2010 Washington State Ambient Air Monitoring Network Assessment

Washington State Department of Ecology

Air Quality Program

July 1, 2010

Publication no. 10-02-016

Publication and Contact Information

This report is available on the Department of Ecology's website at www.ecy.wa.gov/pubs/1002016.pdf .

For more information contact:

Air Quality Program
PO Box 47600
Olympia, WA 98504-7600
Phone: (360) 407-6800

Washington State Department of Ecology - www.ecy.wa.gov

Headquarters, Olympia	(360) 407-6000
Northwest Regional Office, Bellevue	(425) 649-7000
Southwest Regional Office, Olympia	(360) 407-6300
Central Regional Office, Yakima	(509) 575-2490
Eastern Regional Office, Spokane	(509) 329-3400

To ask about the availability of this document in a format for the visually impaired, call the Air Quality Program at (360) 407-6800. Persons with hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call 1-877-833-6341.

Table of Contents

Executive Summary

On October 17, 2006, the U.S. Environmental Protection Agency (EPA) amended its ambient air monitoring regulations. This amendment requires states to conduct detailed assessments of their air monitoring networks every five years. This document describes the Washington Department of Ecology's (Ecology's) 2010 Washington State Ambient Air Monitoring Network Assessment. This is the first assessment of the Washington network under the requirement.

Purpose of the Assessment

Ecology's policy goal is to ***characterize the health consequences of air pollution in Washington.*** Ecology evaluated the effectiveness and efficiency of the Washington State monitoring network in relation to this goal. Ecology's assessment provides decision-makers with information needed to maximize the effectiveness of Washington's ambient air monitoring network. The assessment also ensures Ecology and its partners have the information needed to protect human health and the environment for current and future generations in Washington.

The Washington State Network

Most of Washington's monitoring network is dedicated to characterizing the two pollutants that have been shown to pose the greatest risk to public health — Fine Particulate Matter ($PM_{2.5}$) and ozone. The remainder of the network is made up of monitors that measure Larger Particles (PM_{10}), Carbon Monoxide (CO), Sulfur Dioxide (SO_2), Reactive Oxides of Nitrogen (NO_Y), fine particle chemical composition, air toxics, and meteorological parameters.

As of December 31, 2009, Ecology and its partners operated a network of 137 monitors at 71 monitoring stations as part of Washington's official ambient air monitoring network. The data from these monitors serve a variety of needs. The data are used to:

- Determine if air quality is meeting federal standards
- Provide near-real-time air quality information for the protection of public health
- Forecast air quality
- Make daily burn decisions and curtailment calls
- Assist with permitting activities
- Evaluate the effectiveness of air pollution control programs
- Evaluate the effects of air pollution on public health
- Determine air quality trends
- Identify and develop responsible and cost-effective pollution control strategies
- Evaluate air quality models

Assessment

To relate the value of its monitoring activities to the policy goal, Ecology evaluated the state network on a pollutant-by-pollutant basis. Ecology generally conducted its assessment in accordance with EPA guidance, though other analyses and tools were also used.

Findings

- Overall, the Washington State network is efficient and effective at meeting the monitoring policy goal.
- Wholesale network changes are not needed.
- Several specific, targeted changes will improve overall network effectiveness.
- If resource savings are achieved through improvements in network efficiency, they should be reinvested to address monitoring gaps and high priority future monitoring requirements.

Recommendations

Retain:

Retain nearly all of the existing monitoring network.

Add:

Monitors:

- Install meteorological monitors at Colville in order to improve understanding of $PM_{2.5}$ levels.
- Move meteorological monitors from Burbank to Kennewick.

Activities:

- Establish temporary ozone monitor in NE Olympic Peninsula to assess accuracy of modeled hot spot.
- Encourage research opportunities to further understand elevated nitrate levels in the Columbia Basin.
- Prioritize and routinely update nephelometer-$PM_{2.5}$ correlations as needed in order to maintain data quality.
- As funding or resources are available, prioritize which new federal monitoring requirements will be implemented.

Replace:

Replace the $PM_{2.5}$ Federal Reference Method (FRM) monitors with continuous Federal Equivalence Method (FEMs) except at Seattle-Beacon Hill and Tacoma- L St which should retain FRMs in order to meet National Core Monitoring Station (NCore) and collocation requirements.

Remove:

Stations:

- Discontinue carbon monoxide stations in Bellevue and Spokane due to low values.
- Discontinue the continuous $PM_{2.5}$ station at Woodinville as it is redundant to Bellevue.
- Discontinue the Burbank station and relocate the meteorological monitors to nearby Kennewick station in order to achieve resource savings.
- Discontinue the ozone station at La Grande as it is redundant to other ozone monitors.

Monitors:

- Discontinue nephelometer and Aethalometer monitoring at Seattle-Beacon Hill as these monitors are redundant to other onsite monitors.
- Discontinue the continuous $PM_{2.5}$ monitor at Enumclaw due to low values.
- Discontinue the PM_{10} FRM monitor at Yakima due to low values.

Reinvest:

Any resource savings achieved by removing existing stations and monitors should be reinvested in order to address monitoring needs identified in this assessment.

Introduction

On October 17, 2006, EPA amended its ambient air monitoring regulations. This amendment requires states to conduct detailed assessments of their monitoring networks every five years. The purpose of the 5-year assessment is to evaluate the effectiveness and efficiency of monitoring networks in accordance with stated monitoring objectives and goals. The first 5-year assessment is due on July 1, 2010.

To meet the new requirement, Ecology assembled a team to assess and evaluate the Washington State ambient air quality monitoring network. The team is comprised of Ecology staff with expertise in the following areas:

- Monitoring
- Quality assurance
- Modeling
- Planning
- Smoke management
- Permitting

To the extent that it was practical and helpful, this assessment was conducted in general accordance with EPA guidance on monitoring network assessments. However, Ecology deviated from EPA guidance when more germane or robust analysis methodology was available.

This document is intended to provide decision makers with the information needed to maximize the effectiveness of Washington's ambient air monitoring network and serve as a guide for future network changes. In addition, the Recommendations section of this document identifies opportunities for overall improved network efficacy through specific, targeted reductions in monitoring activities as well as the identification of gaps in monitoring where new stations or monitors are needed. To the extent possible, any resource-savings achieved through these targeted monitoring reductions should be leveraged to address emergent monitoring needs such as the gaps in coverage identified in this document. EPA has identified new monitoring requirements for Nitrogen Oxides (NO_2) and may issue additional monitoring requirements resulting from its proposals dealing with the ozone, SO_2, and lead National Ambient Air Quality Standards (NAAQS). As funding or resources are available, Ecology will prioritize which new federal monitoring requirements will be implemented.

Ecology Policy Goal and Objectives

Ecology evaluated the effectiveness and efficiency of the Washington State monitoring network in accordance with its policy goal and objectives for ambient air monitoring. Ecology's policy goal and its objectives for air monitoring are as follows:

Goal: Characterize the Health Consequences of Air Pollution in Washington

Monitoring objectives:

- Collect only credible data that has the greatest opportunities to benefit public health
- Increase public understanding of the health effects and costs of air pollution in Washington
- Focus monitoring where the information is critical to protect or assess public health consequences of air pollution
- Select continuous method monitoring over filter-based monitoring methods
- Conserve limited financial and staff resources by using only one continuous method for each pollutant
- Continue FRM filter-based monitoring only at sites where projections show that future values will be higher than 60 percent of the NAAQS or will exceed Air Quality Program health goals and/or where exceedances have been seen in the last 2 years

The Washington State Network

As of December 31, 2009, the official Washington State ambient air monitoring network consisted of 137 monitors at 71 monitoring stations. The network is funded, operated, and maintained by a diverse group of entities with a vested interest in ensuring healthy air for present and future generations of Washingtonians. Partners in the Washington State network include Ecology, 7 local air agencies, 7 tribal nations, EPA, the U.S. Department of the Interior, National Park Service, and the U.S. Department of Agriculture, Forest Service. Table 1 shows the Washington network partners. It should be noted that there are other entities within Washington State that monitor ambient air quality. However, for reasons discussed in detail in the Analyses section of this document, only official Washington State network monitors were evaluated for the purpose of this assessment.

Table 1: Washington State Ambient Air Monitoring Network Partners

Washington State Ambient Air Monitoring Network Partners			
Local Clean Air Agencies	**Tribal Nations**	**Federal Agencies**	**State Agency**
Benton Clean Air Agency	Kalispel Tribe of Indians	Dept. of Agriculture Forest Service	Dept. of Ecology
Northwest Clean Air Agency	Makah Nation	Dept. of Interior Park Service	
Olympic Region Clean Air Agency	Puyallup Tribe of Indians	Environmental Protection Agency	
Puget Sound Clean Air Agency	Quinalt Indian Nation		
Southwest Clean Air Agency	Spokane Tribe of Indians		
Spokane Regional Clean Air Agency	The Chehalis Tribe		
Yakima Regional Clean Air Agency	Yakama Nation		

As stated previously, public health protection is the primary policy driver for the Washington State monitoring network. The network is therefore heavily weighted toward monitoring the pollutants that are known to pose the greatest threat to public health; $PM_{2.5}$ and ozone.

Ecology and its partners operate a variety of instruments as part of this network. The majority of monitors fall into two categories:

- ***Continuous monitors*** – “near-real-time” monitors that provide hourly or finer resolution data
- ***Daily filter-based samplers*** – samplers that run for 24-hours (midnight to midnight) on an EPA-defined schedule that varies from:
  - Every day (1/1)
  - Every third-day (1/3)
  - Every sixth-day (1/6)
  - Every twelfth-day (1/12)

Table 2 presents a breakdown of the Washington State monitoring network by monitored parameter as of December 31, 2009:

Table 2: Number of Monitoring Locations by Monitor Type

Monitored Parameter	Number of Monitoring Locations	Monitor Type [Continuous or Daily (frequencies vary)]
$PM_{2.5}$	56	56 continuous (8 of which also equipped with daily-FRM)
Ozone	12	Continuous (3 year-round and 9 seasonal stations)
Meteorological (PSD-Quality wind speed, wind direction, and ambient temperature)	11	Continuous
Chemical Speciation	5	Daily
PM_{10}	5	3 continuous + 2 daily-FRM
Nephelometer (without $PM_{2.5}$ correlation)	3	Continuous
CO	2	Continuous
Trace Gas (NO_Y, CO, SO_2)	2	Continuous
Air Toxics	1	Daily

The data from the Washington State monitoring network serves a variety of needs. Among other things, it is used to:

- Determine if air quality is meeting federal standards
- Provide near-real-time air quality information for the protection of public health
- Forecast air quality
- Make daily burn decisions and curtailment calls
- Assist with permitting activities
- Evaluate the effectiveness of air pollution control programs
- Evaluate the effects of air pollution on public health
- Determine air quality trends
- Identify and develop responsible and cost-effective pollution control strategies
- Evaluate air quality models

Climate, Topography, and Sources

The location of the state of Washington on the windward coast in mid-latitudes is such that the climatic elements combine to produce a predominantly marine-type climate west of the Cascade Mountains, while east of the Cascades, the climate possesses both continental and marine characteristics. Considering its northerly latitude, 46° to 49°, Washington's climate is mild (DRI, 2008).

There are several climatic controls which have a definite influence on the climate, namely; (a) terrain, (b) the Pacific Ocean, and (c) semi-permanent high and low pressure regions located over the North Pacific Ocean. The effects of these various controls combine to produce entirely different conditions within short distances.

The Cascade Mountains, 90 to 125 miles inland and 4,000 to 10,000 feet in elevation, are a topographic and climatic barrier separating the state into eastern and western Washington. The wet season begins in October, reaches a peak in winter, and then gradually decreases in the spring. High peaks in the Cascades are snowcapped throughout the year. The Columbia River, draining approximately 259,000 square miles in the Pacific Northwest and second only to the Mississippi River in volume flow, enters near the northeastern corner of the state and flows in a semi-circular pattern through eastern Washington. Before reaching the Pacific Ocean, it drains all of eastern Washington and the western slope of the Cascade Mountains between Mt. Rainier and the Oregon border.

Reservoirs on the windward slopes of the mountains provide an abundance of water for metropolitan areas, and hydroelectric projects have been developed along several rivers. Hydroelectricity supplies about two thirds of Washington's electricity requirements.

The mountainous areas over the entire state and a major portion of the lowlands west of the Cascades are covered by timber, ranging from large Douglas fir, spruce, hemlock and cedar, a dense undergrowth of fern and moss in the rainforest on the Olympic Peninsula, to open stands of Ponderosa pine in eastern Washington. Logging and other forest management practices are major activities in these areas.

The Washington State Department of Natural Resources regulates silvicultural burning, while Ecology and the local air agencies regulate agricultural and other outdoor burning.

Western Washington: West of the Cascade Mountains, summers are cool and comparatively dry and winters are mild, wet and cloudy. Snowfall is light in the lower elevations and heavy in the mountains in the interior valleys, measurable rainfall is recorded on 150 days each year and on 190 days in the mountains and along the coast. During July and August, the driest months, it is not unusual for two to four weeks to pass with only a few showers; however, in November and December, the wettest months, precipitation is frequently recorded on over 20 days each month.

The highest summer and lowest winter temperatures are usually recorded during periods of easterly winds. Agriculture is confined to the river valleys and well-drained areas in the lowlands.

Although the Cascade Range divides the state into two major climatic regions, there are several climatic areas within each of these regions.   Figure 1 presents a terrain map of Washington overlaid with climatic zones (based on annual rainfall received) and locations of most network monitors. Meteorological sites, CO, trace gas and air toxics sites are not shown, to prevent overcrowding. The salient zones 1-5 are described below.

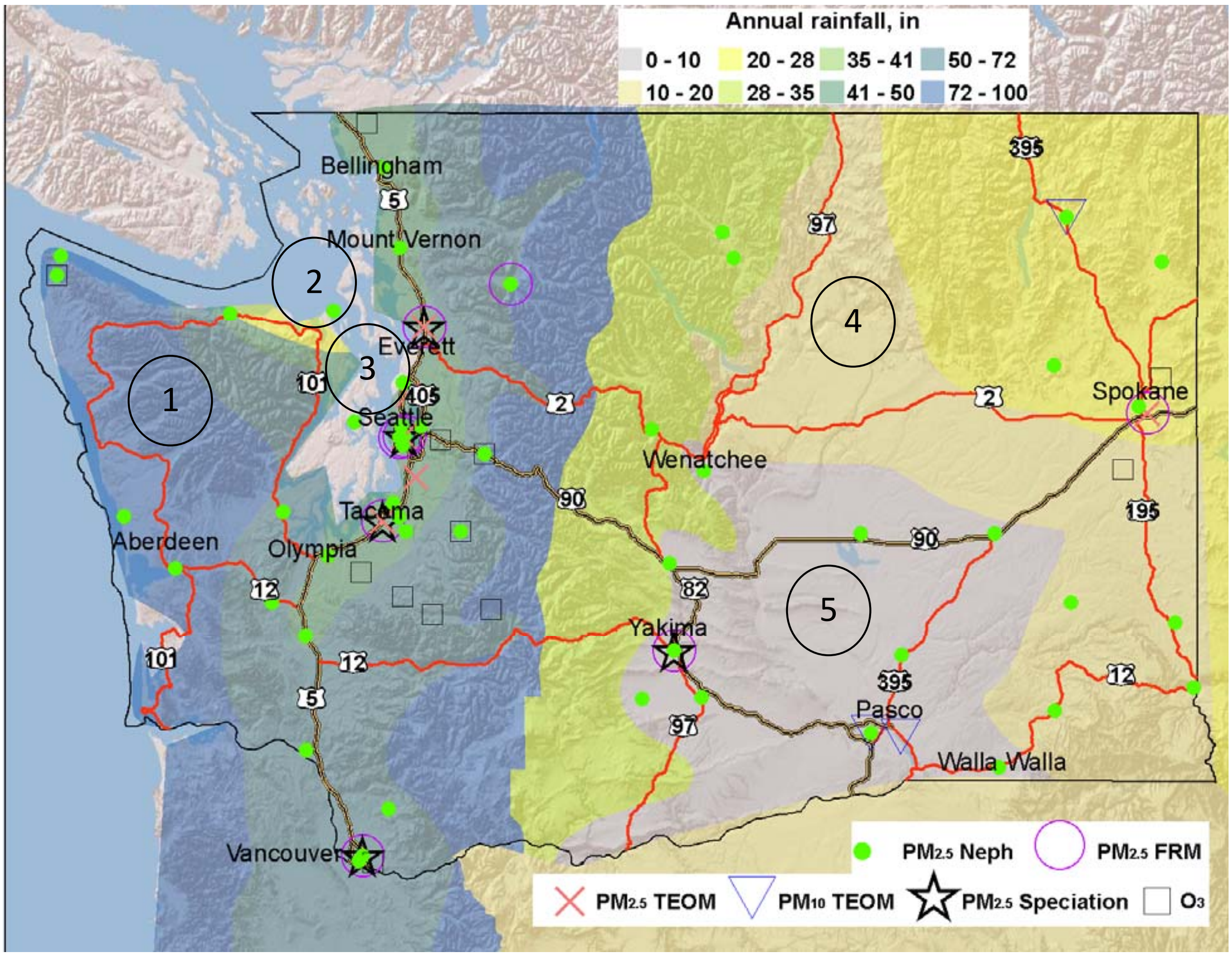

Figure 1: Washington State Climatic Zones and Network Monitors

(1) The West Olympic coastal area receives the full force of storms moving inland from over the ocean, thus heavy precipitation and winds of gale force occur frequently during the winter season. The "rainforest" area along the southwestern and western slopes of the Olympic Mountains receives the heaviest precipitation in the continental United States, with annual precipitation exceeding 150 inches along the windward slopes.

Air pollution sources in this sparsely populated area include a few industries, outdoor/ silvicultural burning and smoke from woodstoves and other home heating devices in some communities.

(2) The northeast Olympic- San Juan Islands area is shielded from winter storms moving inland from the ocean by the Olympic Mountains and the extension of the Coastal Range on Vancouver Island. This belt in the “rain shadow” of the Olympic Mountains is the driest area in western Washington. The coldest weather is usually associated with outflows of cold air from the interior of Canada.

The few air quality concerns in the area are mostly caused by smoke from woodstoves and other home heating devices in larger communities, outdoor burning and by some industrial facilities.

(3) The Puget Sound Lowlands includes a narrow strip of land along the west side of Puget Sound, extending southward from the Canadian border to the Centralia area. Variations in the temperature, length of the growing season, fog, rainfall and snowfall are due to such factors as distance from the Sound, the rolling terrain, and influx of air from the ocean through the Strait of Juan de Fuca and the Chehalis River valley. Most of this area is near the eastern edge of the rain shadow of the Olympic Mountains. The prevailing wind direction is south or southwest during the wet season and northwest in summer.

This is the most densely populated and industrialized area in the state. Vehicular, industrial, domestic, and marine sources (shipping, ferries) and both vessels and traffic at ports are among the main anthropogenic sources in the area. Summertime $PM_{2.5}$ concentrations are usually low due to sufficient atmospheric mixing, but $PM_{2.5}$ can be elevated under conditions of clear skies, light wind and a sharp temperature inversion during the home heating season (October - March) when woodstoves and other heating devices are typically used. Some sheltered valleys (such as Darrington, Kent and Duwamish) can experience a buildup of pollutants even when most other areas are moderately ventilated. Some areas with a high density of woodstove use (South Tacoma, Marysville, Lynnwood, Darrington, and Bremerton) frequently experience rapid rises of $PM_{2.5}$ levels in the home heating season, during periods of poor dispersion. Emissions of ozone precursors in industrial and populated areas can result in elevated ozone levels downwind on hot summer days characterized by low-to-moderate northerly/easterly winds.

Eastern Washington: This section of the state is part of the large inland basin between the Cascade and Rocky Mountains. East of the Cascades, summers are warmer, winters are colder and precipitation is less than in western Washington. The major agricultural areas are in eastern Washington.

During most of the year, the prevailing direction of the wind is from the southwest or west. The frequency of northeasterly winds is greatest in the fall and winter. Melting of the snow provides irrigation water for orchards and other agricultural areas in the Okanogan, Wenatchee, Methow, Yakima and Columbia River valleys. Dry land farming practices are generally followed in the small-grain growing areas.

(4) The Okanogan-Big Bend area includes fruit-producing valleys along the Okanogan, Methow and Columbia rivers, grazing land along the southern Okanogan highlands, the Waterville Plateau and part of the channeled scablands. Major air pollution sources are outdoor burning (year round, except during summer fire safety burn bans), agricultural burning (spring and fall burn seasons), orchard heaters, smudge pots, silvicultural burning and woodstove use. In rare instances, smoke from some burns may become entrained in evening downslope flow and settle in sheltered valleys (examples include Wenatchee, Twisp, Winthrop, Omak and Leavenworth). Smoke from any combination of these sources, if coupled with a strong temperature inversion and calm conditions often result in elevated $PM_{2.5}$ concentrations.

(5) The Central Basin includes the Ellensburg valley, the central plains area in the Columbia Basin south from the Waterville Plateau to the Oregon border and east to near the Palouse River. This is the lowest and driest section in eastern Washington.

Wheat and barley are the most widely grown crops in this area, while alfalfa, lentils and potatoes are also grown on a smaller scale. Agricultural and outdoor burns are the main $PM_{2.5}$ sources. Except for the Tri Cities, Ellensburg and Walla Walla, smoke from home heating devices and prescribed burning is not a major concern in this sparsely populated area. Tilling operations, windblown dust and re-suspended road dust sometimes give rise to elevated levels of PM_{10}.

Air Quality Monitoring in Washington State (Past and Present)

This section describes the evolution of air quality monitoring in Washington over the last several decades and provides background information that helps to explain the current network.

Carbon monoxide

CO sampling has been conducted in Washington since the 1960s. Though much of the very oldest data has not been electronically maintained, Figure 2 depicts the annual maximum 8-hour averages for representative areas throughout Washington. CO presented a major air quality problem throughout the 1970s and 1980s. In 1976 there were 33 CO monitoring stations, 28 of which measured values that exceeded the NAAQS (9.0 Parts Per Million (ppm)). That same year a single site in Seattle measured an 8-hour maximum value of 24 ppm and recorded 48 days that exceeded the NAAQS. In Spokane a single site measured an 8-hour maximum value of 35 ppm and recorded 118 days that exceeded NAAQS.

Since 1970, when the federal Clean Air Act first mandated motor vehicle emission controls, tailpipe emissions of CO, hydrocarbons and oxides of nitrogen have decreased. Motor vehicle emission inspection and repair programs also helped reduce tailpipe emissions. These reductions of CO emissions resulted in lower CO concentrations throughout the state. During the 1990s, older vehicles were being replaced by newer less-polluting ones. However, an increase in the number of automobiles and vehicle miles traveled caused concern that overall CO emissions, and thus ambient concentrations, would increase. For this reason, CO saturation studies were conducted in Spokane and throughout the Puget Sound area to determine if areas with higher CO concentrations were being missed by the monitoring network. As a result of these studies, CO stations were moved to locations where maximum CO concentrations were expected. Nevertheless, in contrast to concerns regarding CO concentrations, monitored values continued to decrease.

As air quality improved the CO monitoring network was downsized. Today, there are only two remaining CO stations (Bellevue-148th NE and Spokane-3rd St. S.). In 2009, the Bellevue-148th NE station measured a maximum 8-hour value of 2.9 ppm and the Spokane station 3.1 ppm.

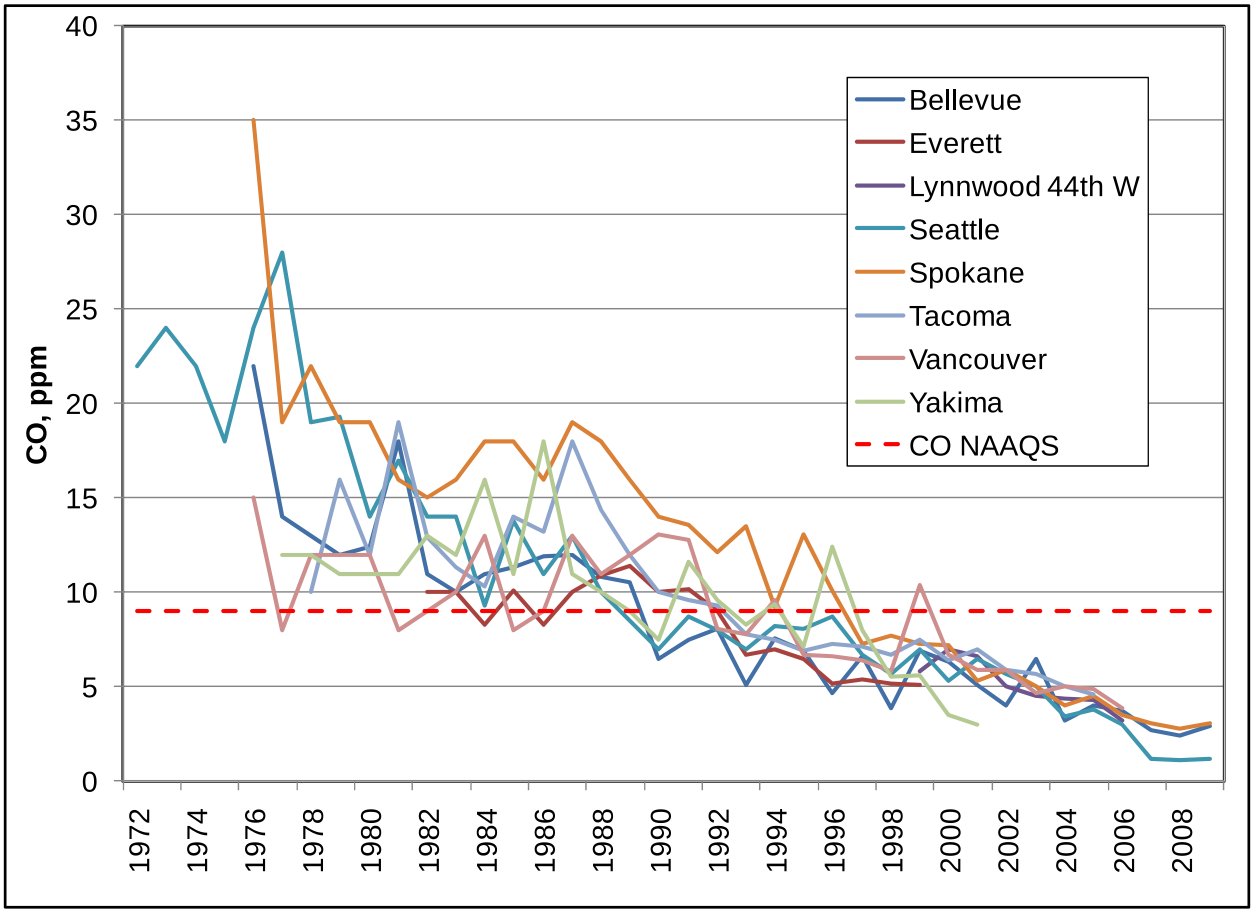

Figure 2: Annual Maximum CO 8-hour Average Concentrations

Nitrogen Dioxide

NO_2 sampling in Washington started in 1975. At first there were several stations in Seattle and one in Tulalip. The values from these initial stations were very low (< 3 ppb). Additional stations were established in the early 1980s and in 1981 the all-time maximum annual average value of 40.5 ppb was recorded at a station in Seattle. However, the NO_2 monitors in Washington State never exceeded the NAAQS and recorded relatively low concentrations. Due to this fact and the high cost of operation and maintenance, NO_2 monitoring was discontinued in 1987. NO_2 monitoring was re-established in 1995 at the Seattle-Beacon Hill (then a National Air Monitoring station, NAMS).

