mean black carbon, outage ($\mu g\ m^{-3}$) | Mean black carbon, day of outage ($\mu g\ m^{-3}$) | Mean $NO_x$, outage (ppb) | Mean $NO_x$, day of outage (ppb) |
|---|---|---|---|---|---|---|---|---|
| Yahoo | 2/7/2018 | 12:30-14:15 PST | 3.0 | 1.8 | 0.30 | 0.24 | 8.9 | 6.9 |
| Microsoft Oxford | 2/9/2018 | 16:38-18:26 PST | 2.7 | 3.0 | 0.13 | 0.070 | 1.2 | 2.4 |

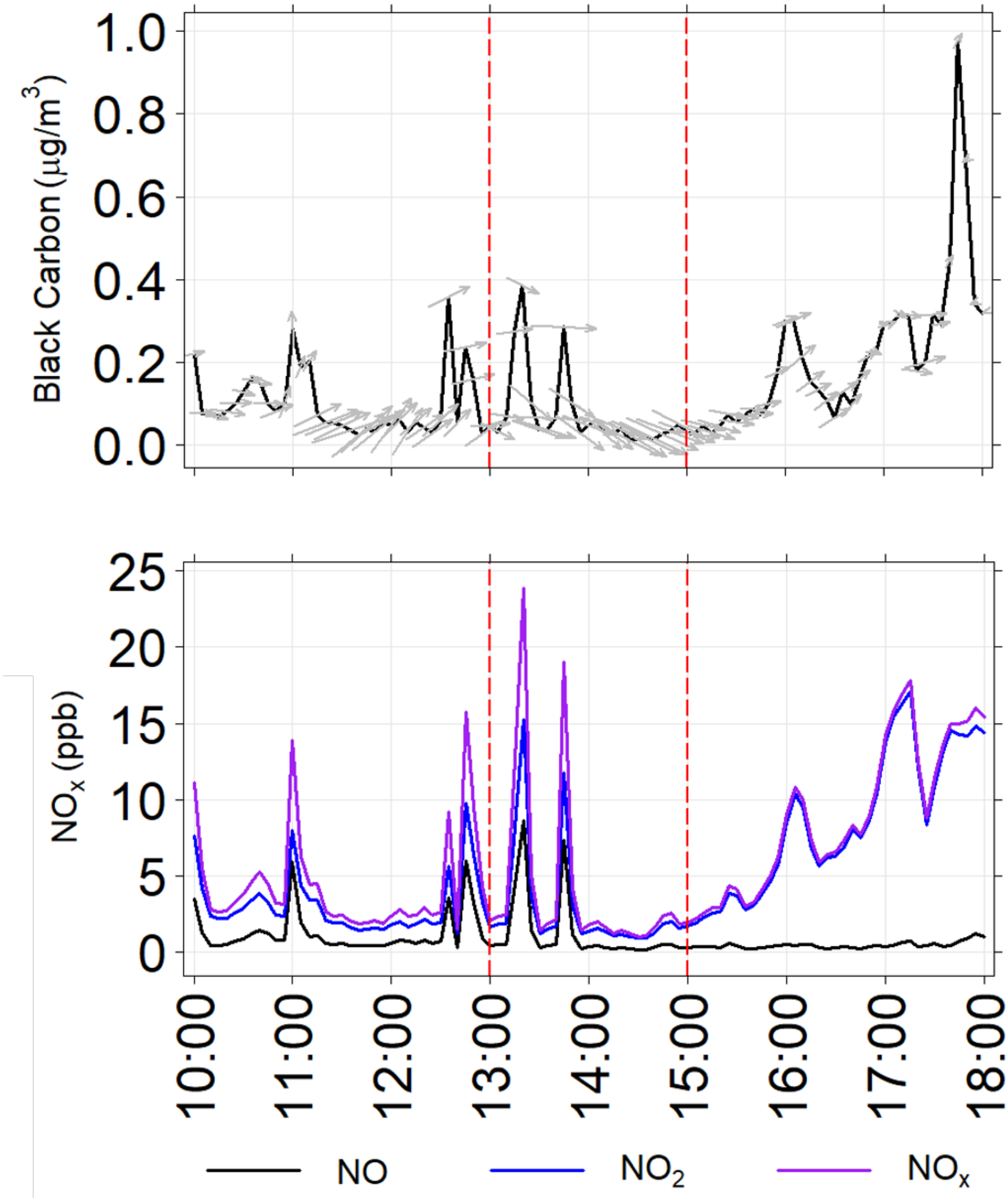


**Figure C18**. Timeseries (5 minute averages) of black carbon and $NO_x$ the day of the Microsoft Columbia outage on 11/17/2017. The red dashed lines denote the start and end of the outage. Arrows shown on the black carbon timeseries represent the wind direction and speed.