During the 1990s, several NO_2 studies were conducted to determine concentrations at potential hot spots and evaluate downwind photochemistry. The results from these studies revealed concentrations well below the NAAQS in effect at the time.

In 2007 the existing NO_2 monitor at Seattle-Beacon Hill was replaced with a high sensitivity sampler measuring reactive oxides of nitrogen (NO_Y = Nitric Oxide (NO) + NO_2 + other oxidized nitrogen species), as required by the station's present classification as a NCore station. Since Beacon Hill is located in an urban area, there is little time for freshly emitted Nitrogen Oxides (NO_x) to react with atmospheric oxidants and form other oxidized nitrogen species. Consequently, NO_Y minus NO is a good approximation of NO_2 at this location. NO_Y is also monitored at the Cheeka Peak station, which is a rural background site located in the northwestern-most corner of the state. As NO_x may be oxidized en route to this site, NO_Y minus NO represents the upper limit of NO_2. NO_2 levels at these two stations are well below the new NAAQS established on February 9, 2010.

Ozone

Ozone monitoring started in 1972 at a single station in Spokane. The ozone network was rapidly expanded to over 10 stations statewide. Stations in the Puget Sound and the Portland, OR/Vancouver, WA area violated the old one-hour average NAAQS of 120 ppb. As a result, EPA designated the Portland, OR/Vancouver, WA area nonattainment. After the 1990 Amendments to the Clean Air Act, EPA also designated the Puget Sound area nonattainment. Following successful control strategies and accompanying reductions in ozone concentrations, EPA designated the Puget Sound area attainment in 1996 and the Portland–Vancouver area to attainment in 1997.

Though ozone has been monitored at over 50 different stations throughout the state, many of these were exploratory in nature and only operated for a year or two. On average there have been about 10 to 12 ozone stations operating during the ozone season (May to September).

In an attempt to better understand the formation and the locations of maximum ozone concentrations, Ecology has conducted ongoing studies that measure and model ozone and its precursors NO and Volatile Organic Compounds (VOC). In 1996 hydrocarbons and carbonyls were sampled at nine locations throughout western Washington. In addition, NO were measured continuously at the Beacon Hill, Enumclaw, and Vancouver stations. NO were also measured with portable samplers at several stations in Thurston and Lewis counties. Ozone was also measured with passive samplers at 20 locations in major river drainages downwind from the Puget Sound metropolitan area. That same year Washington State University and the National Center for Atmospheric Research measured hydrocarbons and ozone aloft.

In 1997 EPA revised the ozone NAAQS from a 0.12 ppm 1-hour maximum to an 8-hour average concentration of 0.080 ppm. In 2008 the 8-hour average NAAQS was lowered to 0.075 ppm. Compliance is based on the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor. Washington is currently in attainment for ozone.

Between 2007 and 2009 portable ozone samplers were deployed to verify that the current monitoring stations represent maximum ozone impacts.

Figure 3 depicts the annual maximum 8-hour average ozone concentrations for stations with more than two years of data and the long-term linear trend line is based on the annual maximum 8-hour average ozone concentrations from ozone monitoring stations in the Enumclaw area. The trend line is flat. The Enumclaw stations have historically recorded the highest values in the ozone network.

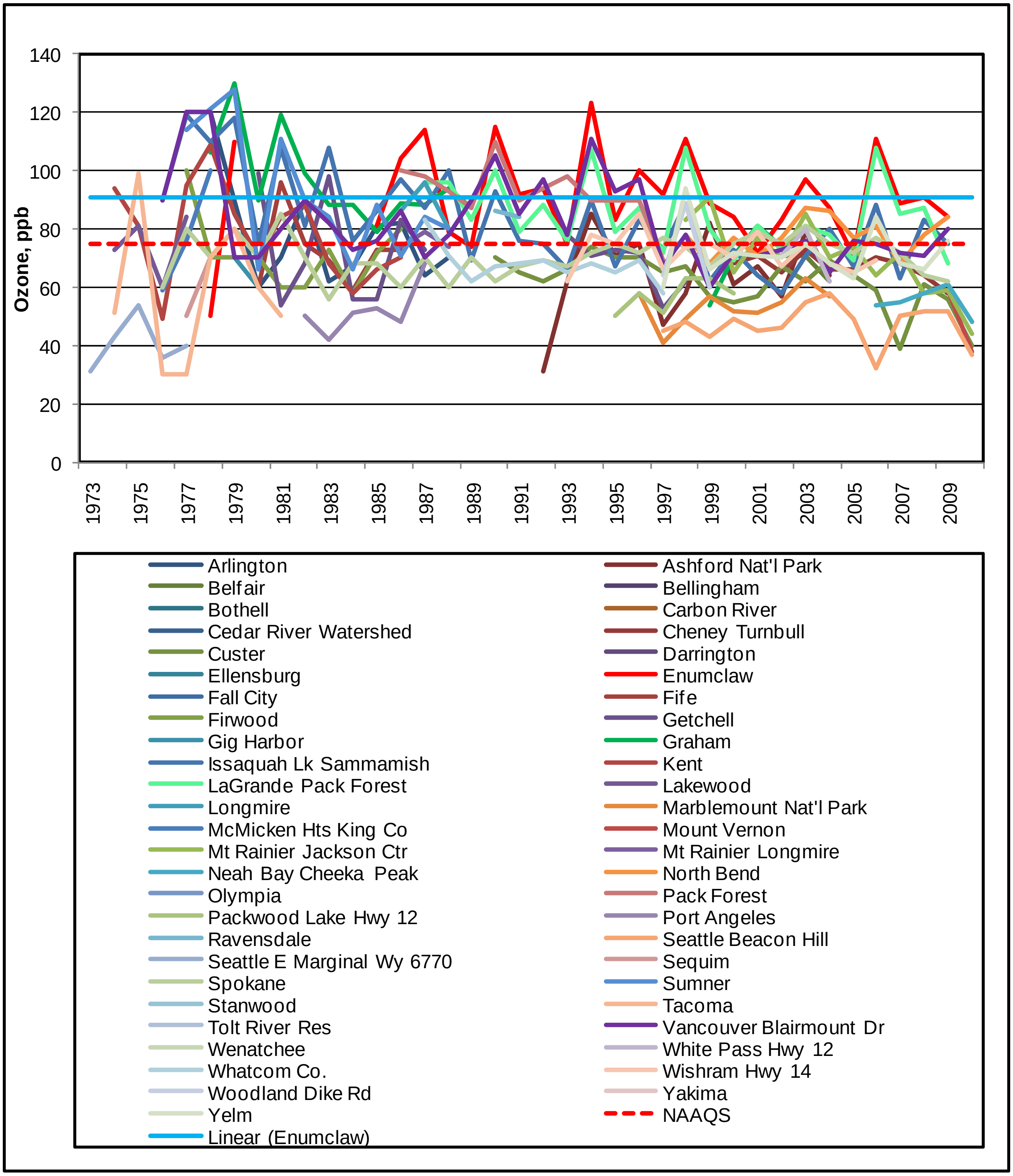

Figure 3: Annual Maximum 8-hour Average Ozone Concentrations

Sulfur Dioxide

By the early 1970s there were as many as 28 SO_2 monitoring stations located throughout the State. Most areas exceeded the State one-hour standard and several (Port Angeles, Tacoma, and Everett) occasionally exceeded the federal 3-hour secondary NAAQS. Figure 4 depicts the annual maximum one-hour SO_2 values for each of the historical and current monitoring areas.

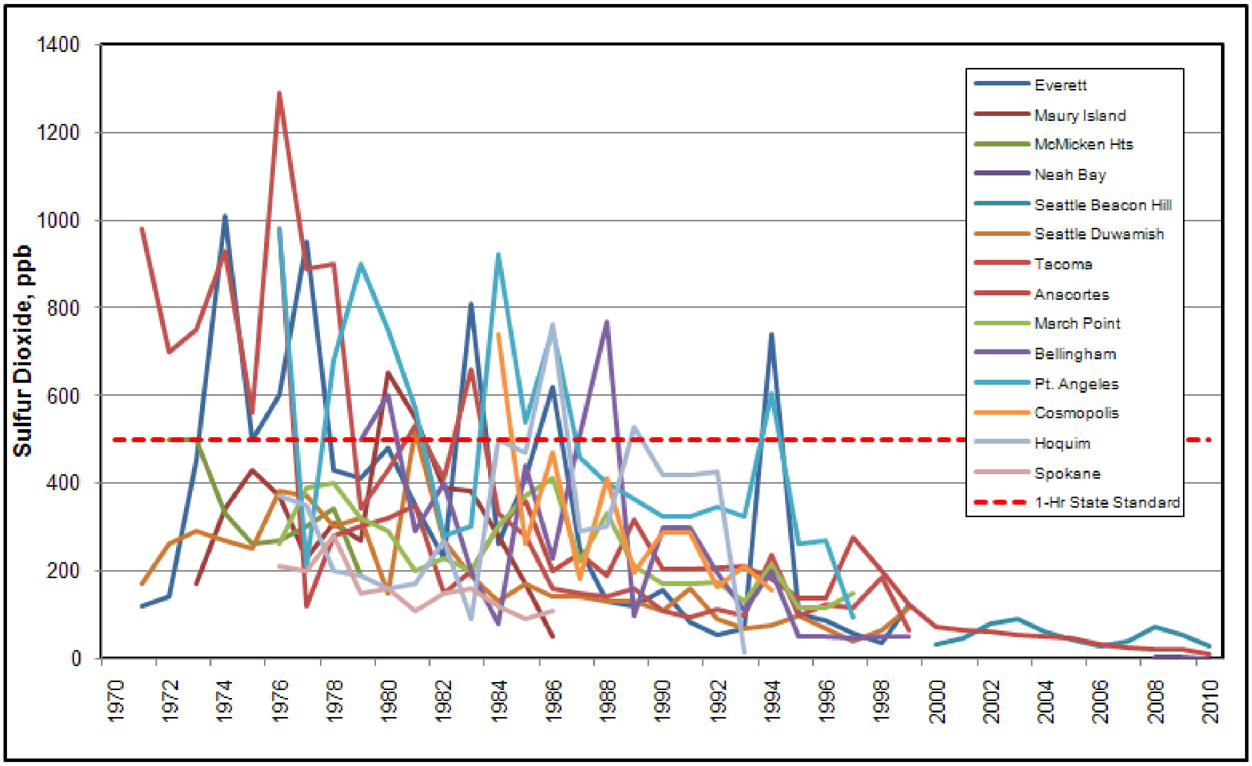

Figure 4: Annual Maximum 1-hour Average SO_2 Concentrations (ppb)

Figure 5 depicts the tons per year of SO_2 from the emission inventory. Reductions in the emission inventory are reflected by the measured ambient SO_2 concentrations. The emissions reductions were realized as; (a) source control measures were implemented, (b) many of the larger SO_2 sources shut-down, and (c) during the last decade gasoline and diesel fuel sulfur content was cut by nearly 90%.

As air quality improved and pollution levels dropped well below the NAAQS, SO_2 monitoring for compliance with the federal standards was discontinued. Currently, there are two trace-level SO_2 monitors in the Washington State network at the Seattle-Beacon Hill and Cheeka Peak stations. The Seattle-Beacon Hill NCore station measures values representative of the overall region and Cheeka Peak provides background and long-range transport data.

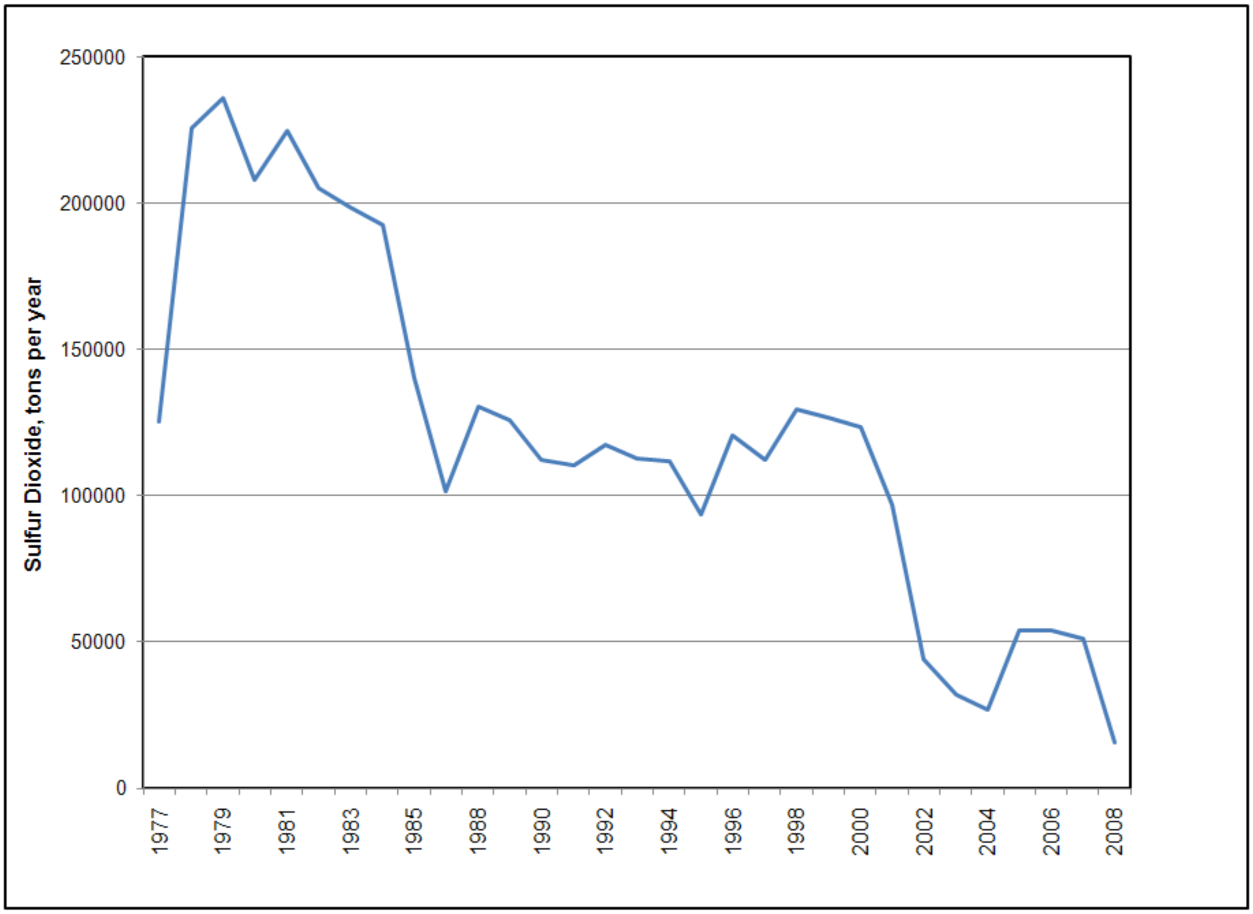

Figure 5: SO_2 Emissions (Tons Per Year)

Particulate Matter

Particulate Matter (PM) monitoring in the form of gross particle fallout and Total Suspended Particulate (TSP), PM with a nominal size of 25-to-45 µm) started in the 1960s. PM presented a considerable air quality problem. By 1971 the State had over 100 TSP sampling stations. Several of these exceeded the primary or the secondary NAAQS for TSP. The primary NAAQS standards were 75 $\mu g/m^3$ (annual average) and 260 $\mu g/m^3$ (24-hour average, not to be exceeded more than once a year). The secondary standard was 150 $\mu g/m^3$ (24-hour average, not to be exceeded more than once a year). Throughout the 1970s and 1980s the following areas were designated nonattainment for TSP:

- **Primary NAAQS:**
  - Annual Primary NAAQS
    - Tacoma Tide Flats
    - Seattle Duwamish industrial area (northern portion)
    - Spokane
  - 24-hour Primary NAAQS
    - Vancouver (small portions of the industrial port area)
- **Secondary NAAQS:**

- Seattle Duwamish (extending approximately 2½ miles south of the primary nonattainment area)
- Kent
- Renton
- Longview industrial area
- Clarkston

In the early 1980s, scientific research was emphasizing the adverse health effects of smaller particles. As a result, Ecology began PM_{10} sampling at 24 stations across the state in 1985. Many of the new PM_{10} monitoring stations exceeded the PM_{10} NAAQS (50 $\mu g/m^3$ for the annual arithmetic mean) and (150 $\mu g/m^3$ for the 24-hour average) when it was promulgated in 1987. EPA rescinded the TSP NAAQS in recognition of the new health based PM_{10} NAAQS, and TSP sampling was phased out by 1996.

Exceedances of the PM_{10} NAAQS at the time of enactment of the 1990 Amendments to the Clean Air Act resulted in nonattainment designations for Olympia–Lacey–Tumwater, Seattle, Kent, Tacoma, Yakima, Spokane, and Wallula. By 1993 PM_{10} was being measured at 40 locations. By 1994 air pollution control strategies, including programs to limit wood stove use, regulate outdoor burning, and better control industrial emissions, resulted in only three exceedances of the NAAQS.

Despite this downward trend, occasional elevated 24-hour PM_{10} values continue to be measured in the Colville, Spokane, Tri-Cities, and Yakima. Recent elevated values are primarily attributable to windblown dust natural events.

EPA revoked the annual PM_{10} standard in 2006 due to a lack of evidence linking PM_{10} to chronic health problems but retained the 24-hour standard to address acute health impacts. PM_{10} is still monitored at Burbank, Colville, Kennewick, Spokane, and Yakima. See the Analyses section of this document for a detailed discussion of the present PM_{10} network and analysis of the data.

Fine Particulate Matter

In 1997 EPA issued a new PM standard for particles with an aerodynamic diameter of 2.5 microns or less $PM_{2.5}$. The new $PM_{2.5}$ NAAQS were based on human population exposure and laboratory studies that demonstrated the harmful effects of finer particles. The 1997 standard limited $PM_{2.5}$ to 65 $\mu g/m^3$ averaged over 24 hours, and 15 $\mu g/m^3$ averaged annually. In 1999 $PM_{2.5}$ monitoring was implemented at 30 stations - all of which were eventually determined to be below the 1997 standards.

In 2006 EPA revised the 24-hour $PM_{2.5}$ NAAQS to 35 $\mu g/m^3$. This has resulted in one new nonattainment area for $PM_{2.5}$ (Wapato Hills-Puyallup River Valley). Two additional areas were near the revised 24-hour standard (Yakima, Vancouver) but were deemed unclassifiable. Currently there are 56 $PM_{2.5}$ monitoring stations.

As of 12/31/2009 Ecology and its partners operated an extensive $PM_{2.5}$ monitoring network. The network is comprised of 8 FRM and 56 continuous monitors at stations throughout Washington. The FRMs are filter-based instruments that provide a 24-hour sample while the continuous network provides hourly data. The continuous network represents Ecology's single largest ongoing resource investment for any pollutant and provides near-real-time data for a variety of users with a diverse array of data needs and applications. A primary driver for the use of the continuous monitors is public health protection through the use of the near-real-time data.

Lead

Lead monitoring began in 1979. Initially there were six lead monitoring stations in the Seattle/Tacoma area, and one in Spokane. Four stations in Seattle exceeded the NAAQS quarterly average of 1.5 µg/m^3. Over the years lead was monitored at 16 different locations. Lead remained a problem in the Seattle area through the mid-1980s. Due to the phase out of leaded gasoline and the regulation of industries that produced lead, concentrations dropped drastically. As lead concentrations decreased, the size of the lead monitoring network was reduced. By 1996 lead monitoring was being conducted only at one station in Seattle. The values from this last station were less than half the NAAQS. Consequently lead monitoring was discontinued in 1997 (see Figure 6).

Lead is currently monitored at the Seattle-Beacon Hill station as part of the National Air Toxics Trends Station (NATTS) and Chemical Speciation Network (CSN) programs. However, EPA's promulgation of a revised lead NAAQS in 2009 will require a FRM lead monitor at the Seattle-Beacon Hill Station in addition to the existing NATTS and CSN lead monitoring.

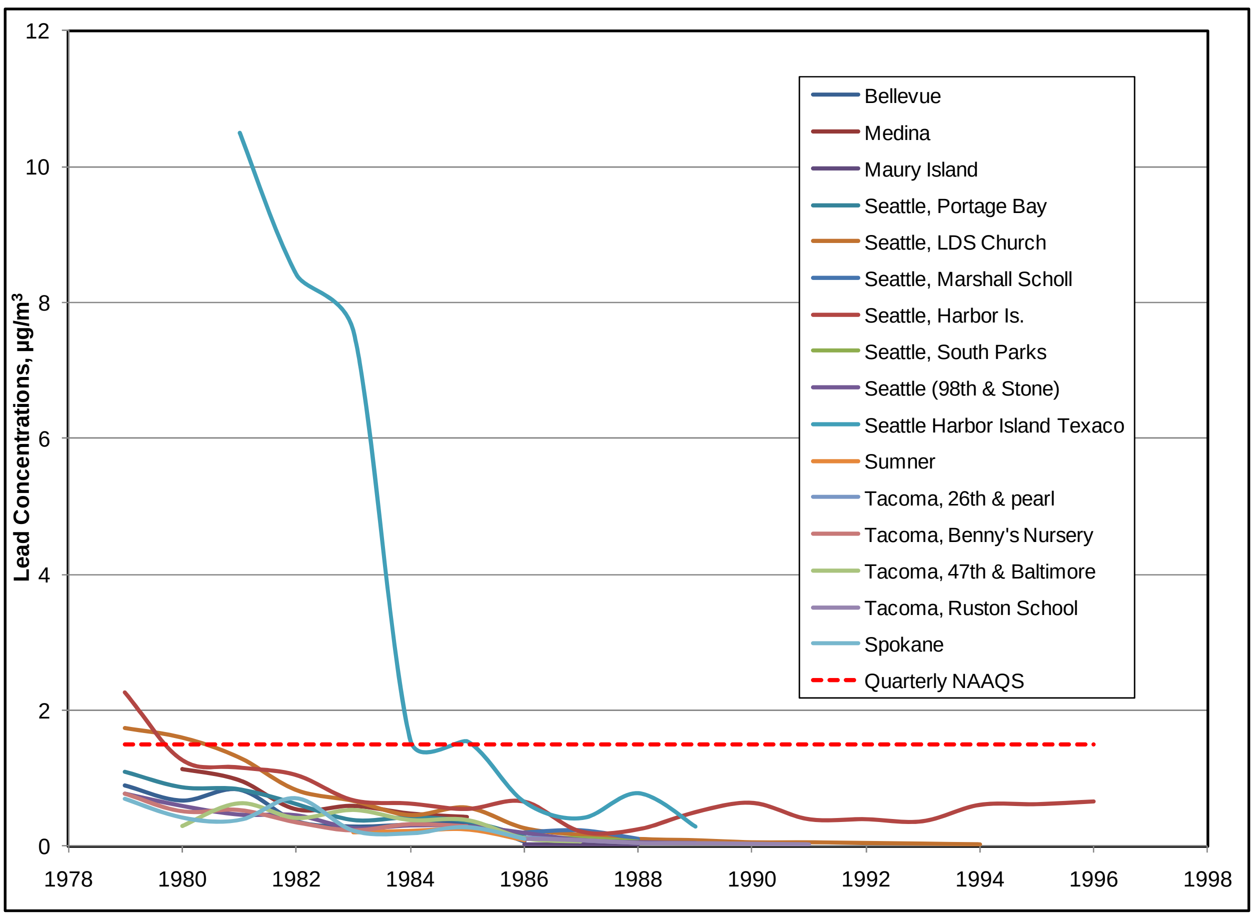

Figure 6: Quarterly Maximum Lead Concentrations

Chemical Speciation Network

The CSN is part of a national network that analyzes 24-hour integrated, filter-based $PM_{2.5}$ samples for several metals, Nitrate (NO_3^-), Sulfate (SO_4^{2-}), Elemental Carbon (EC) and Organic Carbon (OC). The main objectives of this network are to:

- Determine the chemical makeup of $PM_{2.5}$
- Understand which sources contribute to $PM_{2.5}$ at each site
- Determine the spatial and temporal differences of $PM_{2.5}$ composition between geographical areas
- Provide representative $PM_{2.5}$ speciation data to support exposure assessments (i.e. determine health risks)
- Provide data for source apportionment

There are currently five CSN stations in Washington State. They include one EPA-designated CSN monitoring station (Seattle-Beacon Hill) and four supplemental stations. Washington State CSN stations are shown in Table 3.

Table 3: $PM_{2.5}$ CSN sites in Washington State

Site	Estimated 2009 $PM_{2.5}$ FRM design value, µg/m^3	CSN sampling started
Seattle-Beacon Hill	18.5	February 9, 2000
Tacoma- L Street	45.7	January 11, 2006
Yakima- 4th Ave	37.2	November 8, 2007
Vancouver- 4th Plain Blvd	34.4	June 29, 2008
Marysville-7th Ave	33.8	April 7, 2009

Seattle-Beacon Hill operates on an every third-day (1/3) schedule. In addition to the filter-based sampler, an automated semi-continuous organic and elemental carbon sampler is also operated at this station. The four supplemental stations run on an every sixth-day (1/6) schedule.

Historical Speciation Stations – Supplemental speciation was previously conducted on a 1/6 schedule at the following stations:

- **Seattle-Georgetown –** From 4/30/2000 to 10/29/2004
- **Lake Forest Park-Town Center –** From 10/15/2001 to 12/18/2005
- **Seattle-Maple Leaf Reservoir –** From 8/11/2001 to 12/28/2002
- **Seattle-Olive St. –** From 1/2**/**2003 to 9/9/2007
- **Seattle-Duwamish** – From 6/1/2002 to 12/26/2007
- **Spokane**-Ferry St. **–** From 1/6/2005 to 1/1/2009

Several source apportionment studies have been conducted with CSN data from historical and current sites (Wu et al., 2006; Hopke et al., 2006; Naeher et al., 2007; Kim and Hopke, 2008; WA Dept of Ecology, 2010).

Air Toxics Monitoring

As part of the National Air Toxics Monitoring Pilot Program, Ecology received an EPA grant to conduct an extensive air toxics study in the Seattle area. Air toxics sampling for VOCs, carbonyls, metals, Polycyclic Aromatic Hydrocarbons (PAH), and Semi Volatile Organic Compounds (SVOCs) was conducted at six sites between 2000 and 2002. The study successfully characterized ambient air toxics concentrations, and the results were used to evaluate modeling results, and determine health risks in the Seattle area.

After the Pilot Study the Seattle-Beacon Hill station became a NATTS. The primary purpose of the NATTS network is to track trends in ambient air toxics levels to facilitate measuring progress toward emission and risk reduction goals. Long term goals of NATTS sampling include assessing the effectiveness of emission reduction activities and evaluating and subsequently improving air toxics emission inventories and model performance. The NATTS program provides for long-term sampling of VOC, carbonyl, PM10 metals, hexavalent chromium, PAH, and SVOC at the Beacon Hill NATTS.

Air toxics have been sampled at the Seattle-Beacon Hill station since 1/13/2000.

In 2005, Ecology, in cooperation with the Spokane Regional Clean Air Agency, received a grant and conducted an Air Toxics Community Assessment in Spokane, Washington. The study successfully characterized ambient air toxics concentrations and their spatial and temporal patterns, determined base-line air toxics concentrations, evaluated local area modeling results, and determined health risks from exposure to the sampled air toxics.

Aethalometer Monitoring

Ecology currently operates an Aethalometer at the Seattle-Beacon Hill station. This instrument was once a part of the NATTS network suite of monitors and provides a proximate measure of elemental carbon concentrations. However a separate onsite continuous analyzer makes direct measurements of both elemental and organic carbon. As the Aethalometer is no longer required for NATTS purposes and is somewhat duplicative of the continuous elemental carbon monitor, Ecology expects to discontinue Aethalometer monitoring at Seattle-Beacon Hill.

There is an additional Aethalometer at the Spokane-Augusta Ave station that is operated by the Spokane Region Clean Air Agency. While there is no collocated continuous elemental and organic carbon analyzer at the station, Ecology is consulting with the agency to determine whether there is sufficient interest in the data to warrant continued operation of the Aethalometer.

Meteorological

Ecology and its partners currently operate a network of eleven Prevention of Significant Deterioration (PSD) - quality meteorological stations equipped with a wind vane and anemometer. These stations serve permitting, air quality forecasting and burn management program needs. They are located as follows:

Table 4: Network Meteorological Stations

Station name	Date established
Seattle-Beacon Hill	1/1/1990
Tacoma-Tower Dr	9/25/1991
North Bend-North Bend Way	1/11/2000
Enumclaw-Mud Mtn.	2/1/2004
Burbank-Maple St	6/1/2004
Cheeka Peak	7/25/2006
Vancouver-Blairmont Dr	12/20/2007
Toppenish	6/9/2009
Spokane-Augusta Ave	7/14/2009*
Oakville	10/16/2009
White Swan	11/10/2009

***Initially operated at Ferry St. ~1 mile away, from 8/1/2001 to 3/24/2009**

Temporary Monitors

Temporary monitors can provide a cost-effective supplement or alternative to more permanent monitoring stations. They allow for relatively quick response to emergent air quality issues such as monitoring smoke from wildfires or monitoring in areas with persistent public air quality complaints. They also represent a less-costly approach to characterizing air quality in air sheds where air quality is unknown.

Ecology employs two types of temporary monitors for these purposes:

- Mobile monitors - trailers equipped with nephelometers
- Portable monitors - no shelter (monitors must be transported and housed)

Ecology currently uses these monitors for $PM_{2.5}$ and ozone monitoring throughout the state.

Mobile Monitors

Ecology has three mobile monitors that are used primarily to characterize air quality in air sheds where air quality is unknown, but air pollution problems are suspected based on complaints and other information. Each mobile monitor consists of a nephelometer housed in a trailer that can be hitched to a vehicle. They are therefore relatively quickly and easily deployed and are generally used for short-term monitoring. Although nephelometers do not report absolute $PM_{2.5}$ concentrations, they do report Measurements of Light Backscatter (bscat), a measure of light-scattering by fine particles. For particles with similar optical properties, the amount of scattering is proportional to the particle concentration. Analysis of bscat data from the mobile monitors may therefore be used as a qualitative indicator of possible $PM_{2.5}$ problems, and help track day-to-day trends.

Among the many areas to which mobile monitors have been deployed, Omak, a rural community in the Okanogan River valley in north central Washington, consistently recorded high bscat readings over two successive home heating seasons. High woodstove use and outdoor burning are the likely causes. Data collected with the mobile monitor was instrumental in motivating authorities from the Confederated Tribes of the Colville Reservation, in collaboration with EPA, to establish a permanent $PM_{2.5}$ monitor with co-located meteorological measurements in Omak. These data will help Ecology's air quality forecasting and burn management program efforts to protect public health in the area.

Portable Monitors

Ecology currently has two portable, non-Federal Reference Method (non-FRM), Environmentally-Protected Beta Attenuation Monitors (EBAMs). These monitors are used to investigate smoke complaints, verify modeled hot spots, monitor smoke from wildfires or other fires, and identify additional monitoring needs throughout the state.

In addition, Ecology has two portable FEM ozone monitors. These monitors are used to verify modeled hot spots, track ozone plumes, verify that the current ozone network is adequate and sited properly, and better understand ozone transport issues.

Air Monitoring – The Next Five Years

Proposed and Final Rules Affecting Ambient Monitoring

The current monitoring network assessment reviews ambient air quality monitoring in Washington as of the end of 2009. Accordingly, the assessment reflects the current focus on particulate matter and ozone.

EPA is taking or has taken actions that will impact ambient air quality monitoring in Washington—and the rest of the country—over the next five years. Completed and proposed regulatory actions are as follows:

- Proposed revisions to lead ambient air monitoring requirements (U. S. EPA, 2009b)
- Proposed revisions to the ambient ozone monitoring network design requirements (U. S. EPA, 2009a)
- Monitoring requirements for the Primary NAAQS for SO_2 (U. S. EPA, 2010c)
- Monitoring requirements for the Primary NAAQS for NO_2 (U. S. EPA, 2010b)

All of these rules, proposed and final, specify a time frame for addressing monitoring requirements in the annual monitoring network plan and for the deployment of the monitors. The remainder of this section provides more information on the requirements with the caveat that proposed monitoring requirements are not adopted monitoring requirements and EPA can revise them before adoption of final rules. The section is organized chronologically by date of the impacted annual monitoring network plan.

Spring 2011 Update to the 2010 Annual Monitoring Network Plan. The proposed revisions to the lead ambient air monitoring requirements require an update to the state's annual monitoring network plan six months after the effective date of the final rule. EPA expects to adopt the revised lead monitoring requirements in Fall 2010. Since the annual monitoring network plan is submitted in July, Washington will need to prepare an update to the 2010 plan in Spring 2011 to address revised lead monitoring requirements.

The major proposed revisions to lead monitoring are:

- The reduction of the emission threshold for required monitoring of lead sources from 1.0 ton or more of lead per year to 0.50 ton or more per year.
- Treatment of airports as sources of lead due to the use of lead in general aviation fuel. The NAAQS for lead; Final Rule required installation of monitors at sources of lead emitting 1.0 ton per year or more by January 1, 2010 (U. S. EPA, 2008b).

While both the 2002 and 2005 inventories indicated that Washington had two qualifying airports, the preliminary 2008 NEI indicates four airports at or above the 0.50 ton per year threshold. The discrepancy is being investigated.

The proposed rule requires deployment of the monitors one year after the rule is finalized. Under EPA's expected timeline this would be Fall 2011.

July 1, 2011 Annual Monitoring Network Plan. Under the proposed rules, Washington will be required to address revised ozone monitoring requirements and monitoring for compliance with the primary sulfur dioxide NAAQS in the 2011 monitoring network plan.

Ozone:

EPA proposed the following revisions to ozone network design in 2009:

- Monitoring in metropolitan statistical areas without current minimum monitoring requirements, i.e., those with populations over 50,000 and under 350,000
- Three non-urban monitors, each of which would address at least one of three following monitoring goals:
    - Monitoring of ozone-sensitive vegetation and ecosystems
    - Monitoring in micropolitan areas (counties with a core city or town and a population of 10,000 to 49,999) with expected ozone concentrations within 85% of the standard
    - Monitoring in areas affected by transport
- For Washington, revision of the required ozone monitoring season to March through September from May through September

The proposed rule calls for stations to be operational by January 1, 2012, or the first day of the required ozone season in 2012. This is currently May 1, 2012 but would be March 1, 2012 if EPA finalizes the proposed revision to Washington's monitoring season.

Ecology had a number of issues with this proposal. First, the analysis of the state's ozone network presented in this assessment indicates good coverage of areas of elevated ozone levels that would not benefit by placing monitors in smaller metropolitan areas. Second, the revision to the ozone season is not justified. Elevated ozone levels in Washington are highly dependent on temperature and meteorological conditions and the historical record indicate exceedances, even of a 0.060 ppm standard, are not expected in March and April. Third, the proposed revisions to the ozone network are costly whether considered alone or in concert with other recent and forthcoming NAAQS monitoring requirements.

Ecology's comments on the proposed non-urban monitors were more specific. EPA proposed that each state operate at least 3 monitors that address the following monitoring objectives: (1) ozone exposure of ozone-sensitive vegetation and ecosystems, (2) non-urban areas affected by ozone transport, (3) smaller population centers (10,000-50,000) with ozone concentrations at least 85% of the 0.075 ppm NAAQS. Ecology could most easily meet the measurement of ozone concentrations in ozone-sensitive vegetation and ecosystems. Non-urban monitors could also be sited in areas affected by transport if monitors are allowed in micropolitan areas (the proposal is not clear about this). It is not possible to identify a micropolitan area with ozone concentrations near the standard unless monitoring data are available first because of the small populations of these areas.

EPA has committed to finalizing the ozone network rule when it completes the reconsideration of the ozone standard (U.S. EPA, 2010a). EPA has committed to finalization of the ozone standard reconsideration by August 31, 2010.

SO_2:

EPA signed a final rule on June 2, 2010 that strengthened the public health protection of the SO_2 NAAQS, especially for children, the elderly, and people with asthma. The rule establishes a 1-hour NAAQS of 75 ppb. EPA is revoking the existing 24-hour standard of 140 ppb and the existing annual standard of 30 ppb because they do not add additional public health protection to the new 1-hour standard.

EPA has revised the monitoring requirements for SO_2. The number of required monitors is based on a population-weighted index that reflects population and total SO_s emissions in a metropolitan area. The end result for Washington is the requirement for one monitor in the Seattle-Tacoma-Bellevue, WA Metropolitan Statistical Area (MSA). The monitor is to be deployed by January 1, 2013.

July 1, 2012 Annual Monitoring Network Plan. The primary NO_2 NAAQS adopted in January 2010 calls for a two-tier monitoring network structure. The first tier specifies roadway monitoring. One monitor is required in any metropolitan statistical area with a population of or greater than 500,000. A second monitor is required if the population is at or exceeds 2,500,000.

The second tier requires area-wide monitoring in any metropolitan statistical area with 1,000,000 or more people.

The final rule requires monitors to be deployed by January 1, 2013.

Ongoing National Ambient Air Quality Standards Reviews

Three NAAQS reviews scheduled to be completed in 2011 and 2012 may result in new or revised ambient monitoring requirements.

- EPA is under court order (Communities for a Better Environment, et al. v. EPA) to propose a revised CO NAAQS by October 28, 2010 and finalize the standard by May 13, 2011.

  The low ambient levels being measured by the existing CO monitoring network have raised questions about the usefulness of the network for estimating exposure. Consideration is being given to the possible use of trace level CO methods for monitoring today's low ambient levels and to the possibility of roadway monitoring.

- EPA established an expedited timeline for the PM NAAQS review. EPA plans to propose revised PM standards in February 2011 and final standards in October 2011.

  EPA's review focuses on both $PM_{2.5}$ and Coarse Particulate Matter ($PM_{10-2.5}$). PM_{10}-related evidence is being used to provide a context for understanding health and welfare impacts of fine and coarse particles.

  The current review is finding a stronger causal link between $PM_{2.5}$ and health effects than the previous standards review in 2006. EPA's preliminary conclusion is the available information clearly calls the adequacy of current $PM_{2.5}$ standards into question. It also provides strong support for considering revisions to the current standards to increase public health protection.

  In previous reviews, EPA has concluded that while protection is warranted against potential effects associated $PM_{10-2.5}$ particles, important uncertainties remain about associations with mortality and morbidity. EPA's preliminary conclusion is that the available evidence could support either revising the current PM_{10} standard to increase public health protection against exposures to $PM_{10-2.5}$ or retaining the current PM_{10} standard depending on the emphasis placed on different aspects of the evidence and associated uncertainties.

  EPA is considering a secondary (or welfare) $PM_{2.5}$ standard for urban visibility. EPA has consulted with the Clean Air Scientific Advisory Committee's monitoring subcommittee about measuring light extinction.

- EPA is under court order (Center for Biological Diversity, et al. v. EPA) to propose revised secondary standards for both NO_2 and SO_2 by July 12, 2011 and to finalize these standards by March 20, 2012.

  While primary standards protect public health, secondary standards protect welfare. The welfare impacts being examined by EPA are the acidification of lakes, streams, and other aquatic environments and the nutrient enrichment of terrestrial ecosystems by nitrogen deposition. EPA is considering monitoring total reactive NO_Y and $PM_{2.5}$ sulfate to judge compliance.

Analyses

Ecology evaluated the Washington monitoring network in accordance with Ecology's policy goal and objectives. The two pollutants of greatest concern for threats to public health in Washington are $PM_{2.5}$ and ozone. For this reason, $PM_{2.5}$ and ozone comprise the majority of monitoring activities in Washington State and Ecology's assessment focuses primarily on these pollutants.

In general, Ecology conducted its assessment in accordance with EPA guidance but other analyses and tools were also used. Specifically, decision matrices were used to evaluate the $PM_{2.5}$ and ozone networks. Decision matrices are designed to create a single ranking for stations based upon disparate analyses. Detailed descriptions of the decision matrix analyses for $PM_{2.5}$ and ozone are included in the appendices of this document. Decision matrices and spatial patterns were constructed only to evaluate the $PM_{2.5}$ and ozone networks, as other networks are much smaller and relative importance between monitors is more readily identifiable. Ecology also performed removal bias analyses on its $PM_{2.5}$ and ozone networks.

It should be noted that the topography, meteorology and emissions in Washington, particularly Western Washington, are quite heterogeneous as compared to other areas of the country, such as the Midwest. For this reason, the guidance and tools provided by EPA for identifying redundancies in monitoring were not particularly useful for Washington State. Specifically, cross-comparing stations as suggested by EPA, and calculating correlation matrices was of little utility as many stations with high R^2 values nevertheless represented unique air sheds, including those within the same metropolitan statistical areas.

Therefore, Ecology examined a variety of factors for monitors that were believed to be in the same air shed to determine whether redundant information was being collected. Ecology looked at how well trends tracked each other as well as the magnitude of those trends in a variety of ways. Sites with $R^2 > 0.7$ from the EPA correlation matrices were also examined this way, even though many such site pairs were clearly located in separate air sheds.

Scope of Analysis

Ecology decided to limit its analysis to the official Washington State network monitors for the following reasons:

- It is unknown whether non-network monitors are operated and maintained in accordance with established Ecology data quality requirements for quality control and quality assurance.
- Ecology has little control over the decision making processes regarding the siting, establishment, operation, relocation or removal of non-network monitors.
- While resource-savings could be achieved by leveraging non-network monitors (i.e., turning off Ecology monitors in air sheds where a non-network monitor provides similar information), non-network monitors may be discontinued without input from Ecology and its partners. This situation could leave data users without potentially important information.

It should be noted that non-network monitors often provide useful data for users in areas where Ecology does not monitor. Some non-network monitor data were used to inform Ecology's analysis of spatial pollution patterns, removal bias analysis, and identification of potential gaps in monitoring.

Fine Particulate Matter

Washington's $PM_{2.5}$ problems are primarily in relation to the 24-hour NAAQS. Washington's $PM_{2.5}$ pollution episodes are relatively short in duration and are most often associated with wintertime stagnation events. Unlike other areas of the country, secondary $PM_{2.5}$ formation during summertime, either from smog episodes or SO_2 oxidation, does not cause concern. Depending on the area, $PM_{2.5}$ pollution in Washington comes mainly from smoke associated with home heating devices, and agricultural field stubble and outdoor (non-agricultural) burning. Transportation and other mobile (on- and off-road) sources are also contributors but much less than smoke in its various incarnations. Because there is a great amount of epidemiologic data associating $PM_{2.5}$ with adverse health effects, Ecology has made reducing the health threats associated with $PM_{2.5}$ a priority and has invested heavily in $PM_{2.5}$ monitoring.

In general, $PM_{2.5}$ values are highest during the home heating season (October through March) and drop off markedly during the warmer months. However, high $PM_{2.5}$ values occasionally occur at other times of year, particularly east of the Cascade Mountains, during wildfires or agricultural field stubble burning.

Federal Reference Method Fine Particulate Matter

Ecology and its partners currently operate a network of 8 FRM $PM_{2.5}$ monitors as listed in Table 5 below. Table 5 presents estimated design values based on 2007-2009 monitoring data.

Table 5: FRM $PM_{2.5}$ Network Stations and Estimated 2009 Design Values

Station Name	Sampling Frequency	Estimated 2007-2009 24-hour Design Value
Tacoma-L Street	1/3	45.7
Yakima-4th Ave	1/3	37.3
Marysville-7th Ave	1/1	33.8
Vancouver-Fourth Plain Rd	1/1	34.4*
Darrington-Fir St	1/3	38.1
Spokane-Augusta Ave (combined with Ferry St)	1/3	27.3
Seattle-Duwamish	1/3	25.8
Seattle-Beacon Hill	1/3	18.5

***incomplete data**

In 2009, EPA made $PM_{2.5}$ attainment/nonattainment designations for the 2006 revised 24-hour standard. These designations were based on the 2006-2008 monitoring data. The Tacoma-L Street monitor violated the 24-hour standard based on 2006-2008 data. As a result, the surrounding area known as the Wapato Hills-Puyallup River Valley was designated as being in nonattainment for the 24-hour standard in 2009. It is the only $PM_{2.5}$ nonattainment area in Washington State. Two additional areas that were near the 24-hour standard at the time – Yakima and Vancouver- were deemed unclassifiable for the revised 24-hour standard on account of incomplete data.

As can be seen in Table 5, the Washington FRM $PM_{2.5}$ network consists mainly of monitors that are near the 24-hour standard, the exceptions being Seattle-Beacon Hill and Duwamish, and Spokane-Augusta Ave. The Seattle-Beacon Hill monitor is located at an NCORE station and is part of the suite of monitoring required at NCORE stations. The Spokane-Augusta Ave (formerly Ferry St.) design value is very close to 80% of the 24-hour NAAQS, and could possibly be discontinued in favor of a continuous FEM Tampered Elemental Oscillating Microbalances (TEOM), after the performance of such a monitor in Eastern Washington is evaluated. The Duwamish monitor was discontinued at the end of 2009 in favor of a continuous FEM TEOM.

As can be seen in Figure 7, all of Washington's FRM $PM_{2.5}$ monitors are in compliance with the annual $PM_{2.5}$ NAAQS of 15 μg/m^3.

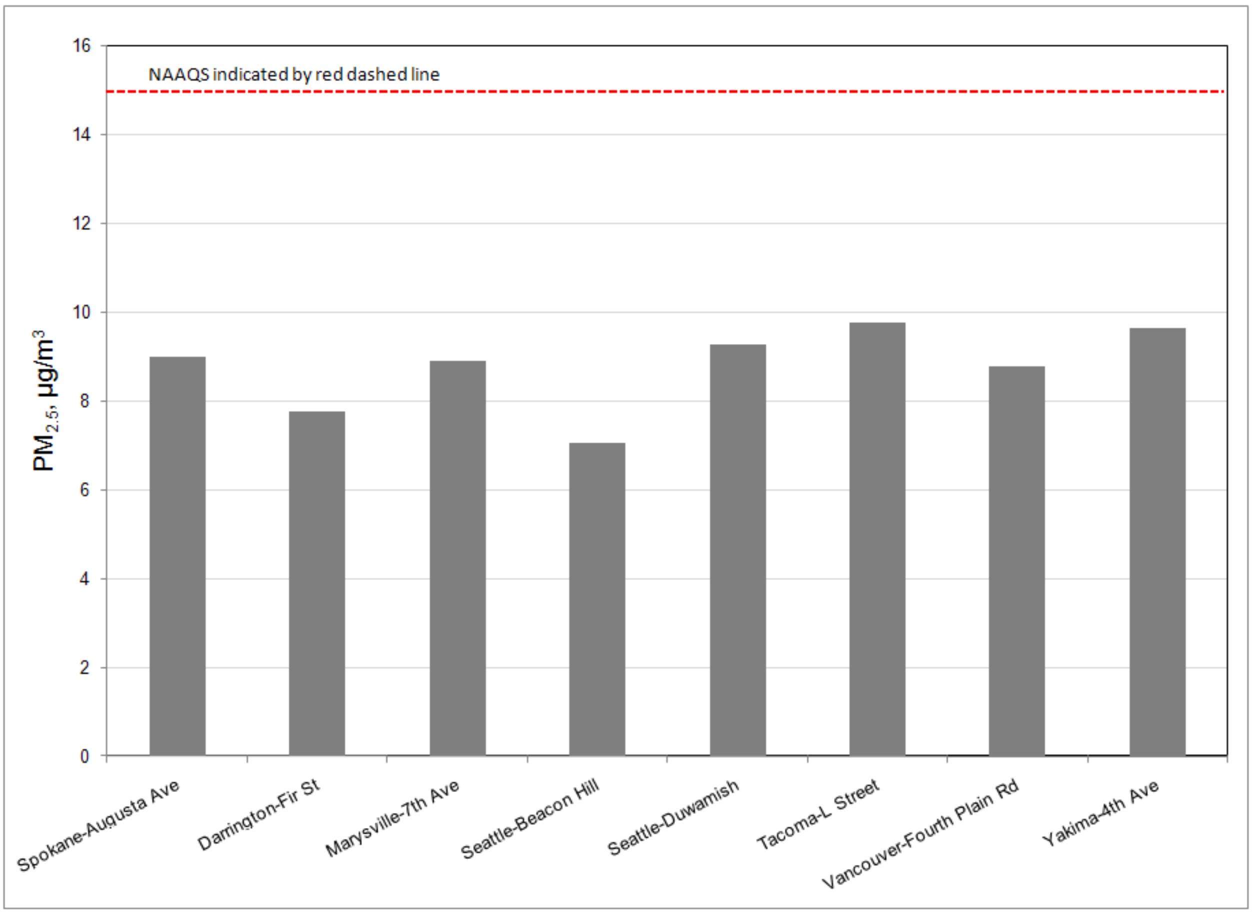

Figure 7: Estimated 2007-2009 Annual $PM_{2.5}$ FRM Design Values

Continuous Fine Particulate Matter

Ecology and its partners operate an extensive network of 56 continuous $PM_{2.5}$ monitors statewide. This network represents Ecology's single largest ongoing resource investment for any pollutant and provides near-real-time data for a variety of users with a diverse array of data needs and applications. The

Washington State network consists of two types of continuous $PM_{2.5}$ monitors. Most of these monitors are nephelometers that have been correlated with a FRM to produce FRM-like $PM_{2.5}$ concentrations, as per EPA guidance (US EPA, 2002). The remaining continuous $PM_{2.5}$ monitors are TEOM.

Updating Fine Particulate Matter Correlations

Ecology relies heavily on its $PM_{2.5}$-correlated nephelometers because they are much less costly to operate than TEOMs and FRMs. However, aerosol composition can change over time. In addition, most of the nephelometer-FRM correlations were established several years ago. For these reasons, Ecology believes it is important to prioritize the updating of its FRM- nephelometer correlations as resources permit, to ensure reliable estimates of $PM_{2.5}$ concentrations from this large network.