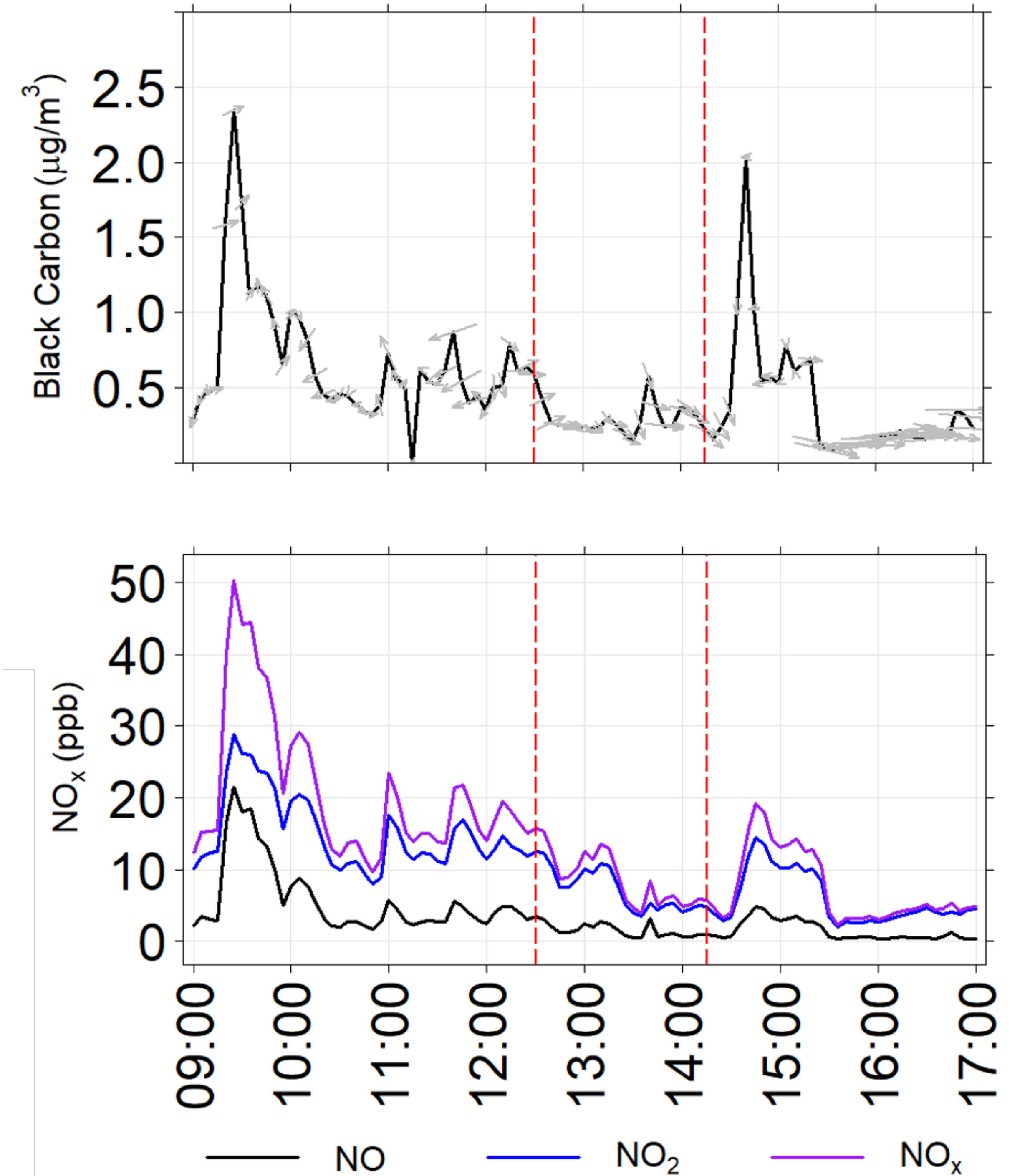


**Figure C19**. Timeseries (5 minute averages) of black carbon and $NO_x$ the day of the Yahoo outage on 2/7/2018. The red dashed lines denote the start and end of the outage. Arrows shown on the black carbon timeseries represent the wind direction and speed.