Supporting a Single Continuous Onsite Monitor

Ecology believes it is important to *conserve limited financial and staff resources by using only one continuous method for each pollutant.* There is one continuous $PM_{2.5}$ monitoring redundancy at the Seattle-Beacon Hill station. Specifically, the $PM_{2.5}$-correlated nephelometer is redundant to the collocated $PM_{2.5}$ TEOM monitor and should be discontinued. As of the writing of this document, the TEOM has been upgraded to FEM status and therefore is the preferred instrument.

$PM_{2.5}$ Non-Federal Reference Method Tapered Elemental Oscillating Microbalances Bias

In performing the analysis of the $PM_{2.5}$ network, Ecology noted the extent to which the non-FEM TEOM underestimated $PM_{2.5}$ compared to collocated FRM monitors. Figure 8 presents a comparison of the estimated design value trends from 2003 through 2009 at Tacoma-L Street.

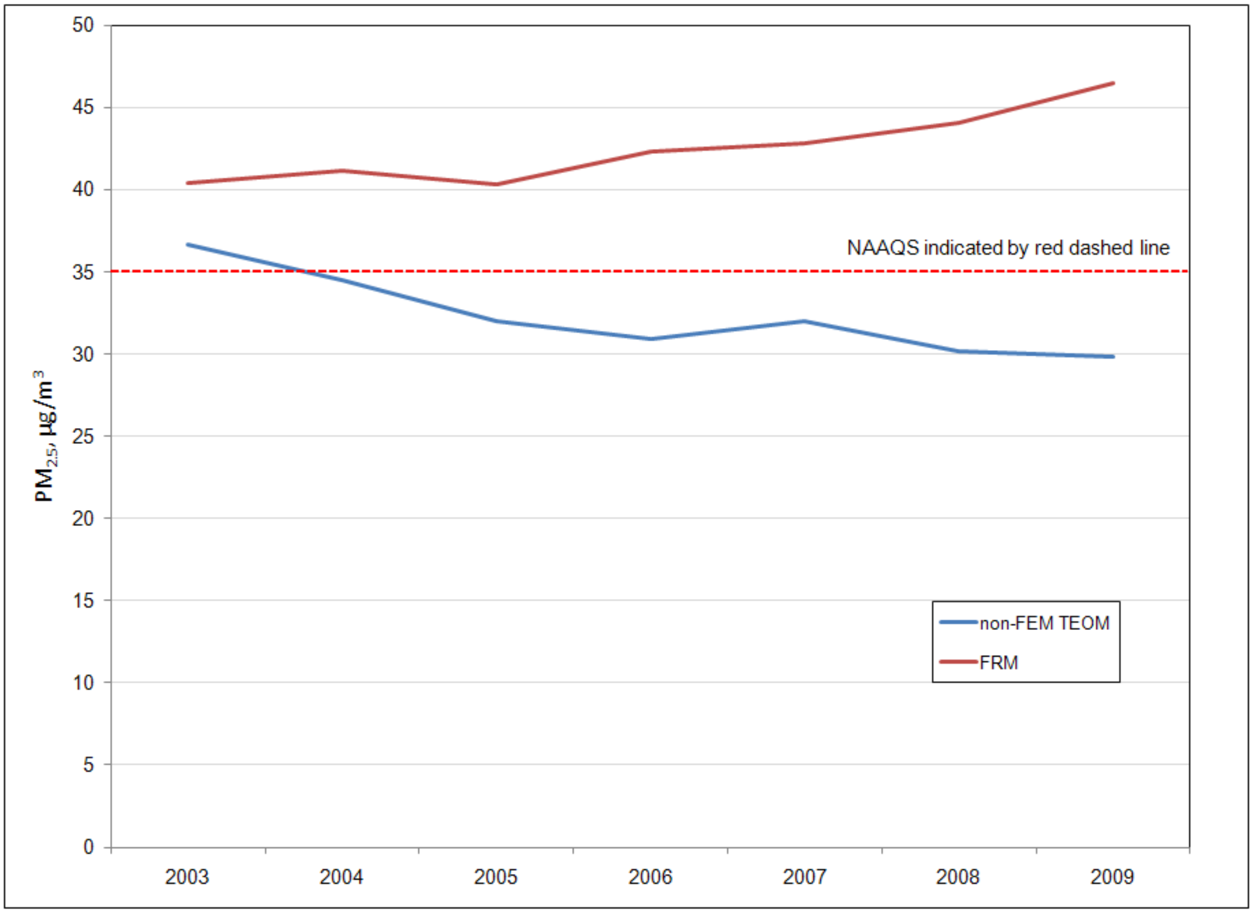

Figure 8: Tacoma-L Street Design Value Trend Comparison (TEOM vs. FRM)

The TEOM data at Marysville-7th Ave and Spokane, Augusta Ave. (formerly Ferry St.) were also biased low as compared to the collocated FRMs.

As of the writing of this document, nearly all of the non-FEM TEOMs in the network have either been replaced with FEM TEOMs, or are scheduled to be replaced in the coming months. Because the FEM TEOM has received EPA equivalency, Ecology hopes the low bias issue has been resolved. However, EPA did not conduct testing of its FEM TEOMs in the woodsmoke dominated areas of the western US, and it bears mentioning that aerosol composition may differ somewhat in Washington as compared to the test environments. As more data are collected, Ecology plans to track how the FEM TEOMs compare to the FRMs, particularly during the home-heating season when $PM_{2.5}$ levels are generally highest in Washington.

Federal Equivalent Method Fine Particulate Matter Monitoring

As mentioned above, as of the beginning of 2010, Ecology and its partners have begun the transition away from FRM $PM_{2.5}$ monitoring. It is anticipated that within the 2010 calendar year, nearly all of the FRM monitors listed in Table 5 above will be replaced with FEM TEOM monitors. FRM monitoring will continue at the Seattle-Beacon Hill and the Tacoma-L Street stations in order to meet NCore and EPA collocation requirements, respectively.

FEM TEOMs offer the advantage of continuous data that can be used to provide near-real-time information on $PM_{2.5}$ pollution levels while still allowing for the determination of compliance with the NAAQS. In addition, it is expected that following an initial capital investment, the operational costs will be significantly lower than that of the FRMs. FRMs have an estimated cost of approximately $100 per sample. Any eventual cost savings associated with the implementation of FEMs at the former FRM stations should be reinvested in order to address other monitoring activities such as filling data gaps identified in this assessment.

For reasons stated in the $PM_{2.5}$ Non-FEM TEOM Bias Discussion section above, Ecology plans to pay close attention to ensure that the FEM TEOM data compare well to that of the FRM.

The Agricultural Burning Network

As a result of a federal court case settlement, several years ago Ecology implemented a sub-network of 8 continuous $PM_{2.5}$ monitors to assist with smoke management associated with wheat stubble burning in Eastern Washington. This network deserves special mention because although the concentrations are relatively low, this sub-network allows Ecology to keep air quality levels safe from elevated $PM_{2.5}$ episodes.

Historically, field stubble burning during post-harvest field clearing was often the cause of elevated $PM_{2.5}$ levels in these areas. Following implementation of the agricultural burning monitoring network, concentrations have been reduced. The monitors - along with information from meteorological monitors, field reports, burn permit applications and both meteorological and atmospheric dispersion models – provide data that are used on a daily basis by Ecology to make burn decisions. These monitors are both a vital resource for the proper implementation of the agricultural burn smoke management program and for evaluating the performance thereof.

The $PM_{2.5}$ levels recorded by these monitors are highest during the fall burning season, which typically runs from late July to October. In addition, the Walla Walla station is also impacted by wintertime smoke from home heating devices. To ascertain the presence of a trend in $PM_{2.5}$ levels and the extent to which such trends were driven by meteorology, we compared the number of days with impaired air quality (defined as days on which the Washington Air Quality Advisory (WAQA) was anything other than "Good", when 24-hour $PM_{2.5}$ levels were ≤ 13.4 $\mu g/m^3$) from July-October each year, with the 75th percentile of the wind speed measured at the nearest available meteorological station. The 75th percentile wind speed was chosen in an attempt to determine whether higher winds in particular years helped suppress $PM_{2.5}$ levels.

Figure 9 shows that in the absence of impacts from wildfires (in 2003 and 2006 Washington had a multiple wildfires that burned for a long time), $PM_{2.5}$ levels and corresponding wind speeds between July and October have remained steady since 2002. This suggests that stronger winds did not ***consistently*** suppress $PM_{2.5}$ levels in any particular year. Figure 9 also includes the number of acres authorized for burning throughout the whole county during the fall burning season. There is no obvious correlation between impaired air quality and the extent of burning, except perhaps for a period of time in Whitman County (encompassing Pullman, Rosalia and La Crosse), where most wheat field stubble burning takes place. Further, the number of days of impaired air quality in the region has been has been declining in the last 3 years.

Ecology strongly feels that these monitors are vital to the continued success of the agricultural burn smoke management program.

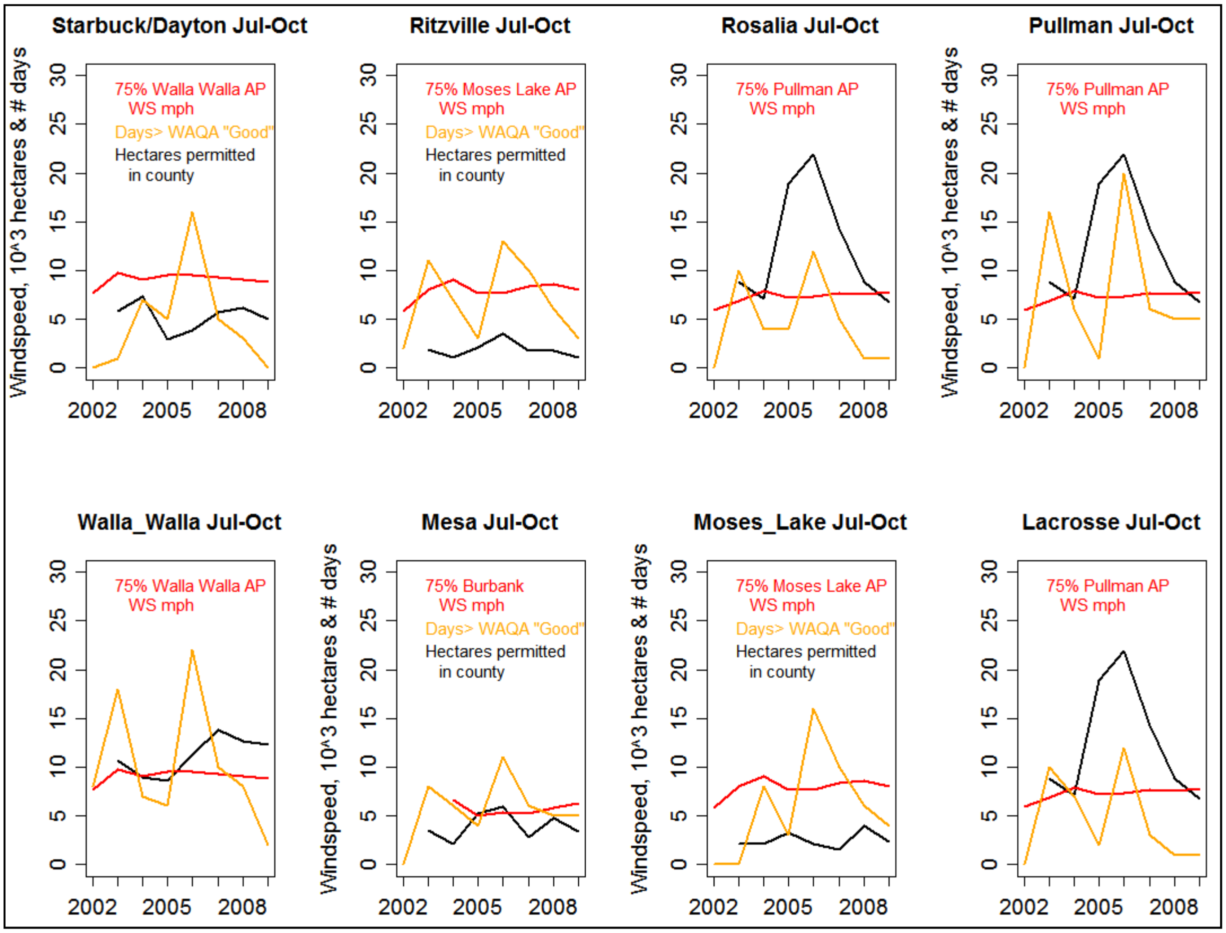

Figure 9: Agricultural Burning Network $PM_{2.5}$, Wind Speed and Acreage Burned Trends

Note that the station was located in Starbuck from September 2003- March 2009, before being moved to Dayton

Fine Particulate Matter Decision Matrix

Ecology used a decision matrix to analyze the official $PM_{2.5}$ monitoring network. Stations were ranked in order of value in relation to Ecology's monitoring policy goal and objectives. Therefore, protection of public health was emphasized.

The $PM_{2.5}$ decision matrix should serve as a valuable tool for the purposes of network planning and a guide for decisions regarding future monitoring network changes.

The Chehalis-Market St. and White Swan $PM_{2.5}$ monitors were not included in this assessment as monitoring began too recently to compile meaningful summary statistics.

Scoring

The number of adverse health effects increase as $PM_{2.5}$ concentrations rise. Therefore, the decision matrix was inherently weighted to reflect greater value for monitors that record higher levels of pollution coupled with population exposure. This was accomplished by the inclusion of multiple categories that were driven by $PM_{2.5}$ concentrations, as well as an estimate of the population represented by each monitor; a surrogate for exposure and risk. However, several other categories encapsulating other factors were also incorporated into the decision matrix. The categories for the $PM_{2.5}$ decision matrix are as follows:

Pollution/Public Health:

- Estimated 2009 design value (24-hour)
- Number 24-hour NAAQS exceedances (2007-2009)
- Number Program Healthy Air Goal exceedances (2007-2009)
- Percentage of days other than Good air quality

Other Factors:

Whether the monitor:

- Satisfies a forecasting/curtailment need
- Is part of Ecology's partnership with EPA for monitoring on tribal lands
- Is part of Ecology's partnership with USFS for monitoring silvicultural burning impacts
- Is used for decisions regarding whether to allow agricultural burning
- Is located at an NCORE/potential NCORE station
- Is the sole monitor in an air shed
- Is in an Environmental Justice area
- Has a long historical record
- Is collocated with other monitors
- Is in a densely populated area
- Is in an area with a rapidly growing population

EPA guidance recommended states analyze pollution trends as part of the network assessment. Ecology examined trends from its CO, PM_{10}, $PM_{2.5}$, and ozone networks. Clear downward trends were discernable in the case of CO (see Figures 21 and 22). However, it is important to note that while Ecology analyzed the trends for its largest networks, $PM_{2.5}$ and ozone, upward or downward trends were not clearly discernable and therefore trends analyses weren't included in the matrices for $PM_{2.5}$ and ozone.

Each category in the matrix represents a separate analysis and constitutes a column in the worksheet. Scores for some categories were awarded on a relative-ranking basis and other categories were *all or nothing* meaning, for example, that a "Y" (or yes) constitutes a score of 1, and a blank (or no) is given no score. Scores were normalized across the disparate categories such that the maximum score for any monitor in any column was "1". Because the decision matrix was inherently weighted to reflect greater value for monitors recording higher pollution levels, analyses were not weighted between categories. Scores across the categories (i.e., columns in the worksheet matrix) were summed for each station and a final $PM_{2.5}$ station ranking established. The highest-scoring (highest ranked) stations are theoretically of greatest value for meeting Ecology's priorities and goals for $PM_{2.5}$ monitoring.

The complete $PM_{2.5}$ decision matrix worksheet can be found in Appendix A at the end of this document.

Figure 10 below shows the relative ranking of $PM_{2.5}$ monitors within the Ecology network based on the decision matrix assessment. Monitors are listed by stations name and are ranked in descending order according to their relative importance in the Ecology network (i.e., higher score = greater importance in the network).

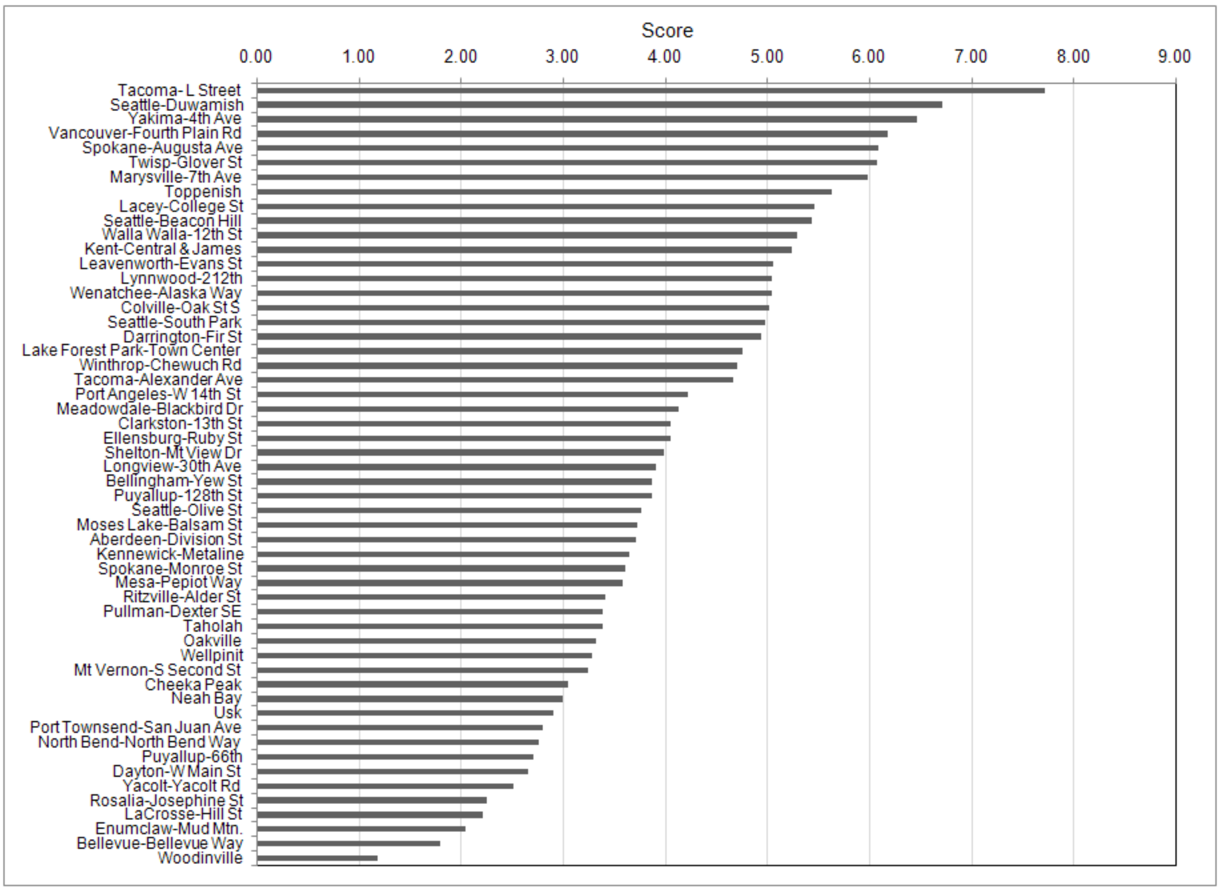

Figure 10: $PM_{2.5}$ Station Relative Ranking

Statewide Fine Particulate Matter Design Values

EPA suggested the use of Voronoi Polygons to determine the area represented by each monitor, as a means of determining the spatial variability of pollutant concentrations statewide. Polygons are drawn by splitting the distance between a given site and its nearest neighbor. While this technique may have some value in relatively flat terrain, Figure 11 illustrates its shortcomings when used in areas of complex terrain, with no consideration of meteorology and heterogeneity of emissions.

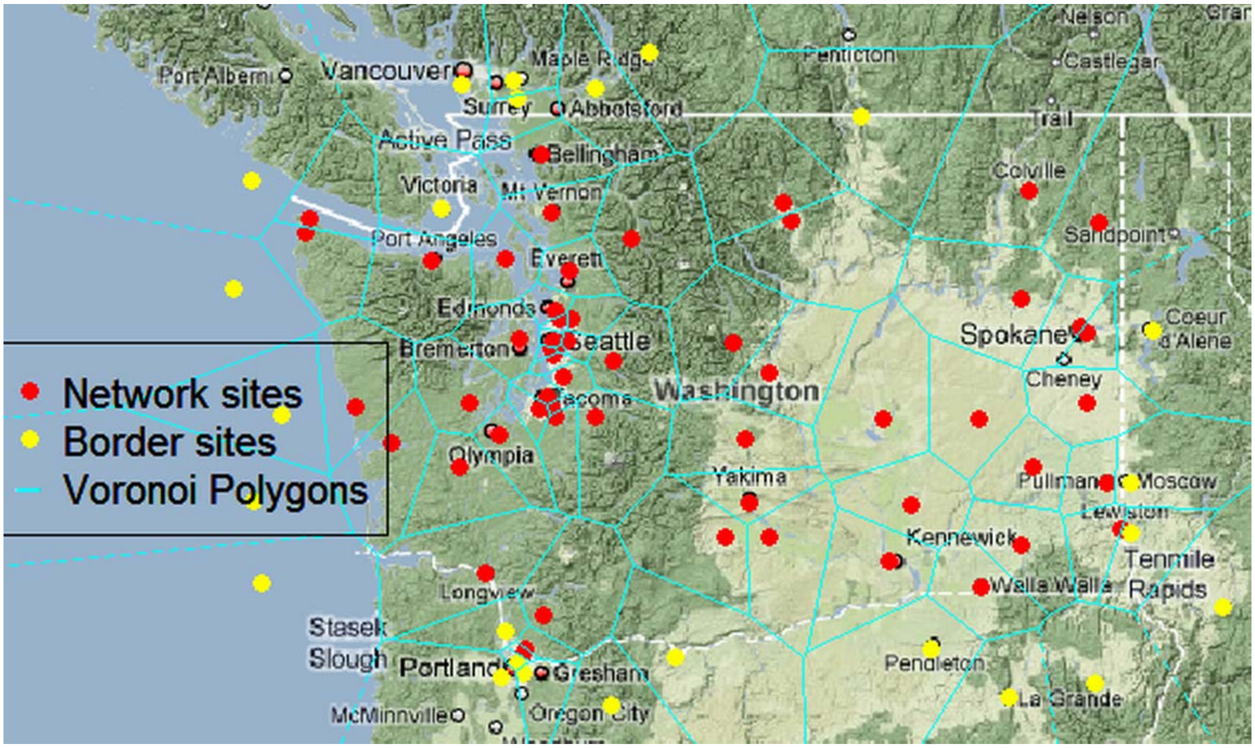

Figure 11: Polygons Drawn Around $PM_{2.5}$ Monitors in and Around Washington State

The Google terrain map in Figure 11 shows how this technique erroneously considers several monitors in valleys/ lowlands to be representative of areas well into the high elevations of the Cascades or other sparsely populated areas. The polygons around the Yakima, Methow Valley and Colville sites are but a few examples. To address these shortcomings and obtain a reasonable representation of the spatial distribution of $PM_{2.5}$, Ecology:

- **Calculated current design values from each $PM_{2.5}$ monitor, using 2007-2009 data.**
  FRM data were used instead of continuous $PM_{2.5}$ data, where available. At sites where 2007-2009 data were incomplete, the most recent 98th percentile value was used.

- **Calculated the median modeled $PM_{2.5}$ for each 12km x 12km grid cell, over same period.**
  Washington State University runs a gridded photochemical atmospheric dispersion model Community Multi-Scale Air Quality Model (CMAQ) in predictive mode at a 12km spatial resolution, every day (http://airpact-3.wsu.edu). Predicted meteorological fields are available twice daily from the University of Washington's WRF model (http://www.atmos.washington.edu/mm5rt). A separate gridded emissions module incorporates statewide land use patterns, traffic volumes, industrial and biogenic emissions, all adjusted as appropriate by season, day of week, time of day and predicted temperature and solar radiation. Ecology maintains several years of archived 24-hour averages of modeled $PM_{2.5}$ concentrations throughout the modeling domain, which encompasses all of Washington, Oregon and Idaho. Thus with the use of model data, this process is able to account for the effects of terrain, meteorology, emissions and photochemistry on the spatial variability of $PM_{2.5}$.

Since the model constantly over-predicts $PM_{2.5}$ from wildfires, Ecology used modeled medians rather than means, for each grid cell. This further served to reduce the impacts of poor model performance in certain areas, seasons or events, yielding a more robust dataset.

- **Performed a spatial interpolation, using the monitor to fix the value, and the monitor/ model ratio to spatially scale the data.**
  We used the Voronoi nearest neighbor and inverse distance squared ($1/D^2$) weighted averaging for this part of the analysis. $1/D^2$ weighting was used instead of 1/D, to limit the radius of influence of a given monitor, given the complex terrain throughout most of Washington State. Even though the dispersion model incorporates the effects of terrain, the spatial interpolation scheme does not respect such barriers.

  Since the dispersion model serves to spatially scale the monitor data (i.e., is a grid cell higher or lower than its neighbor), the process assumes that the dispersion model captures the spatial variation of $PM_{2.5}$ reasonably well. However the dispersion model is not required to accurately predict $PM_{2.5}$ concentrations at each monitor, since the interpolation result is most heavily weighted by the concentration at the nearest monitor.

  Border monitors from British Columbia, Canada, Oregon, Idaho, and fictitious marine monitors (assigned estimated background design values of 5 µg/m^3) were used to prevent unreasonable values at border areas. The relevant algorithms were available for easy use in a separate EPA model (BenMAP- US EPA, 2008).

The outcome of the model-monitor interpolation, added as a semi-transparent layer to a terrain map, is shown in Figure 12. For color-coding purposes, Ecology used breakpoints associated with the WAQA. It can be seen that areas of $PM_{2.5}$ concentrations over 35 µg/m^3, namely Tacoma, Darrington and Yakima, are confined to the immediate grid cell(s) around the monitors. Upon closer examination, it was seen that the high value near the Canadian site of Grand Forks is the result of a slight $PM_{2.5}$ overprediction in the area. The actual extent of areas experiencing $PM_{2.5}$ concentrations over 20 µg/m^3, particularly in eastern Washington, might be somewhat exaggerated owing to the relatively lower monitor density. Nevertheless this spatial representation is far more realistic than using Voronoi polygons.

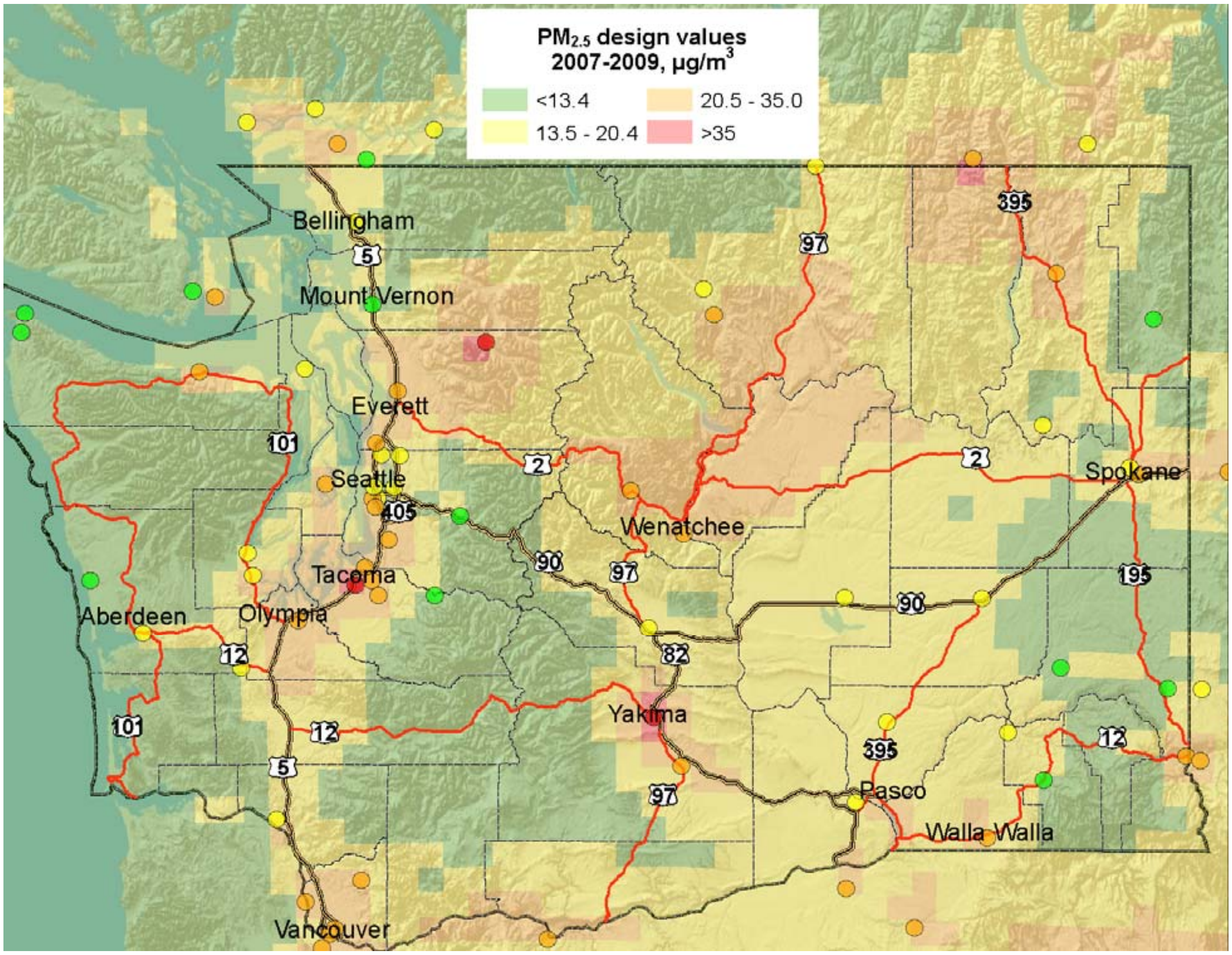

Figure 12: 2009 $PM_{2.5}$ 24-hour Design Values in Washington State

Fine Particulate Matter Removal Bias Analysis

Analyses conducted for the decision matrix identified the Woodinville and Enumclaw continuous $PM_{2.5}$ monitors as providing little additional useful information (see Appendix A). The above mentioned spatial interpolation using monitors and dispersion modeling data, was rerun after omitting these sites. The resulting change in the spatial distribution of $PM_{2.5}$ (i.e. the removal bias, defined as $PM_{2.5}$ from the rerun minus $PM_{2.5}$ in Figure 12) is displayed in Figure 13. A positive removal bias at a particular location suggests increased $PM_{2.5}$ levels, after the sites in question are omitted.

A negative removal bias at the grid cell containing the Woodinville site in Figure 13 suggests that the monitor there recorded concentrations higher than what could be interpolated from the surrounding sites alone. Yet, since the Bellevue monitor could be used as a surrogate, the omission of this site does not result in misleading information. Removal of the Enumclaw $PM_{2.5}$ monitor appears to cause little bias at the same grid cell. The remaining impacts are largely confined to the Cascades. These sparsely populated areas are characterized by low $PM_{2.5}$ concentrations, and an added uncertainty of a few $\mu g/m^3$ is unlikely to affect the $PM_{2.5}$ pattern significantly.

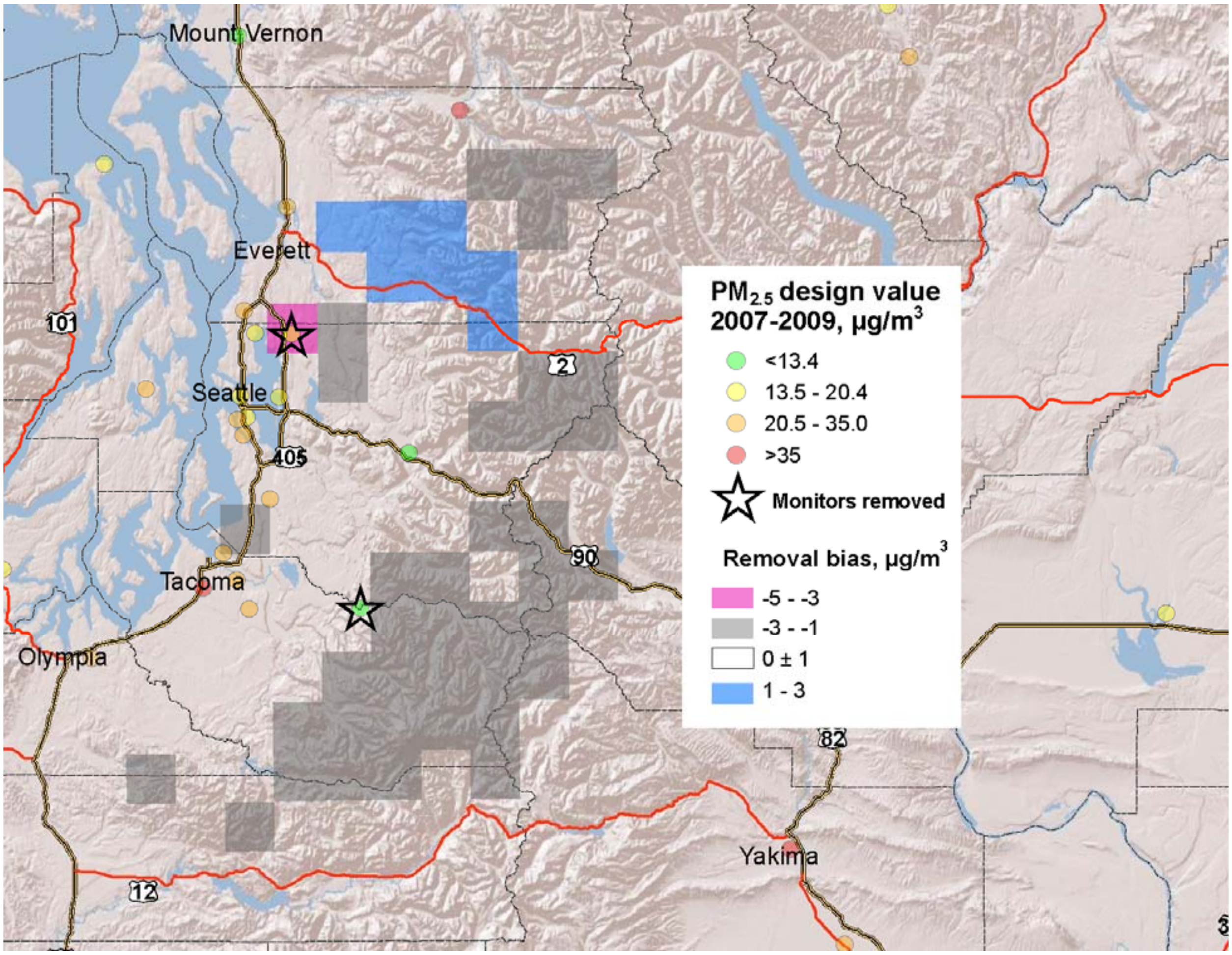

Figure 13: Woodinville and Enumclaw $PM_{2.5}$ Site Removal Bias

Ozone

Ecology and its partners operate a network of 12 continuous ozone monitors statewide. This network provides near-real-time data for a variety of users with a diverse array of data needs and applications.

The Washington State ozone network serves a wide variety of needs. The data are used to determine compliance with the NAAQS, provide near-real-time information on air quality for public health protection through Ecology's WAQA and EPA's Air Quality Index (AQI), forecast air pollution episodes and make ozone action-day calls, and determine efficacy of control measures. Ecology's ozone network consists of FEM monitors.

Ozone Decision Matrix

Ecology used a decision matrix to analyze the relative value of its continuous ozone monitoring network. Stations were ranked in order of value in accordance with established Ecology monitoring policy goal and objectives. Therefore, factors important for public health protection were emphasized. Other factors, such as whether the monitor is part of EPA's NCore strategy, are also important and were incorporated in the decision matrix.

Scoring

The ozone decision matrix was weighted to reflect greater value for monitors that record higher levels of ozone. Because all categories were worth the same amount of points, this weighting was accomplished by the inclusion of three categories that were driven by ozone concentrations.

The categories for the ozone decision matrix are as follows:

Pollution/Public Health:

- Estimated 2009 design value
- Number of 8-hour NAAQS exceedances (2007-2009)
- Number of 8-hour daily maximums above .060 ppm (2007-2009)

Other Factors:

Whether the monitor:

- Is collocated with other network parameters
- Has a long historical record
- Satisfies a forecasting/Action Day need
- Is located at an NCore/potential NCore station
- Whether the monitor is redundant to other monitors

Each category in the matrix represents a separate analysis and constitutes a separate column in the worksheet. Scores for some categories were awarded on a relative-ranking basis and other categories were *all or nothing* meaning, for example, that a “Y” (or yes) constitutes a score of 1, and a blank (or no) is given no score. Scores were normalized across the different categories such that the maximum score for any monitor in any column was “1”. Because the decision matrix was weighted to reflect greater value for monitors recording higher pollution levels, analyses were not weighted between categories. Scores across the categories (i.e., columns in the worksheet matrix) were summed for each station and a final ozone station ranking established. The highest-scoring (highest ranked) stations are theoretically of greatest value for meeting Ecology’s priorities and goals for ozone monitoring.

The ozone decision matrix can be found in Appendix B at the end of this document.

Discussion

In contrast to Ecology’s analysis of its continuous $PM_{2.5}$ monitoring network, ozone monitors were not evaluated in terms of the population represented by a given monitor. Public health protection is a key policy goal for Ecology and estimates of the population represented by a monitor can serve as a surrogate for exposure and health risk. However, there are several factors that complicate these estimates when it comes to ozone monitoring.

In contrast to many states elsewhere in the U.S., ozone precursor sources in Washington State are relatively less uniformly distributed. Ozone concentrations are relatively low in urban areas, because (i) there are no major ozone-precursor-source regions upwind; (ii) precursors have not yet undergone photochemical reactions during short travel times, and (iii) background ozone is subject to NO_x titration. The highest ozone concentrations in Washington State occur in the relatively sparsely populated Western foothills of the Cascade Mountains, which lie downwind of the urban areas of the Puget Sound lowlands. High ozone events occur on hot summer days with low to moderate winds with a northerly component. As ozone precursors originating in different areas undergo photochemical reactions during transport, determining relative contributions of each source area is not straightforward. As such Ecology did not conduct any analyses relating to air sheds and population (i.e. sole monitor in the air shed, population represented by each monitor, population growth trends and population living below poverty level) that were included in the assessment of the continuous $PM_{2.5}$ monitoring network. However, Ecology did examine its ozone network for monitor redundancies by conducting trend analyses of all monitor pairs that were reasonably expected to track each other.

Figure 14 below shows the relative ranking of the ozone monitors within the Ecology network based on the decision matrix assessment. Monitors are listed by stations name and are ranked in descending order according to their relative importance in the Ecology network (i.e., higher score = greater importance in the network).

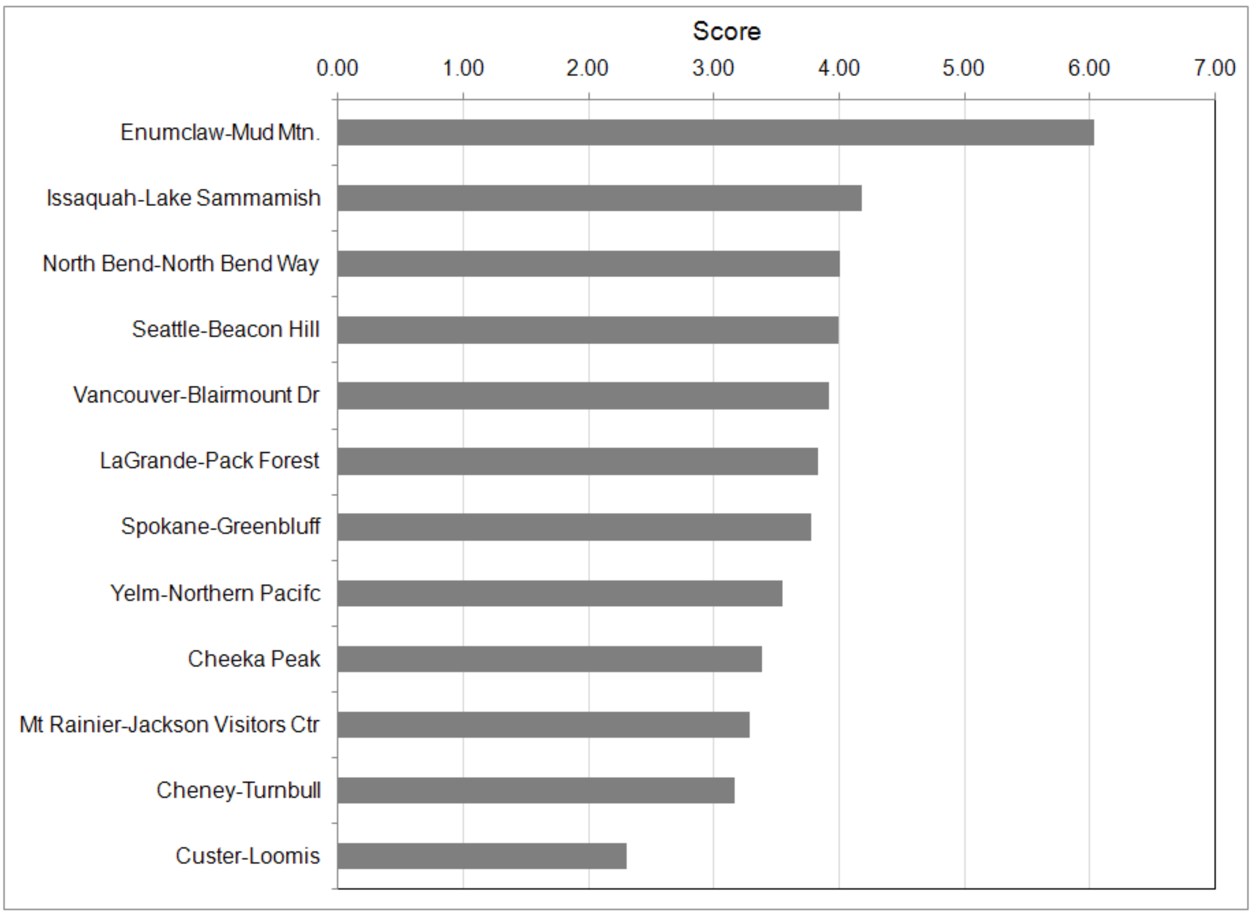

Figure 14: Ozone Monitor Relative Ranking

Statewide Ozone Design Values (Ozone Season)

Ecology followed the general procedures described in the Statewide Fine Particulate Matter Design Values section, and used some historical monitors, those operated by external entities, and Ecology's portable monitors (2B-Technologies Model 202) to improve the spatial coverage of measured data, primarily in Western Washington. Only data from May 1st through September 30th (i.e., the ozone season) were used.

Archives of model data consisted only of 24-hour ozone means, not daily maximum 8-hour concentrations. This could lead to an overestimate of ozone in some areas, as some photochemical models are known to overestimate nighttime ozone, possibly due to poor handling of nighttime stable boundary layer and/or underestimating nighttime NO_x emissions (Chen et al., 2008; Mahmud, 2005). However, this artifact would be less of a concern for this exercise in areas of higher monitor density.

Monitors were weighted using inverse-distance as, unlike $PM_{2.5}$, ozone is unlikely to be confined to localized air sheds.

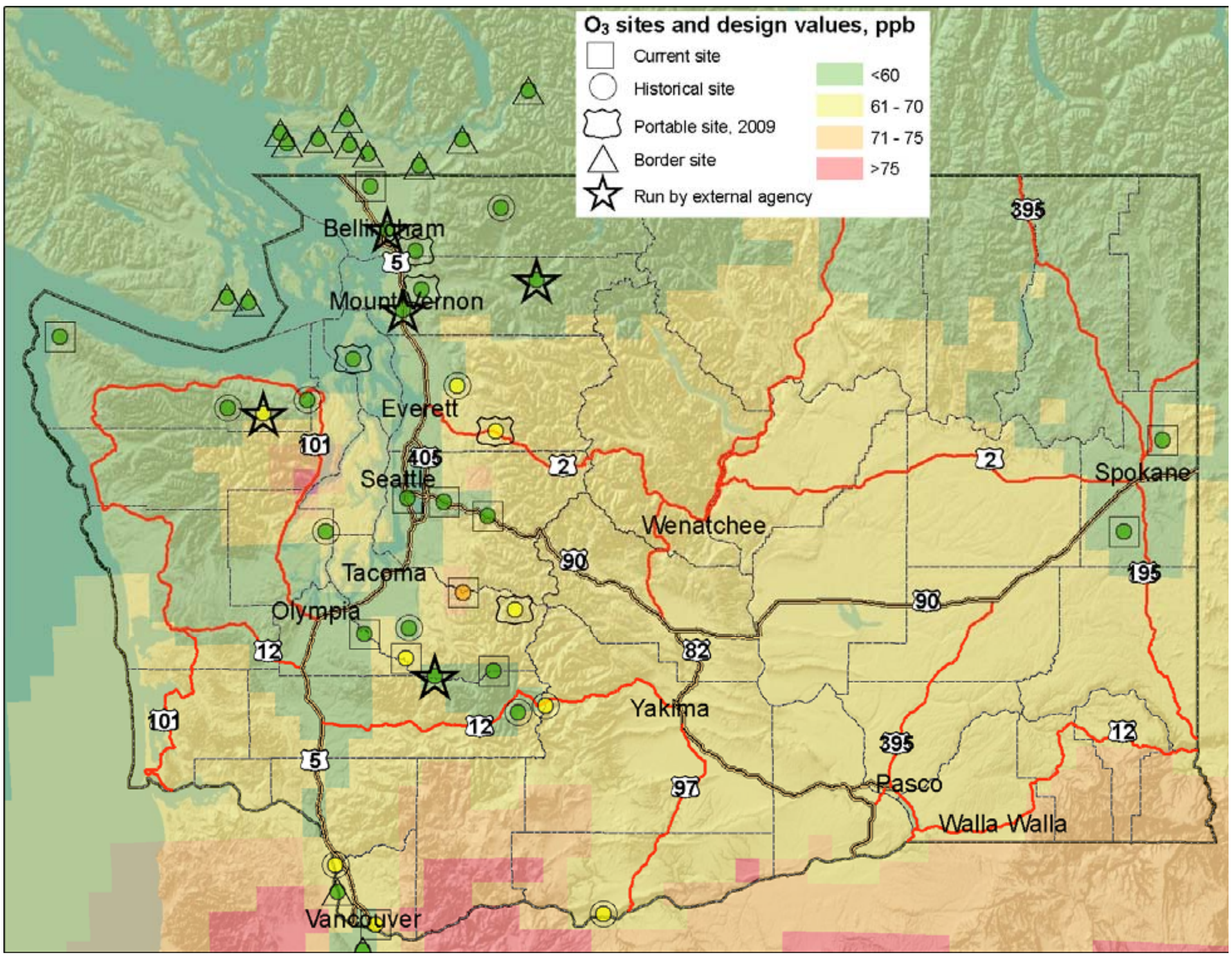

Figure 15: 2009 Ozone Season 8-Hour Design Values

Figure 15 reveals a hotspot in the northeast corner of the Olympic Mountains, despite several nearby monitors being available to ground-truth modeled data. Upon closer investigation it was seen that the model consistently predicted a slight increase of ozone in this area, over its surroundings, since 2006. While the theoretical reasons for ozone accumulation here are understandable (offshore flow damming up against the Olympics, downwind of the ozone precursor source areas), Ecology intends to verify this phenomenon using portable monitors in the summer of 2010. If the area is found to be a genuine hotspot, Ecology may establish a permanent ozone monitor in the Brinnon area.

Due to the few monitors available in eastern Washington, it is possible that the slightly elevated concentrations shown in Figure 15 are driven by the aforementioned model over-predictions at night. Portable samplers deployed for short stints have not recorded high ozone levels. These results highlight the nighttime over prediction issue. Areas to the south of the state are biased high for the same reasons, as well as the occurrence of elevated values at a few monitors in the area.

Impact of lowered ozone National Ambient Air Quality Standards

EPA is in the process of considering a lower ozone NAAQS. Figure 15 also shows the areas that risk exceeding a possible NAAQS of 0.060 ppm (yellow) and 0.070 ppm (orange). However for reasons stated above, the geographic extent with design values in excess of these proposed NAAQS are probably exaggerated, especially in areas of low monitor density.

Ozone Removal Bias Analysis

Analyses conducted for the decision matrix identified the La Grande monitor as being duplicative of the data provided by the North Bend monitor (see Appendix B). As such, little information would be sacrificed by shutting down the La Grande station, as comparable ozone concentrations are expected either at Enumclaw, North Bend or Yelm on most high ozone days. A removal bias analysis was performed according to the procedures described in the section "$PM_{2.5}$ Removal Bias Analysis" and the result is presented in Figure 16. While the omission of this site yields a slightly higher estimate of ozone design values (positive removal bias), it has little impact on the overall spatial pattern. We therefore recommend removing the La Grande ozone site.

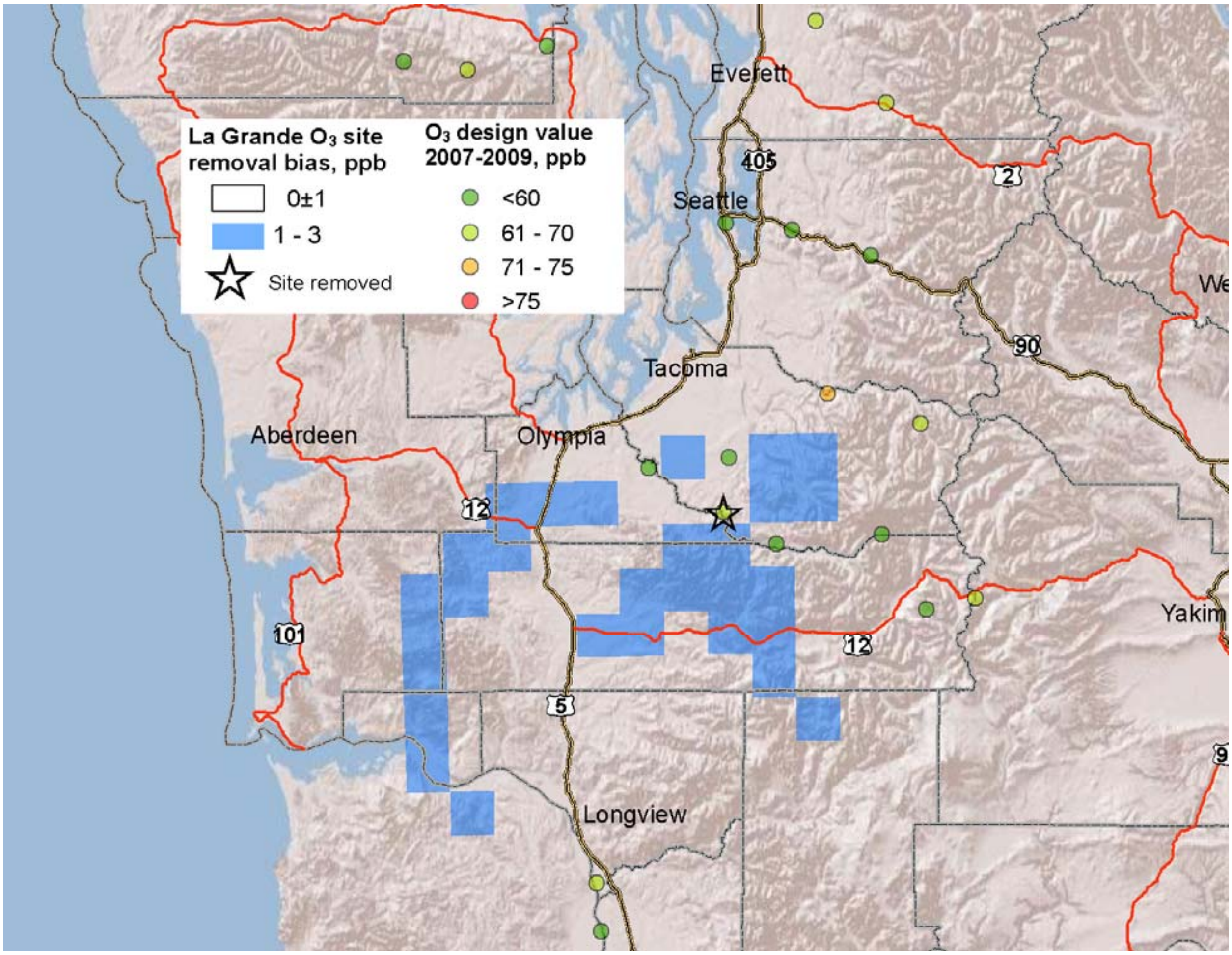

Figure 16: La Grande Ozone Site Removal Bias

Particulate Matter 10

In 1990 there were seven PM_{10} nonattainment areas in Washington State, all of which are now in maintenance as concentrations have decreased due in part to successful control strategies. As a result of declining values and a greater emphasis on fine particles, Ecology has transitioned away from PM_{10} monitoring on a wide scale. While PM_{10} concentrations have decreased over the years and PM_{10} is thought to represent less of a health risk than fine particles, short-term exposure remains a serious threat to human health. For this reason, EPA has maintained the 24-hour NAAQS of 150 $\mu g/m^3$ and Ecology continues to monitor PM_{10} in a few locations that experience occasionally elevated concentrations due primarily to windblown episodes.