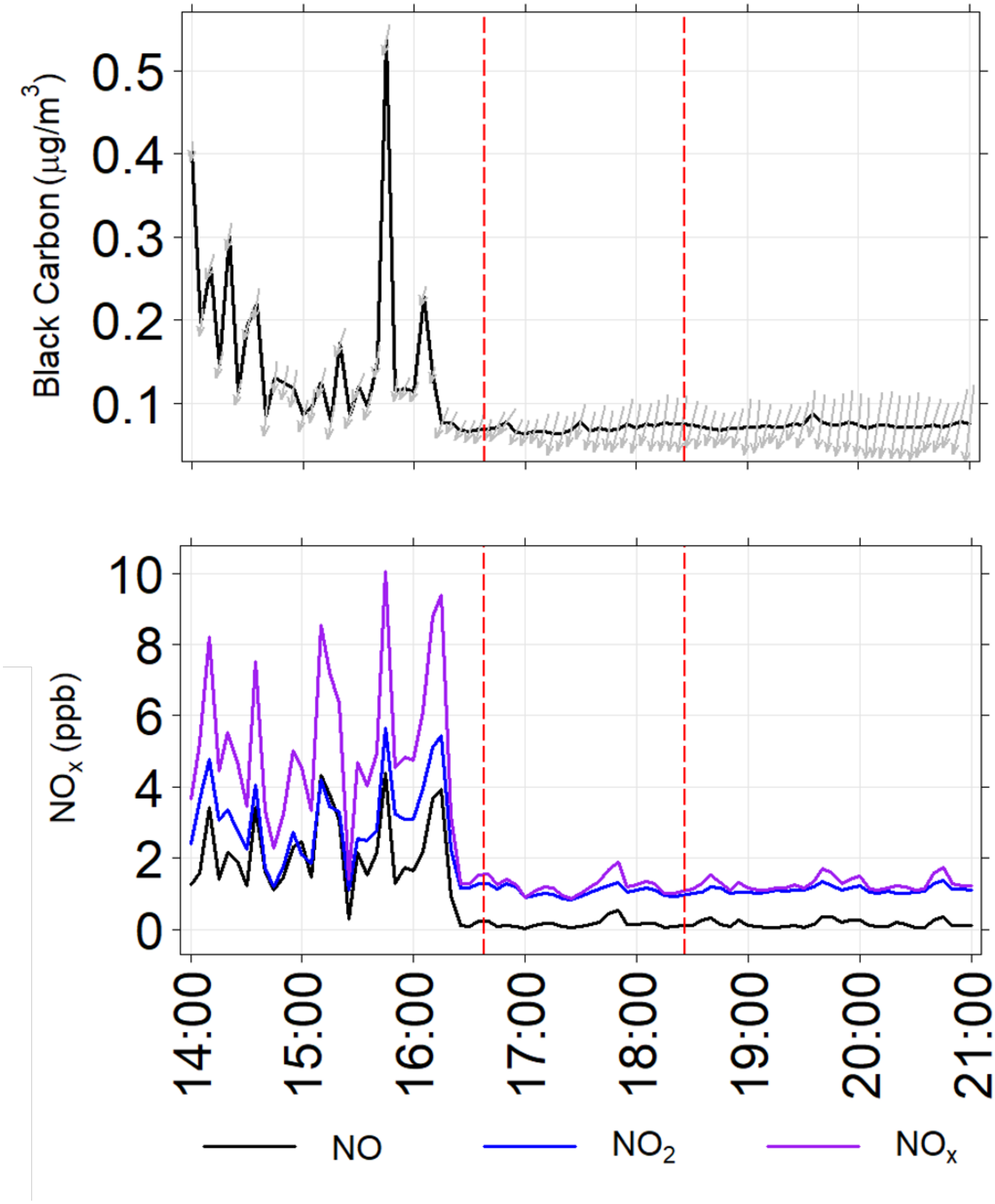


**Figure C20**. Timeseries (5 minute averages) of black carbon and $NO_x$ the day of the Microsoft Oxford outage on 2/9/2018. The red dashed lines denote the start and end of the outage. Arrows shown on the black carbon timeseries represent the wind direction and speed.