Ecology and its partners currently operate and maintain five PM_{10} monitors as part of the Washington ambient air quality network. Two of these monitors are filter-based (manual) FRM PM_{10} samplers and three are continuous TEOM instruments. The manual and continuous method PM_{10} network primarily serves to meet PM_{10} monitoring requirements in maintenance areas [Spokane, Wallula (Burbank) and Yakima] as well as provide information for public health protection during episodes of windblown dust in the Columbia basin. All monitors are located in Eastern Washington. Table 6 presents the monitor locations, monitor types, and frequency of operation.

Ecology did not use a decision matrix nor conduct any spatial analyses to evaluate its PM_{10} network because the network is relatively small.

Table 6: Washington State PM_{10} Monitoring Network

Station Name	Instrument	Sampling Frequency
Burbank-Maple St	TEOM	Continuous
Colville-Oak St S	TEOM	Continuous
Kennewick-Metaline St	TEOM	Continuous
Spokane-Augusta Ave	FRM	1/6; collocated 1/6
Yakima-4th Ave	FRM	1/6

It should be noted that in contrast to $PM_{2.5}$, woodsmoke in Washington does not result in PM_{10} levels close to the PM_{10} NAAQS. With the exception of Colville, all of the 24-hour PM_{10} standard exceedances measured at these stations in the last three years are attributable to high winds and resultant windblown dust (Table 7). High winds, a natural event and the primary driver of high PM_{10} concentrations at most of the stations, occur occasionally in Eastern Washington generating dust storms during the relatively warm and dry months from April through October.

Table 7: 24-Hour PM_{10} NAAQS Exceedances and Wind Speeds (2007-2009)

Station Name	24-hr Conc. μg/m^3	Collection Date	24-hr WS (mph)	Max 3-hr WS (mph)
Kennewick-Metaline	289	10/4/2009	12.3	18.0
Kennewick-Metaline	192	4/9/2007	19.2	25.4
Burbank-Maple St	169	4/9/2007	19.2	25.4
Burbank-Maple St	168	7/10/2008	9.1	24.2
Spokane-Ferry St (now Augusta Ave.)	161	8/18/2008	9.2	18.5
Colville-Oak St S	266	2/19/2008	N/A	N/A
Colville-Oak St S	210	2/20/2008	N/A	N/A
Colville-Oak St S	200	2/21/2008	N/A	N/A
Colville-Oak St S	185	2/22/2008	N/A	N/A
Colville-Oak St S	180	2/14/2008	N/A	N/A
Colville-Oak St S	160	3/5/2008	N/A	N/A

Discussion

The PM_{10} network generally addresses monitoring needs as they relate to Ecology's goal and objectives, and therefore, most of it should be retained. The exceptions (Burbank, Yakima), are discussed in greater detail below.

This section also describes unique monitoring considerations for Colville, which experiences elevated levels of PM_{10} that, in contrast to the rest of the network, are unrelated to windblown dust events.

Colville

The Colville continuous PM_{10} monitor is unique in that it recorded six exceedances of the 24-hour NAAQS during the three year period from January 1, 2007 through December 31, 2009. All of these exceedances fell within a 3 week window from February 14th through March 5th, 2008.

Colville is a rural community of about 5,000 people (U.S. Census Bureau, 2000) located in Stevens County in the northeast corner of Washington. Extended periods of cold weather are common in Colville and the traction material is applied to city streets to ameliorate icy conditions. Several years ago, the City agreed to apply a more dense traction material to its streets and better manage its overall road traction operations in order to minimize the re-entrainment of particulate. As Figure 17 shows, following the exceedances in early 2008, PM_{10} levels have been below the 24-hour NAAQS.

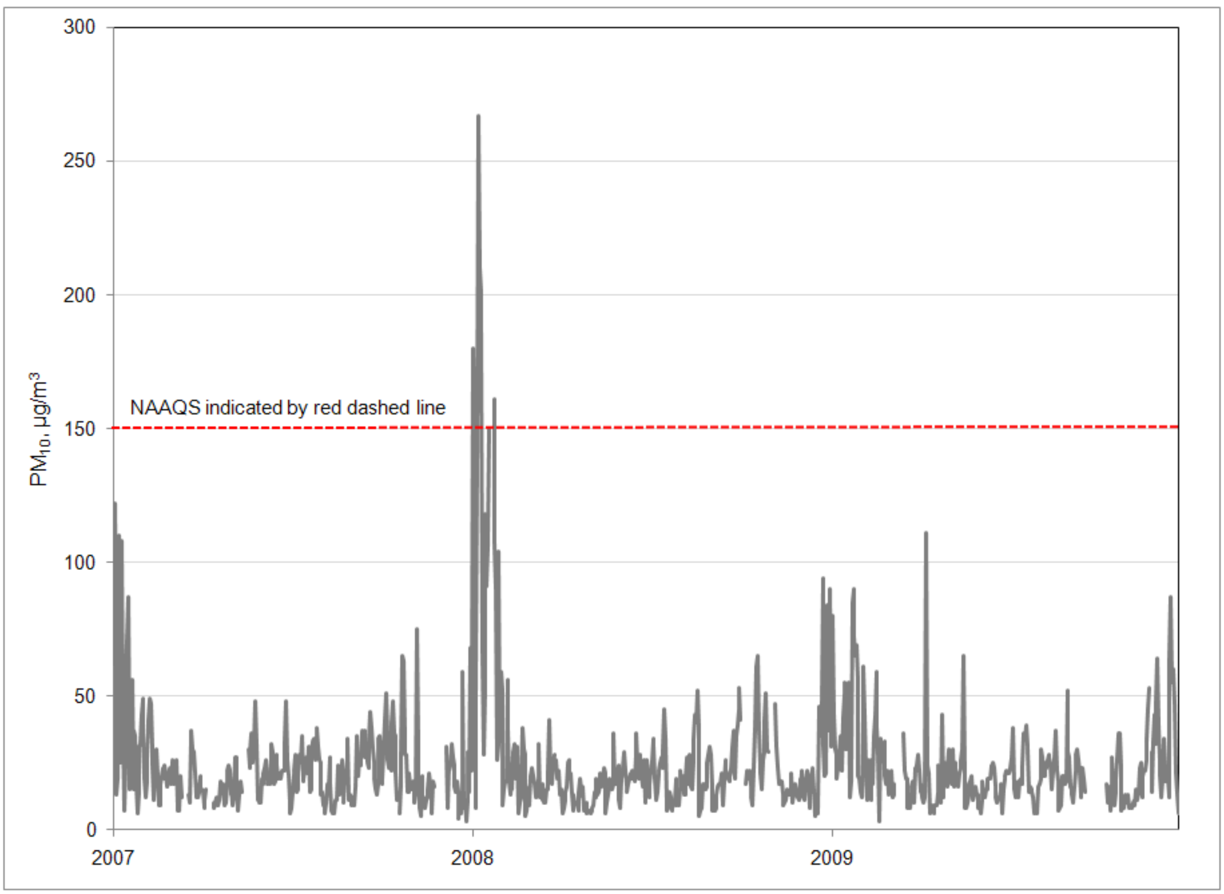

Figure 17: 24-hour PM_{10} Concentrations at Colville (2007-2009)

Figure 18 shows hourly $PM_{10\text{-}2.5}$ and wind speed during part of this 3 week period as recorded by the closest available non-network wind monitor located in Kettle Falls, a small community about 10 miles northwest of Colville. It should be noted that during this high PM_{10} episode, $PM_{2.5}$ concentrations did not rise notably. Therefore the most prevalent fine PM sources in the area (smoke from home heating devices and various types of burning) are unlikely to blame. Figure 18 shows that $PM_{10-2.5}$ concentrations at Colville rise rapidly during the early morning and late afternoon hours on weekdays (except 18th February, which was the President's Day holiday), irrespective of wind speeds. As such, it is very unlikely that windblown dust is responsible for these PM_{10} spikes.

After consulting with officials from the City of Colville, it was discovered that the City applied twice the normal amount of traction material during the winter of 2007-2008 and did not use the wash truck to assist with street sweeping, due to very cold temperatures. Therefore, it is likely that the street sweeper itself was partly responsible for elevated PM_{10} concentrations during this period. Excess traction material could also become re-suspended in air during commute times (US 395, a major north- south transportation route, passes within a few hundred meters of the monitor). Ecology has been working with the City officials to ensure that the real time PM_{10} data are used in the planning of street sweeping operations. It is noteworthy that there have been no wintertime PM_{10} exceedances since March 2008.

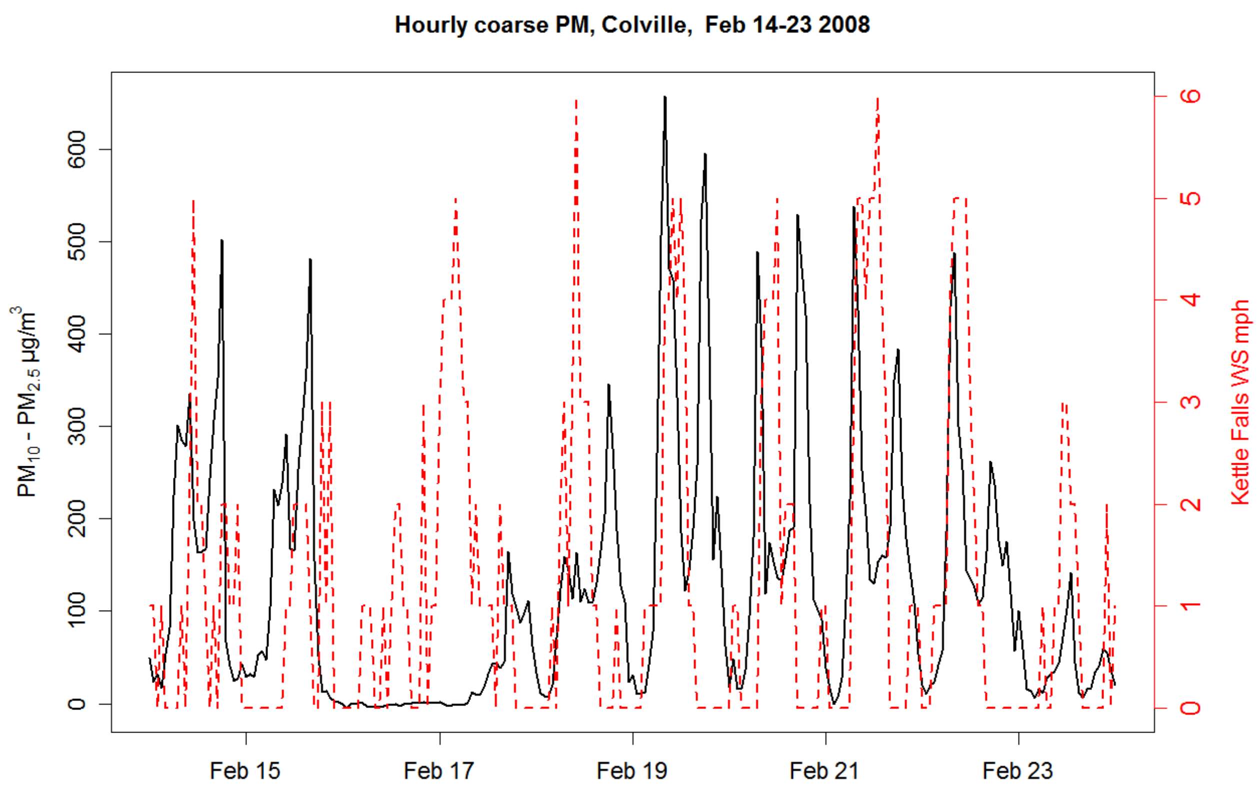

Figure 18: Colville $PM_{10-2.5}$ and Wind Speed (Kettle Falls)

Burbank/Kennewick

Two potential duplicate continuous PM_{10} monitors were identified- Kennewick and Burbank. These monitors are located at stations within the same air shed, are about 7 miles apart, and can likely serve as surrogates for each other. Burbank records slightly higher concentrations overall though Kennewick is sometimes higher during windblown dust events. Reading left to right (top to bottom) in Figure 19, the first graphic shows that with a few exceptions, there have been no pronounced differences between 24-hour concentrations at the two stations, since 2007. The second graphic is a quantile-quantile plot with a nearly straight line. This suggests that data at both sites for the past 3 years are distributed similarly, although Burbank often reads slightly higher concentrations than Kennewick. The third and fourth graphics show the difference in concentrations (Kennewick minus Burbank) as a function of wind speeds and Kennewick PM_{10} concentrations, respectively. With the exception of one event that impacted Kennewick and not Burbank, they do not appear to deviate on account of wind speeds, nor at some threshold PM_{10} concentrations.

Taken together, data shown in Figure 19 suggest there is reason to believe that the continuous PM_{10} TEOMs at Kennewick and Burbank consistently track each other quite closely. Since the lower readings at Kennewick are too small to be significant for operational purposes, these two TEOMs can be considered duplicates. As such Ecology believes that the Burbank station could be discontinued with no loss of important information.

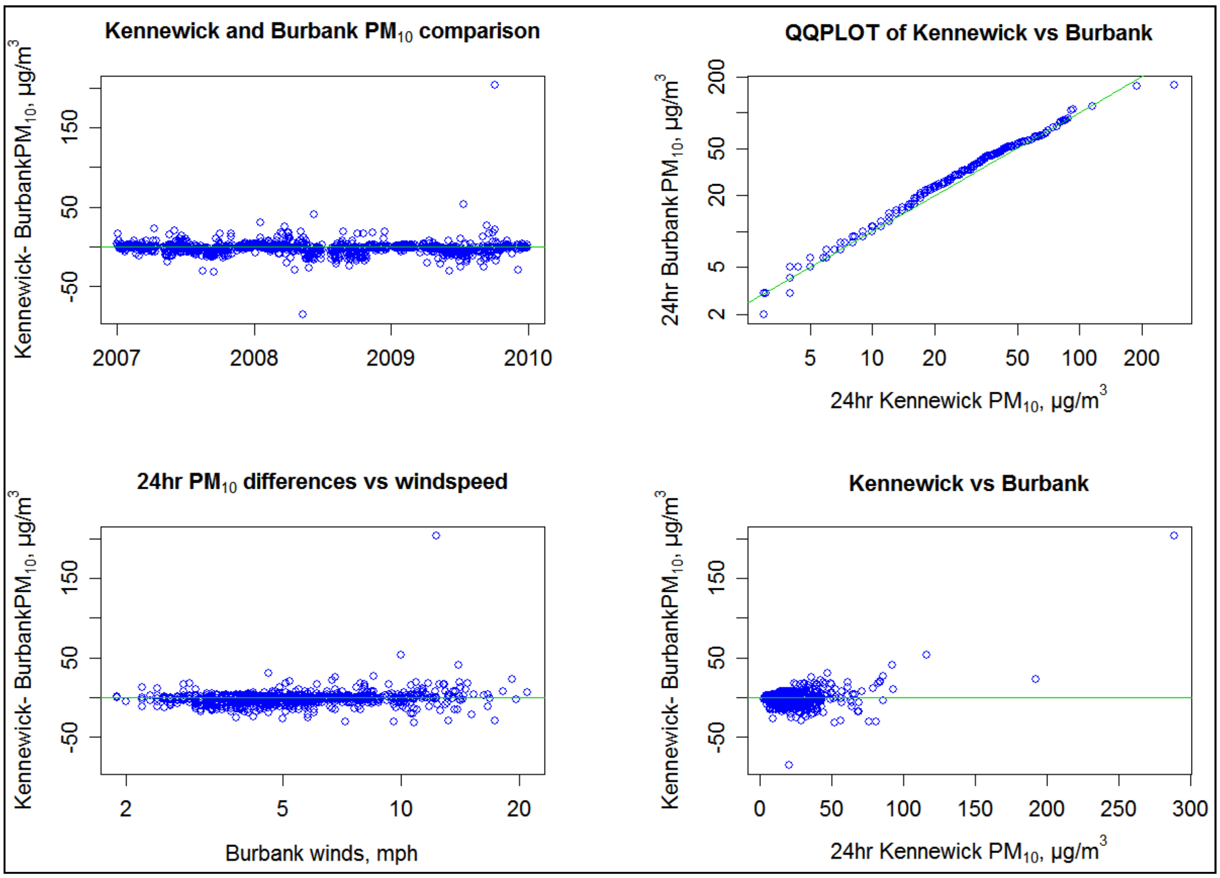

Figure 19: Different Analyses Showing Redundant PM_{10} Monitors at Burbank and Kennewick

Yakima

The Yakima PM_{10} FRM monitor has recorded no exceedances of the standard during the period from January 1, 2000 to December 31, 2009 and the maximum 24-hour concentration for the same period was 105 µg/m^3. As can clearly be seen in Figure 20, PM_{10} levels are well below the NAAQS in Yakima. For this reason, Ecology recommends discontinuing PM_{10} monitoring in Yakima.

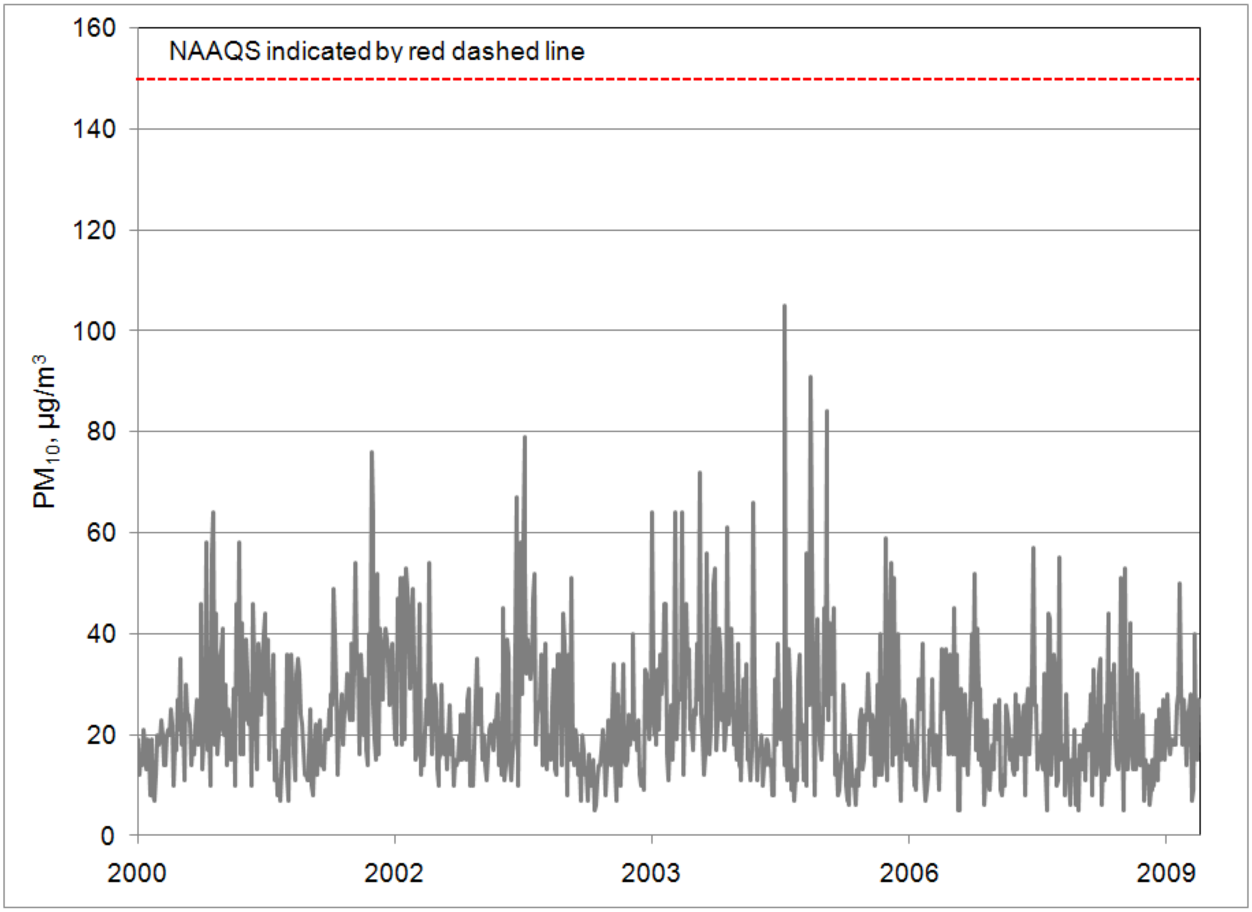

Figure 20: Yakima PM_{10} Concentrations (2000-2009)

Carbon Monoxide

As of December 31, 2009, Ecology operated two CO monitors at the Bellevue-148th NE and Spokane-3rd St. S. stations as part of the Washington ambient air quality network. As a result of control strategies and the gradual replacement of older vehicles with less-polluting ones, CO pollution levels have fallen dramatically in Washington State over the last two decades and are now far below the NAAQS. In addition, CO levels are expected to continue to fall as new vehicles being sold in Washington meet some of the strictest emission standards in the U.S.

For these reasons, Ecology and its partners have divested of CO monitoring and will continue to do so in favor of other emergent monitoring gaps and needs.

Figures 21 and 22 below show these monitors are well below the NAAQS and the overall trends are downward.

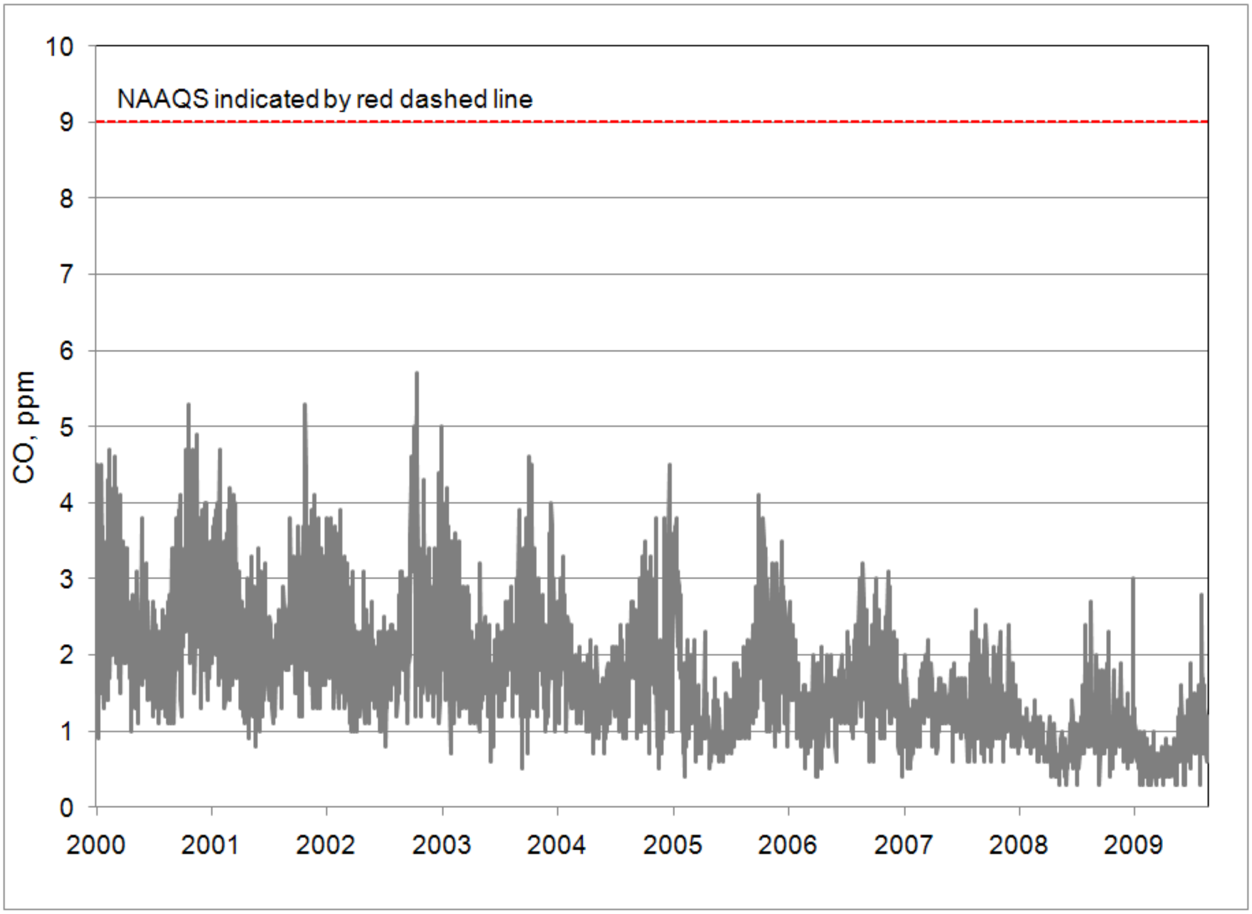

Figure 21: Spokane-3rd St. S. 8-hour Daily Maximum CO Concentrations

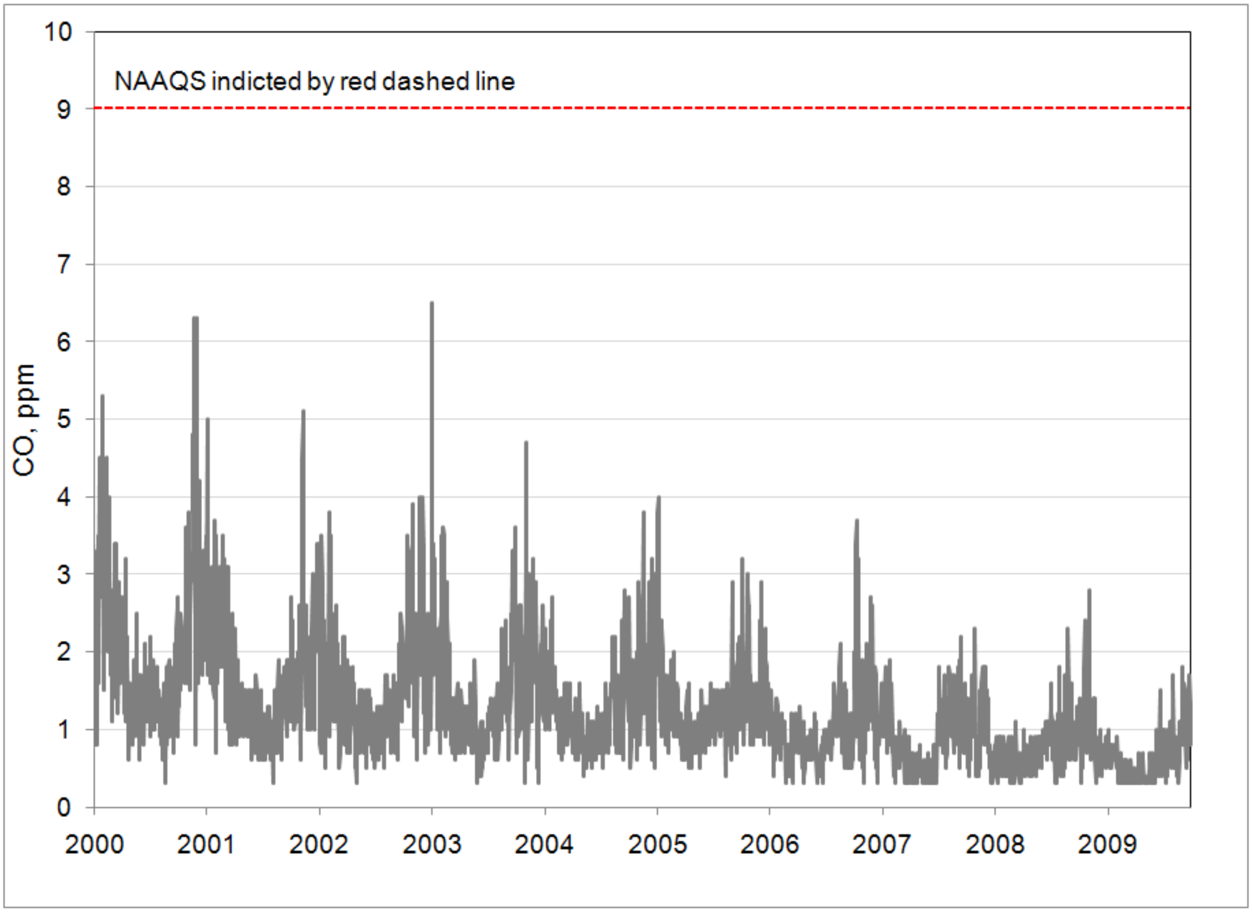

Figure 22: Bellevue-148th NE 8-hour Daily Maximum CO Concentrations

Aerosol Nitrate

The daily air quality forecast model (AIRPACT- http://airpact-3.wsu.edu) has often predicted high aerosol nitrate fractions in $PM_{2.5}$, particularly during wintertime in the Columbia Basin. To ground truth this with the limited monitoring data available, Ecology conducted the same spatial analysis as for $PM_{2.5}$ and ozone (Figures 12 and 15 respectively), using:

1. Aerosol nitrate and $PM_{2.5}$ measured by speciation samplers as well as monitors from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network. Since measurements are made mostly on a 1-in-6 day schedule, 2006-2009 data plus 2 historical CSN and 1 historical IMPROVE monitors were used. Only wintertime data were considered.
2. AIRPACT modeled $NO_3^-/PM_{2.5}$ ratio with $1/D^2$ spatial interpolation.

Figure 23 presents the spatial pattern of wintertime nitrate fraction in $PM_{2.5}$. All particulate nitrate is assumed to be present in the form of Ammonium Nitrate (NH_4NO_3), most of which is formed as secondary aerosol during the winter when the appropriate photochemical reactions are favored. High $NO_3^-/PM_{2.5}$ recorded at Yakima (in spite of high $PM_{2.5}$ concentrations) and at the east end of the Columbia River Gorge (moderate $PM_{2.5}$ levels) provide some evidence to suggest the hotspot in the

Columbia Basin is not a model artifact. Ecology encourages more detailed study to further understand secondary nitrate and its precursors elsewhere in the Columbia Basin in order to verify the model.

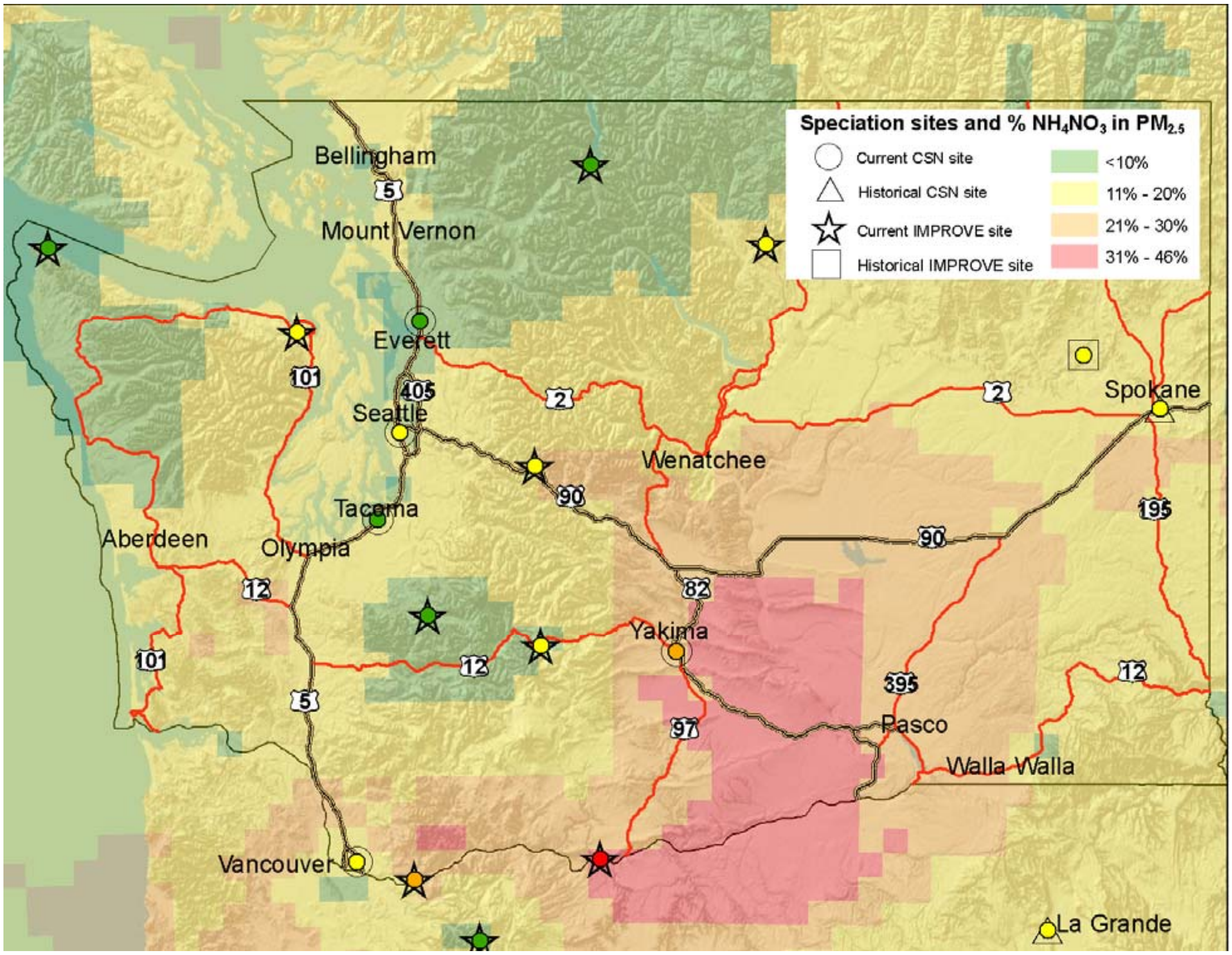

Figure 23: Wintertime Ammonium Nitrate Fraction in $PM_{2.5}$

Meteorological sites

Data from all eleven meteorological sites are routinely used and their continued operation is strongly recommended. There is also an ongoing need for meteorological data in Colville for air quality forecasting and data analysis purposes. There are no representative meteorological monitors in the area, even outside Ecology's official network. Though windspeeds from Kettle Falls were used in the "PM_{10}" section above (see Figure 18), it is uncertain if winds impacting Kettle Falls (mostly flowing along the Columbia River valley) routinely penetrate into the Colville valley and assist with dispersion. The establishment of a meteorological tower at the Colville Station is therefore a necessity.

It has been shown in Figure 19 that the PM_{10} monitor at Burbank can be eliminated, as the Kennewick monitor appears to be a viable surrogate. The Burbank site also hosts a meteorological tower, while the Kennewick site does not. Thus the process of consolidating the PM_{10} monitors at these two sites provides an opportunity to relocate the meteorological tower to Kennewick. No loss of meteorological information is expected with this move.

Findings and Recommendations

Overall, the Washington State ambient air monitoring network is efficient and effective at meeting the monitoring policy goal and objectives. Therefore, wholesale network changes are not necessary. However, several specific, targeted changes will improve overall network effectiveness.

If resource savings are achieved through improvements in network efficiency, they should be reinvested to address monitoring gaps and high priority future monitoring requirements:

- **CO:**
    1. **Discontinue Bellevue-148th NE station** – The data from this monitor is well below the NAAQS, is of little value, and resources could best be used for monitoring elsewhere.
    2. **Discontinue Spokane-3rd St. S. station** – The data from this monitor is well below the NAAQS, is of little value, and resources could best be used for monitoring elsewhere.
- **PM_{10}:**
    1. **Discontinue Yakima-4th Ave. monitor** – The data from this monitor is well below the NAAQS, is of little value, and resources could best be used for monitoring elsewhere.
    2. **Discontinue Burbank-Maple St. station** – Analysis shows that the nearby Kennewick PM_{10} TEOM can be used to provide data generally representative of Burbank. In addition, the Kennewick monitor is located in a population center. Resources saved by discontinuing the Burbank station could best be used for monitoring elsewhere.
- **$PM_{2.5}$:**
    1. **Complete the replacement of all FRM monitors with FEMs over the next year with the following exceptions:**
        - **Retain an FRM at Tacoma-L Street** - needed for EPA collocation requirements.
        - **Retain an FRM at Seattle-Beacon Hill** - needed for NCore requirements.
    2. **Discontinue Woodinville station** – The data from this continuous $PM_{2.5}$ monitor are somewhat duplicative of the Bellevue monitor, and are well below the NAAQS. Resources could best be used for monitoring elsewhere.
    3. **Discontinue the Enumclaw $PM_{2.5}$ monitor** – $PM_{2.5}$ concentrations are very low at this site, as it is far away from most sources. However the onsite ozone and meteorological measurements should be retained.
    4. **Discontinue nephelometer at Seattle-Beacon Hill** – This is a duplicative monitor. In addition, the existing $PM_{2.5}$ TEOM at this station has been upgraded to an FEM TEOM.
    5. **Encourage research opportunities to investigate the buildup of secondary nitrate in the Columbia Basin** – Model runs have consistently identified a particulate nitrate hot spot in this area, verified to some extent by the Yakima and Columbia River Gorge speciation monitors.
- **Ozone:**
    1. **Discontinue La Grande-Pack Forest station** – Although this monitor has the 2nd-highest 2009 design value, analysis of the monitoring data show that this station's trends are represented mostly by the North Bend monitor. Air flow in the area is such that ozone rich plumes are usually detected at one of the other monitors in the region, in similar concentrations as La Grande.

2. **Investigate hot spot in northeast Olympic Peninsula** – Model runs have consistently identified a hot spot in this area. Ecology first intends to verify this phenomenon with the use of a portable ozone monitor in the summer of 2010.

- **Meteorological:**
    1. **Install meteorological parameters wind speed, wind direction, and ambient temperature at existing Colville station** – Meteorological data are needed in this area to assist with air quality forecasting.
    2. **Move Burbank-Maple St. monitors to existing Kennewick-Metaline station** – Moving the Burbank meteorological monitors at the Kennewick station could result in the discontinuance of the Burbank station completely and result in considerable resource savings.
- **Other:**
    1. **Discontinue Aethalometer monitoring at Seattle-Beacon Hill –** This instrument is no longer required as part of the NATTS monitoring and is somewhat duplicative of the preferred continuous elemental and organic carbon sampler onsite.
    2. **Verify nephelometer $PM_{2.5}$ correlations –** Verification of correlations is necessary to ensure accurate estimations of $PM_{2.5}$ concentrations and provide reliable public health information from continuous $PM_{2.5}$ network.
    3. **Work with partner agencies** to collect data aimed at understanding secondary nitrate and its precursors in the Columbia Basin.

- **Wherever practical, resource-savings obtained from discontinuing monitors/stations should be reinvested in order to address the monitoring data gaps described above.**

- **As funding or resources are available, prioritize which new federal monitoring requirements will be implemented.** Forthcoming requirements include those associated with the EPA rule revision for $NO_2$and potential new requirements for ozone, SO_2, lead, and other criteria pollutants that EPA is reviewing over the next 5 years.

Acronyms, Abbreviations, and Terms

AQI	US Environmental Protection Agency's Air Quality Index
bscat	Measurement of Light Backscatter
CMAQ	Community Multi-Scale Air Quality model
CO	Carbon Monoxide
CSN	Chemical Speciation Network
EBAM	Environmental Beta Attenuation Monitor
EC	Elemental carbon
Ecology	Washington State Department of Ecology
EPA	Environmental Protection Agency
FEM	Federal Equivalent Method
FRM	Federal Reference Method
IMPROVE	Interagency Monitoring of Protected Visual Environments
MSA	Metropolitan Statistical Area
NAAQS	National Ambient Air Quality Standard(s)
NATTS	National Air Toxics Trends Station
NCore	National Core Monitoring
NH_4NO_3	Ammonium Nitrate
NO	Nitric Oxide
NO_2	Nitrogen dioxides
NO_3^-	Nitrate ion
NO_x	Nitrogen oxides
NO_Y	Reactive oxides of nitrogen
non-FRM	Non-Federal Reference Method
OC	Organic carbon
PAH	Polycyclic Aromatic Hydrocarbons
PM	Particulate matter
$PM_{2.5}$	Fine Particles or particulate matter with an aerodynamic diameter of 2.5 microns or less
$PM_{10-2.5}$	Coarse particles or particulate matter with an aerodynamic diameter between 10 and 2.5 microns
PM_{10}	Particulate matter with an aerodynamic diameter of 10 microns or more
ppm	Parts per million
PSD	Prevention of Significant Deterioration
SO_2	Sulfur Dioxide
SO_4^{2-}	Sulfate ion
TEOM	Tapered Elemental Oscillating Microbalances
TSP	Total Suspended Particulate
VOC	Volatile organic compound
WAQA	Washington Air Quality Advisory

References

Center for Biological Diversity, et al. v. EPA, 1:05-cv-01814-LFO (U. S. Dist. Ct., DC 2007).

Chen, J., J. Vaughan, J. Avise, S. O'Neill, and B. Lamb (2008). Enhancement and evaluation of the AIRPACT ozone and PM2.5 forecast system for the Pacific Northwest. Journal of Geophysical Research, 113, D14305, doi:10.1029/2007JD009554.

Communities for a Better Environment et al. v. EPA, 07-CV-03678 JSW (U. S. Dist Ct. , N. Dist Ca., San Francisco Div. 2008).

Desert Research Institute (DRI), 2010. "Climate of Washington". http://www.wrcc.dri.edu/narratives/WASHINGTON.htm (Accessed 5/19/2010)

Grayskies, 2009. Pacific Northwest Weather data, available at http://www-k12.atmos.washington.edu/k12/grayskies/nw_weather.html (Accessed 5/19/2010)

Hopke et al., (2006). Analyses of PM-Related Measurements for the Impacts of Ships. Available at http://www.arb.ca.gov/research/seca/hopkefr.pdf (Accessed 5/19/2010)

Kim, E and Hopke, PK, (2008). Source characterization of ambient fine particles at multiple sites in the Seattle area. Atmospheric Environment, 42(24), 6047-6056.

Mahmud, A., 2005. "Evaluation of the Airpact2 air quality forecast system for the Pacific Northwest". MS Thesis, Washington State University. Available at http://www.dissertations.wsu.edu/Thesis/Fall2005/a_mahmud_091605.pdf (Accessed 5/19/2010)

Naeher et al., (2007). Woodsmoke Health Effects: A Review. Inhalation Toxicology, 19 (1), 67 - 106.

PSCAA, 2009. Air Graphing tool, available at http://airgraphing.pscleanair.org (Accessed 5/19/2010)

R, 2009. "R Foundation for Statistical Computing, v2.10.1". Available for free download at http://www.r-project.org (Accessed 5/19/2010)

US Census Bureau. American Fact Finder. 2000 Census information by zip code. Available at http://factfinder.census.gov/home/saff/main.html?_lang=en (Accessed 5/19/2010)

US EPA, 2002. "Data Quality Objectives (DQOs) for Relating Federal Reference Method (FRM) and Continuous PM2.5 Measurements to Report an Air Quality Index (AQI). Available at http://www.epa.gov/ttnamti1/files/ambient/monitorstrat/aqidqor2.pdf (Accessed 5/19/2010)

US EPA, 2008a. "Environmental Benefits Analysis and Mapping Program (BenMAP) v. 3.0.14", available for free download at http://www.epa.gov/air/benmap (Accessed 5/19/2010)

US EPA, 2008b. National Ambient Air Quality Standards for Lead; Final Rule. 73 Federal Register 66964 (November 12, 2008).

US EPA, 2009a. Proposed Ambient Ozone Monitoring Regulations: Revision to Network Design Requirements. 74 Federal Register 34525 (July 16, 2009).

US EPA, 2009b. Proposed Revisions to Lead Ambient Air Monitoring Requirements. 74 Federal Register 69050 (December 30, 2009).

US EPA, 2010a. National Ambient Air Quality Standards for Ozone; Proposed Rule. 75 Federal Register 2938 (January 19, 2010).

US EPA, 2010b. Monitoring requirements in the Primary National Ambient Air Quality Standards for Nitrogen Dioxide; Final Rule adopted in 2010. 75 Federal Register 6474 (January 22, 2010).

US EPA, 2010c. Monitoring requirements in Primary National Ambient Air Quality Standard for Sulfur Dioxide. (signed June 2, 2010).

WA Dept of Ecology, 2010. Sources of Fine Particles in the Wapato Hills-Puyallup River Valley PM2.5 Nonattainment Area. Available at http://www.ecy.wa.gov/pubs/1002009.pdf (Accessed 5/19/2010)

Washington State Office of Financial Management. 2009 population estimates. Available at http://www.ofm.wa.gov/pop/april1/default.asp (Accessed 5/19/2010)

Wu et al., (2006). Source Apportionment of Seattle and Portland Air Toxics and $PM_{2.5}$ Data. Available at http://www.epa.gov/ttnamti1/files/ambient/airtox/rgirept.pdf (Accessed 5/19/2010)

Appendices

Appendix A – Continuous Fine Particulate Matter Decision Matrix

Table 8: Criteria and ranking of each continuous $PM_{2.5}$ site

Site	Name	Network Parameter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
530530029	Tacoma- L Street	FRM	1.00	1.00	0.80	0.68	1.00					1.00	0.20	0.92	0.38	0.70	0.04	7.71
530330057	Seattle-Duwamish	FRM	0.56	0.06	0.39	0.53	1.00					1.00	1.00	1.00	0.50	0.63	0.05	6.71
530770009	Yakima-4th Ave	FRM	0.81	0.64	0.86	0.81	1.00					1.00	0.28	0.53	0.25	0.14	0.13	6.46
530110013	Vancouver-Fourth Plain Rd	FRM	0.75	0.40	0.61	0.59	1.00					1.00	0.13	0.94	0.13	0.53	0.10	6.17
530630021	Spokane-Augusta Ave	FRM	0.60	0.00	0.52	0.71	1.00					1.00	0.32	1.00	0.56	0.33	0.04	6.08
530470009	Twisp-Glover St	NPM25	0.53	0.00	0.72	1.00	1.00		1.00			1.00	0.24	0.48	0.06	0.00	0.04	6.08
530611007	Marysville-7th Ave	FRM	0.74	0.36	0.61	0.57	1.00					1.00	0.07	1.00	0.13	0.17	0.35	5.99
530770015	Toppenish	NPM25	0.51	0.00	0.36	0.65	1.00	1.00				1.00	0.43	0.37	0.25	0.05	0.00	5.63
530670013	Lacey-College St	NPM25	0.68	0.24	0.48	0.59	1.00					1.00	0.13	0.93	0.06	0.16	0.18	5.46
530330080	Seattle-Beacon Hill	FRM	0.40	0.00	0.11	0.31					1.00	1.00	0.22	0.70	1.00	0.63	0.05	5.44
530710005	Walla Walla-12th St	NPM25	0.48	0.00	0.29	0.42	1.00			1.00		1.00	0.23	0.70	0.06	0.06	0.05	5.29
530332004	Kent-Central & James	TPM25	0.52	0.04	0.38	0.57	1.00					1.00	0.20	1.00	0.06	0.38	0.08	5.23
530070010	Leavenworth-Evans St	NPM25	0.49	0.00	0.30	0.59	1.00		1.00			1.00	0.10	0.42	0.06	0.01	0.08	5.06
530610005	Lynnwood-212th	NPM25	0.51	0.06	0.30	0.39	1.00					1.00	0.12	0.95	0.06	0.61	0.04	5.04
530070006	Wenatchee-Alaska Way	NPM25	0.60	0.02	0.61	0.80	1.00					1.00	0.20	0.52	0.06	0.16	0.08	5.04
530650004	Colville-Oak St S	NPM25	0.53	0.06	0.49	0.89	1.00					1.00	0.20	0.70	0.13	0.02	0.01	5.01
530331011	Seattle-South Park	NPM25	0.53	0.04	0.36	0.42	1.00					1.00	0.22	0.68	0.06	0.63	0.05	4.98
530610020	Darrington-Fir St	FRM	0.83	0.32	0.48	0.48	1.00					1.00	0.15	0.32	0.13	0.00	0.23	4.94
530330024	Lake Forest Park-Town Center	TPM25	0.44	0.02	0.21	0.32	1.00					1.00	0.09	1.00	0.06	0.61	0.00	4.76
530470010	Winthrop-Chewuch Rd	NPM25	0.39	0.00	0.10	0.47	1.00		1.00			1.00	0.13	0.38	0.06	0.00	0.16	4.70
530530031	Tacoma-Alexander Ave	NPM25	0.58	0.12	0.45	0.46						1.00	0.48	0.94	0.19	0.41	0.04	4.66
530090009	Port Angeles-W 14th St	NPM25	0.46	0.04	0.21	0.49	1.00					1.00	0.17	0.70	0.06	0.05	0.03	4.22
530351005	Meadowdale-Blackbird Dr	NPM25	0.57	0.10	0.39	0.46	1.00					1.00	0.09	0.25	0.06	0.19	0.00	4.13
530030004	Clarkston-13th St	NPM25	0.55	0.02	0.45	0.57	1.00					1.00	0.22	0.17	0.06	0.00	0.00	4.06
530370002	Ellensburg-Ruby St	NPM25	0.43	0.04	0.17	0.39	1.00					1.00	0.33	0.48	0.06	0.06	0.08	4.05
530450004	Shelton-Mt View Dr	NPM25	0.44	0.04	0.18	0.30	1.00					1.00	0.19	0.68	0.06	0.05	0.04	3.99
530150015	Longview-30th Ave	NPM25	0.40	0.00	0.12	0.26	1.00					1.00	0.21	0.67	0.06	0.14	0.03	3.90
530730015	Bellingham-Yew St	NPM25	0.37	0.00	0.06	0.23	1.00					1.00	0.15	0.70	0.06	0.19	0.10	3.87
530531018	Puyallup-128th St	NPM25	0.58	0.14	0.46	0.49	1.00						0.09	0.68	0.06	0.23	0.12	3.87
530330048	Seattle-Olive St	NPM25	0.36	0.00	0.08	0.19						1.00	0.35	0.67	0.06	1.00	0.05	3.77
530251002	Moses Lake-Balsam St	NPM25	0.36	0.00	0.03	0.24				1.00		1.00	0.23	0.59	0.06	0.02	0.19	3.72
530272002	Aberdeen-Division St	NPM25	0.36	0.00	0.04	0.22	1.00					1.00	0.27	0.70	0.06	0.06	0.00	3.71
530050002	Kennewick-Metaline	NPM25	0.44	0.00	0.19	0.32						1.00	0.23	1.00	0.13	0.17	0.16	3.64
530630047	Spokane-Monroe St	NPM25	0.39	0.00	0.21	0.49						1.00	0.18	0.90	0.06	0.33	0.04	3.61
530210002	Mesa-Pepiot Way	NPM25	0.34	0.00	0.01	0.18				1.00		1.00	0.26	0.67	0.06	0.00	0.05	3.59
530010003	Ritzville-Alder St	NPM25	0.31	0.00	0.01	0.14				1.00		1.00	0.18	0.70	0.06	0.00	0.00	3.42
530750003	Pullman-Dexter SE	NPM25	0.28	0.00	0.01	0.06				1.00		1.00	0.15	0.70	0.06	0.04	0.08	3.38
530270011	Taholah	NPM25	0.24	0.00	0.03	0.03		1.00				1.00	0.47	0.55	0.06	0.00	0.00	3.38
530270008	Oakville	NPM25	0.37	0.00	0.06	0.22		1.00				1.00	0.25	0.29	0.06	0.02	0.04	3.32
530650002	Wellpinit	NPM25	0.31	0.00	0.03	0.13		1.00				1.00	0.45	0.30	0.06	0.00	0.00	3.28
530570015	Mt Vernon-S Second St	NPM25	0.26	0.00	0.00	0.03	1.00					1.00	0.21	0.42	0.06	0.13	0.12	3.24
530090013	Cheeka Peak	NPM25	0.15	0.00	0.00	0.00					1.00	1.00		0.34	0.56	0.00	0.00	3.05
530090014	Neah Bay	NPM25	0.25	0.00	0.00	0.02		1.00				1.00	0.45	0.20	0.06	0.00	0.00	2.99
530510007	Usk	NPM25	0.23	0.00	0.01	0.03		1.00				1.00	0.28	0.29	0.06	0.00	0.00	2.90
530310003	Port Townsend-San Juan Ave	NPM25	0.40	0.00	0.11	0.26						1.00	0.16	0.70	0.06	0.04	0.05	2.79
530330017	North Bend-North Bend Way	NPM25	0.29	0.00	0.01	0.08						1.00	0.06	0.98	0.31	0.02	0.00	2.76
530530022	Puyallup-66th	NPM25	0.46	0.00	0.12	0.41		1.00					0.09	0.19	0.06	0.26	0.12	2.71
530130002	Dayton-W Main St	NPM25	0.27	0.00	0.00	0.03				1.00		1.00	0.18	0.08	0.06	0.01	0.02	2.65
530110022	Yacolt-Yacolt Rd	NPM25	0.46	0.02	0.09	0.22						1.00	0.12	0.24	0.06	0.02	0.28	2.51
530750006	Rosalia-Josephine St	NPM25	0.26	0.00	0.00	0.03				1.00			0.19	0.70	0.06	0.00	0.00	2.25
530750005	LaCrosse-Hill St	NPM25	0.27	0.00	0.01	0.05				1.00			0.12	0.70	0.06	0.00	0.00	2.21
530330023	Enumclaw-Mud Mtn.	NPM25	0.19	0.00	0.00	0.01						1.00		0.49	0.31	0.01	0.02	2.04
530330037	Bellevue-Bellevue Way	NPM25	0.31	0.00	0.03	0.13							0.07	0.67	0.06	0.45	0.07	1.80
530330028	Woodinville	NPM25	0.34	0.00	0.01	0.12							0.04	0.17	0.06	0.37	0.06	1.18