**Source Apportionment Analysis**

Positive Matrix Factorization (PMF) analysis was also run on the measurements at the Quincy monitoring site. Briefly, PMF analysis parses a time series of measured chemical species into a number of source factors. Each source factor has an associated chemical profile and mass contribution to the total measured dataset. In this way a large dataset comprised of many chemical species can be parsed into a finite number of sources that vary over time (*Paatero and Tapper, 1997*). PMF analysis has been used extensively to identify sources of pollution in the atmosphere (*Brown et al., 2007; Kotchenruther, 2013; Kim and Hopke, 2008; Kim et al., 2003; Reff et al., 2007*).

For PMF analysis of the Quincy dataset, inputs included timeseries of all measured parameters at the Quincy monitoring site, including $PM_{2.5}$, all channels measured by the aethelometer (including black carbon), and $NO_x$. The number of source factors comprising the dataset was chosen based on error analysis, knowledge of the potential sources, and previously defined chemical fingerprints. Because PMF is computationally expensive, the full dataset was run using 24-hour averages of each chemical species. Additional PMF analysis runs used hourly data for a six month period, minute data for a week of data, and minute data during each of the power outages described above. Data processing for PMF analysis followed previous work (*Kotchenruther, 2013*).

Four to six factors were found to describe the measured dataset, with variation in the number of factors due to the different timescales of PMF analyses. Factors varied in their concentrations of $PM_{2.5}$, black carbon, and $NO_x$, as well their associated contributions to the total measured timeseries. However, no clear factors were found that were dominated only by black carbon or other indications of diesel exhaust emissions.

Meteorological data allows determination of pollution roses of each factor, which showed no clear source direction. Each factor was similar in that despite its chemical profile, emissions originated from many different directions and could not be isolated solely to the direction of a data center. PMF analysis of the power outage incidents also showed no clear source of diesel generator emissions from the direction of the data center experiencing the power outage.

**Predicting Diesel $PM_{2.5}$**

Previous source apportionment analysis of 2015-2017 Chemical Speciation Network data at Ecology's near-road site in Seattle identified a diesel $PM_{2.5}$ factor. Correlations between that diesel $PM_{2.5}$ factor and $NO_x$ and black carbon concentrations measured concurrently allowed determination of a predictive relationship to describe diesel $PM_{2.5}$ as a function of measured $NO_x$ and black carbon concentrations. That same relationship was applied to Quincy data to predict diesel $PM_{2.5}$ during the measurement campaign. Note that the original relationship to predict diesel $PM_{2.5}$ was developed utilizing 24-hour data at an urban near-road site subject to much higher black carbon and $NO_x$ concentrations than observed at Quincy.

On average, diesel $PM_{2.5}$ is predicted to be 8% of the total $PM_{2.5}$ during the measurement campaign. Removing low concentrations of $NO_x$ and $PM_{2.5}$ to eliminate noise in the dataset (< 2 ppb and < 2 µg $m^{-3}$, respectively) results in an average ratio of predicted diesel $PM_{2.5}$ to measured $PM_{2.5}$ of 0.05, with values ranging from 0.0001 to 0.5. Figure C21 shows the ratio between predicted diesel $PM_{2.5}$ to measured $PM_{2.5}$ as a function of measured $PM_{2.5}$, with points sized by the corresponding $NO_x$ concentrations. With increasing $PM_{2.5}$ concentrations, the ratio between predicted diesel $PM_{2.5}$ and measured $PM_{2.5}$ decreases, suggesting that diesel $PM_{2.5}$ concentrations do not scale with increased $PM_{2.5}$ concentrations. Higher predicted diesel $PM_{2.5}$ correlate with higher $NO_x$ concentrations, but the majority of data points exhibit low $NO_x$ concentrations and a predicted diesel $PM_{2.5}$ concentration that is less than 10% of the total measured $PM_{2.5}$ concentration. Further analysis showed that the ratio of predicted diesel $PM_{2.5}$ to measured $PM_{2.5}$ does not significantly change as a function of day of week or season (Figures C22 and C23).

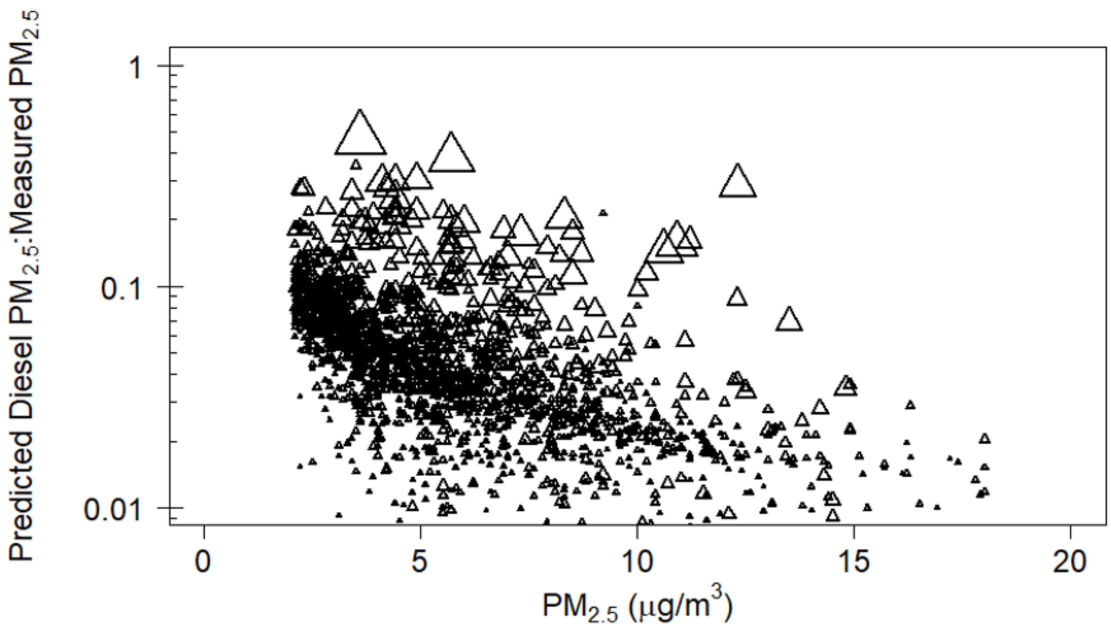


**Figure C21**. Hourly ratios of predicted diesel $PM_{2.5}$ to measured $PM_{2.5}$ as a function of measured $PM_{2.5}$. Points are sized relative to their $NO_x$ concentration. $NO_x$ concentrations less than 2 ppb and $PM_{2.5}$ concentrations less than 2 µg $m^{-3}$ have been removed.

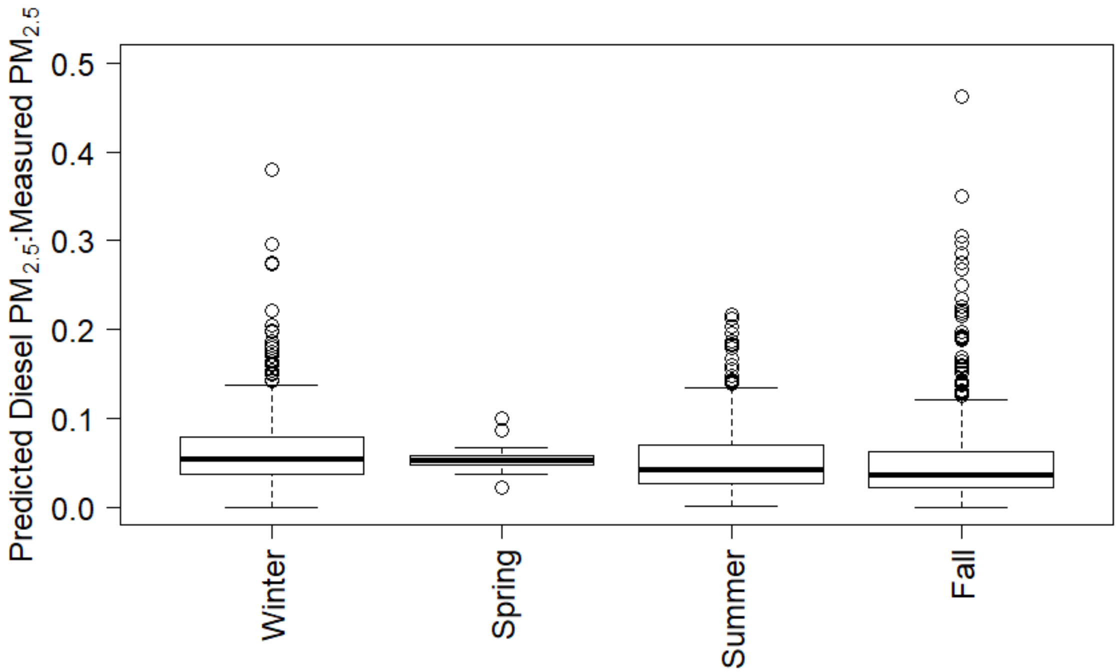


**Figure C22**. Seasonal boxplots of the ratio of predicted diesel $PM_{2.5}$ to measured $PM_{2.5}$

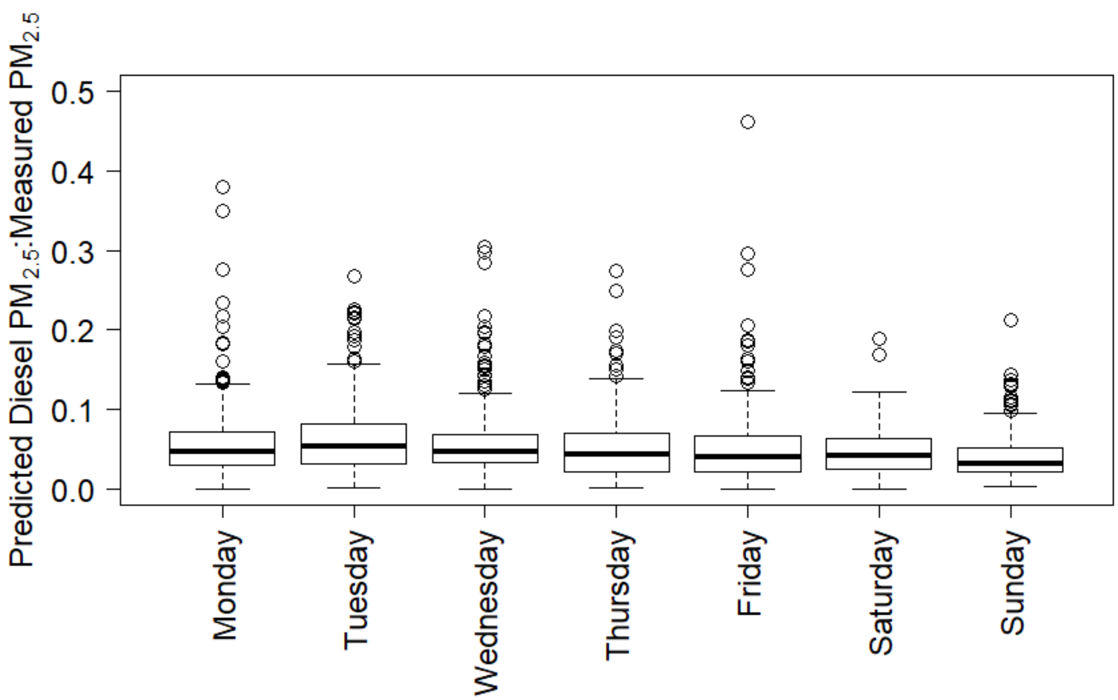


**Figure C23**. Day of week boxplots of the ratio of predicted diesel $PM_{2.5}$ to measured $PM_{2.5}$

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