Ranking Criteria

1. **Estimated 2009 24-hour Design value** (normalized category)
2. **24-hour NAAQS Exceedances (2007-2009)** (normalized category)
3. **Program Healthy Air Goal Exceedances (2007-2009)** (normalized category)
4. **Percentage of Days Other Than Good Air Quality (2007-2009)** (normalized category)
5. **Forecasting/Curtailment Need?** ("Y" or blank where "Y" =1)
6. **Tribal Station?** ("Y" or blank where "Y" =1)
7. **USFS Station?** ("Y" or blank where "Y" =1)
8. **Agricultural-Burning Network Station?** ("Y" or blank where "Y" =1)
9. **NCORE/Potential NCORE Station?** ("Y" or blank where "Y" =1)
10. **Sole Monitor Per Air shed**
11. **Percentage of Individuals Living Below Federal Poverty Level** (normalized category)
12. **Historical Record Length** (normalized category)
13. **Number of Collocated Parameters** (normalized category)
14. **Population Represented by Monitor** (normalized category)
15. **Population Trend** (normalized category)
16. **Total Score**

$PM_{2.5}$ Decision Matrix Detail

This section describes the analyses that were conducted on the $PM_{2.5}$ monitoring network and were subsequently incorporated into the decision matrix to determine the final ranking in Table 8 above.

1. **Estimated 2009 24-hour Design value**

   Ecology estimated 2009 design values (3-year average of the 98th percentiles from the years 2007, 2008, and 2009) for official network $PM_{2.5}$ monitors. Federal Reference Method (FRM) data were used to estimate 2009 design values at the 8 stations that were equipped with an FRM (see Table 8). The official network $PM_{2.5}$ continuous monitor was used for all other stations. The 2009 98th percentile value was used in cases where data completeness was insufficient to calculate a design value. Ecology used validated data exclusively for this analysis as downloaded from EPA's Air Quality System (AQS). The statistical package "R" was used to calculate design values.

   Scores for this category were determined as follows: The monitor with the maximum design value was given a top score of "1" and all other monitors received a relative score as determined by the relationship of a given monitor's design value to the maximum monitor's design value (given monitor/maximum monitor). It should be noted that none of the Ecology network continuous $PM_{2.5}$ monitors that were operated during this time period were designated as Federal Reference or Equivalent Method (FRM or FEM). Therefore, the calculated design values cannot be used for determining compliance with the NAAQS and should be viewed only as surrogates of what pollution levels might have been had air quality been monitored by an FRM/FEM.

   Figure 24 (below) presents the relative ranking for the estimated design value analysis. Monitors are listed by station name.

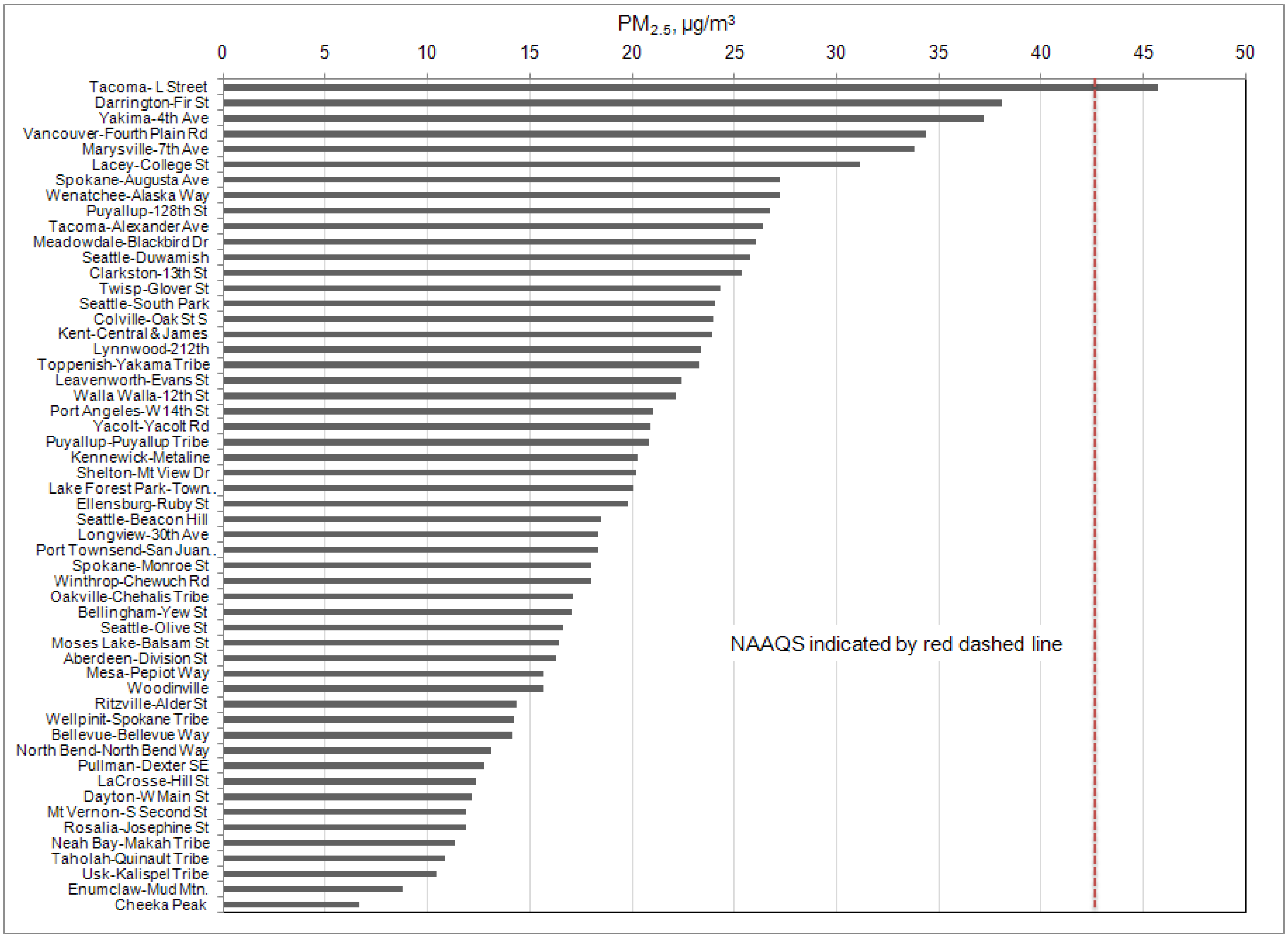

Figure 24: Estimated 2009 $PM_{2.5}$ 24-hour Design Values

2. 24-hr NAAQS Exceedances (2007-2009)

Ecology determined the number of exceedances of the 24-hr $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS) from 2007 through 2009 for each network monitor. FRM data were used to estimate the number of exceedances from 2007-2009 at the 8 stations that were equipped with an FRM (see Table 8). Because FRM sampling frequencies vary (every day, every 3rd day, every 6th day, etc.), Ecology calculated rough estimates of the number of exceedances of the 24-hour standard. As an example, in order to calculate the number of 24-hour exceedances for the three-year period 2007 through 2009 at Yakima-4th Ave. which operates on an every 3rd day sampling schedule, the number of recorded FRM 24-hour NAAQS exceedances during the period (10) was multiplied by the ratio of the total number of days (1096) to the number of valid collected samples (345) during the three year period from 2007-2009:

i.e., (10)*1096/(345) = ~32 exceedances

The official $PM_{2.5}$ continuous monitor was used for all other stations and since these run continuously, the number of exceedances was simply counted. Ecology used validated data exclusively for this analysis as downloaded from EPA's Air Quality System (AQS). Ecology used Excel to estimate the FRM exceedances and the statistical package "R" to count the number of continuous monitor 24-hour NAAQS exceedances.

Like design values, this analysis is an attempt to rank monitors in terms of the 24-hour NAAQS and weight them accordingly. However, it is different from the design value analysis in one important regard: Monitors that have high 24-hour NAAQS design values are very likely to record many (at least 8, on average per complete 365-day year) exceedances above the 24-hour NAAQS. However, some monitors that have lower design values may nevertheless record several exceedances a year, exposing people to high levels of $PM_{2.5}$ pollution. This analysis attempts to account for those monitors.

Scores for this category were determined as follows: The monitor with the maximum number of exceedances was given a top score of "1" and all other monitors received a relative score as determined by the relationship of the count of a given monitor's exceedances compared to the number of exceedances from the monitor with the maximum number of exceedances (# of exceedances/maximum # of exceedances). Figure 25 presents the number of 24-hour NAAQS exceedances during the three year period from 2007 through 2009. Monitors are listed by station name.

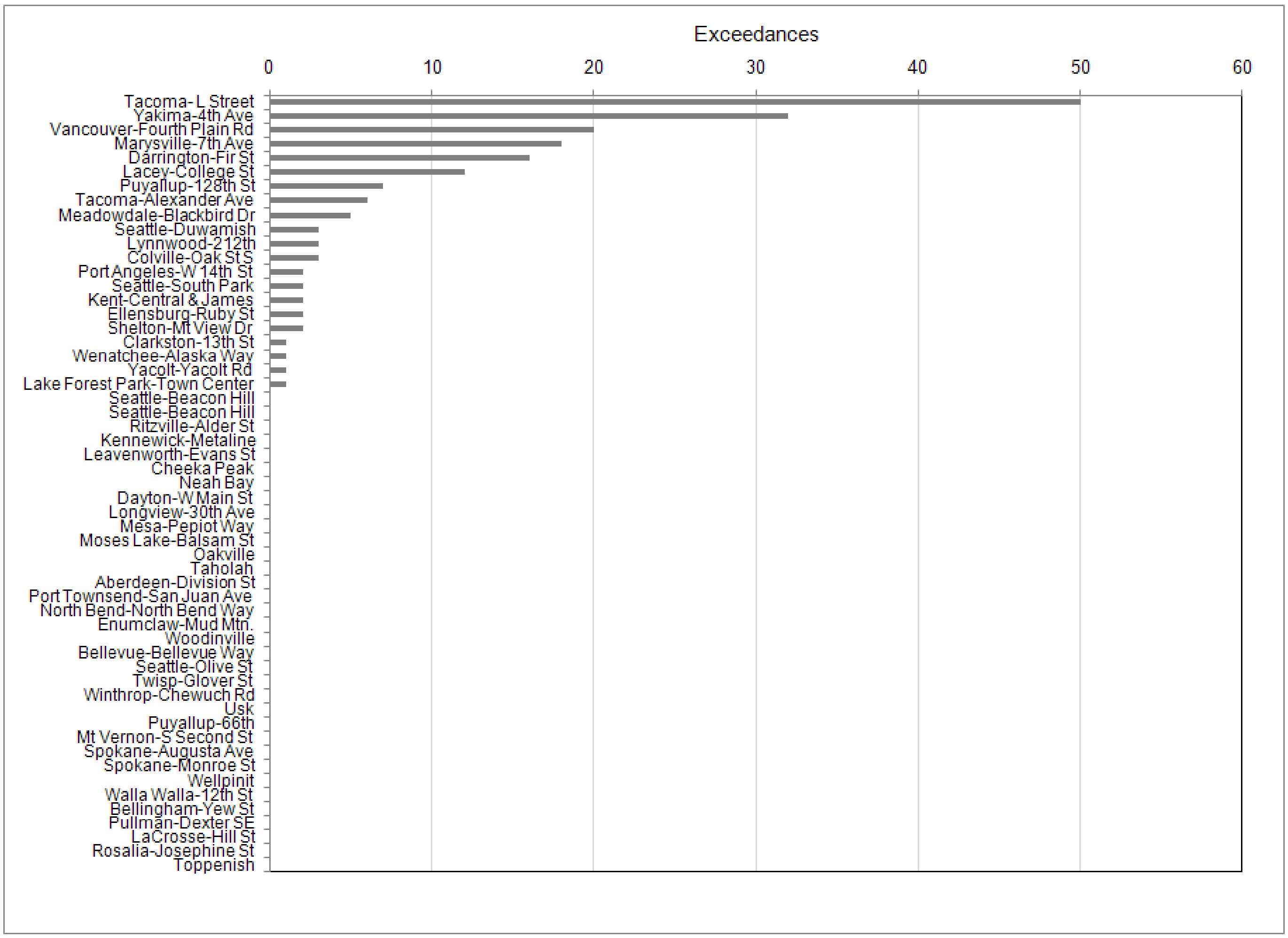

Figure 25: $PM_{2.5}$ 24-hour NAAQS Exceedances (2007-2009)

3. Ecology *Healthy Air Goal* Exceedances (2007-2009)

Hundreds of scientific studies have shown an association of health effects with $PM_{2.5}$ pollution. Data from these studies show that death and illness from exposure to $PM_{2.5}$ occur at levels lower than the EPA's 24-hour standard of 35 $\mu g/m^3$ and that health effects are not limited to highly sensitive populations. Canada's national

24-hour Canada-Wide-Standard (CWS) for $PM_{2.5}$ is 30 µg/m^3 while the World Health Organization recommends 25 µg/m^3. *In fact, epidemiologic data have not identified a threshold for $PM_{2.5}$ exposure below which no health effects are observed*.

For these reasons, Ecology has a non-regulatory *Healthy Air Goal* (HAG) of keeping $PM_{2.5}$ levels across Washington State below 20 µg/m^3, based on a 24-hour average.

This analysis attempts to identify monitors that, while not necessarily recording pollution levels high enough to exceed the NAAQS, are representative of areas where people are nevertheless being exposed to unhealthy air.

Ecology calculated the number of times each network monitor recorded 24-hour concentrations (midnight to midnight) in excess of 20 µg/m^3 from 2007 through 2009. FRM data were used to estimate the number of *HAG* exceedances from 2007-2009 at the 8 stations that were equipped with an FRM (see Table 8). Because FRM sampling frequencies vary (every day, every 3rd day, every 6th day, etc.), Ecology calculated rough estimates of the number of *HAG* exceedances during the 3 year period using the same methodology as described above in for the 24-hour NAAQS exceedances. The network $PM_{2.5}$ continuous monitor was used for all other stations and since these run continuously, the number of exceedances was simply counted. Ecology used validated data exclusively for this analysis as downloaded from EPA's Air Quality System (AQS). Ecology used Excel to estimate the number of FRM station *HAG* exceedances and the statistical package "R" was used to count the number of *HAG* exceedances from the continuous monitors.

Scores for this category were determined as follows: The monitor with the maximum number of exceedances above 20 µg/m^3 was given a top score of "1" and all other monitors received a relative score as determined by the relationship of the count of a given monitor's number of exceedances above 20 µg/m^3 as compared to the maximum number of exceedances (# of *HAG* exceedances/maximum # of *HAG* exceedances). Figure 26 presents the number of days that a given monitor exceeded the *HAG* during the three year period from 2007 through 2009. Monitors are listed by station name.

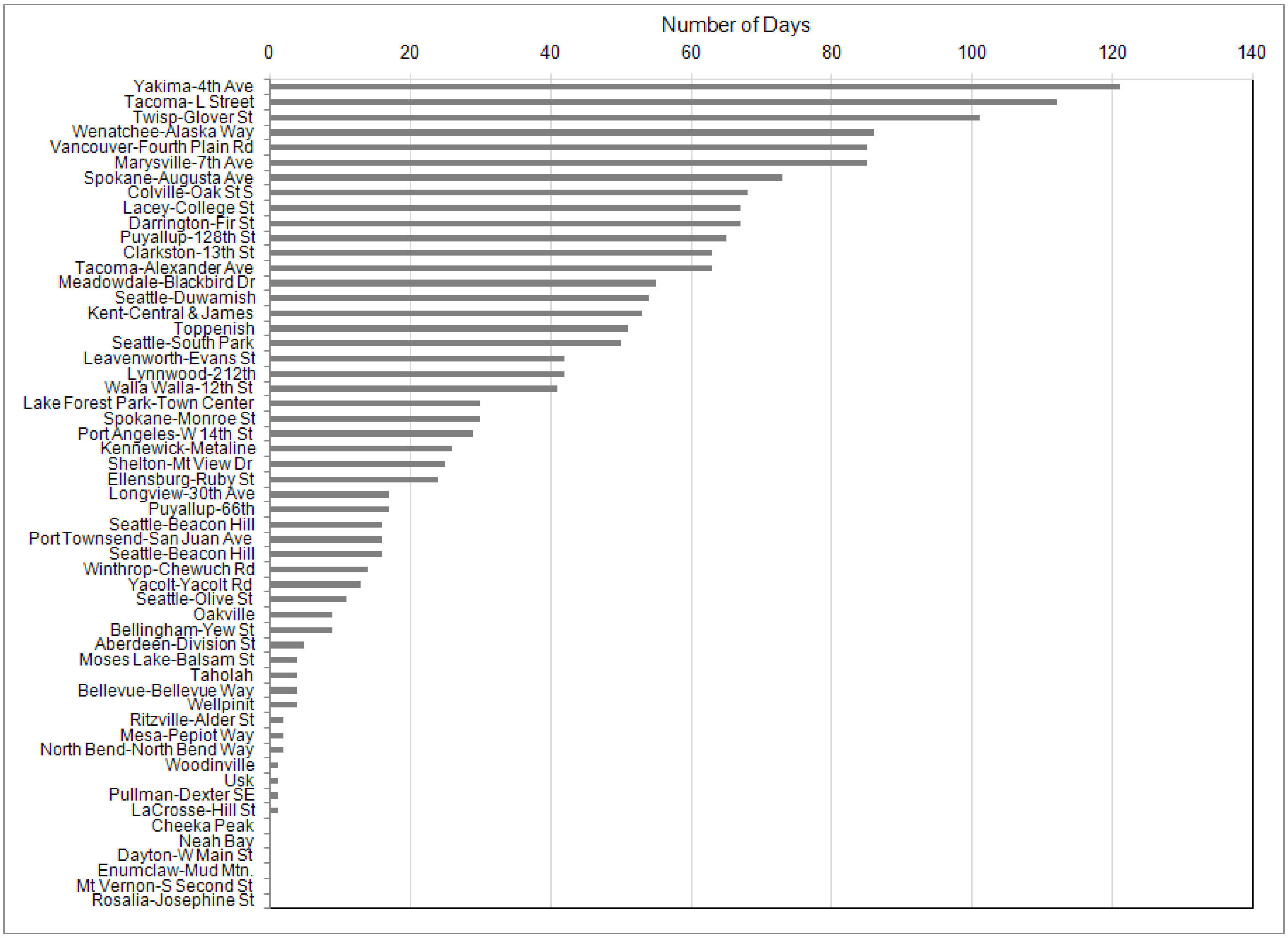

Figure 26: $PM_{2.5}$ 24-hour Exceedances of *Healthy Air Goal* (2007-2009)

4. Percentage of non-Good Monitor Days

In December of 2006, EPA lowered the 24-hour standard for $PM_{2.5}$ from 65 to 35 µg/m^3. EPA did not revise its public information tool, the Air Quality Index (AQI) to reflect the new health-based standard. Ecology needed a way to communicate accurate health risk information to Washington State citizens in lieu of federal action. For this reason, Ecology developed and implemented its own air quality public information tool known as the Washington Air Quality Advisory (WAQA). The WAQA is nearly identical to EPA's AQI except that it shows adverse health effects occurring at lower $PM_{2.5}$ pollution levels. The WAQA Good/Moderate breakpoint is defined as 13.5 µg/m^3, while the AQI breakpoint is 15 µg/m^3.

Ecology analyzed air quality conditions across the state from 2007 through 2009 to determine when $PM_{2.5}$ pollution levels were higher than the Good category. Ecology determined the number of times each monitor recorded a 24-hour average (midnight to midnight) in excess of 13.5 µg/m^3 (i.e., the number of days that air quality was anything other than Good) during the 3-year period from 2007 through 2009. FRM data were used to estimate the number of non-Good days from 2007-2009 at the 8 stations that were equipped with an FRM (see Table 8). Because FRM sampling frequencies vary (every day, every 3rd day, every 6th day, etc.), Ecology calculated rough estimates of the number of exceedances of the 24-hour standard as described above. The network $PM_{2.5}$ continuous monitor was used for all other stations and since these run continuously, the number of exceedances was simply counted. The number of non-Good days was then divided by the total number of complete monitor days possible during the 3-year period to come up with a percentage of non-Good days. Ecology used validated data exclusively for this analysis as downloaded from EPA's Air Quality System (AQS). Ecology used Excel to estimate the number of non-Good days from the FRMs and the statistical package "R" was used to count the number of non-Good days from the continuous monitors.

This analysis is unique in that several monitors that do not rank high in the previous three analyses rank high in this analysis. Many of the monitors with high design values are located in communities that experience several short, relatively infrequent episodes of very high $PM_{2.5}$ pollution concentrations but good air quality the majority of the rest of the time. The design value and exceedance analyses do a good job of identifying these monitors. However, these analyses don't do well in identifying locations with longer episodes of impaired air at lower (non-Good) pollution levels. A clear example of this phenomenon occurs in Wenatchee. The Wenatchee continuous $PM_{2.5}$ monitor's design value was 27.1 µg/m^3; well below the NAAQS. For the same period (2007 through 2009), the monitor in Wenatchee recorded only a single exceedance above the 24-hour standard of 35 µg/m^3. Though it recorded a fairly large number of days over the Ecology *Healthy Air Goal* of 20 µg/m^3 (86 days), by comparison, it recorded an extremely large number of days (214) that were outside the Good WAQA category (over 20% of the monitored days). Obviously, even though the air quality in Wenatchee is not close to violating the NAAQS, on average, air quality is impaired to some degree one out of every 5 days over the last 3 years. This analysis identifies monitors like the one in Wenatchee.

Scores for this category were determined as follows: The monitor with the maximum percentage of non-Good days was given a top score of "1" while all other monitors received a relative score as determined by the relationship of the percentage of a given monitor's non-Good days to the maximum percentage of non-Good days (percentage of non-Good days/maximum percentage of non-Good days). Figure 27 presents the percentage of days (24 hours, midnight to midnight) that were anything other than Good based on the monitor data during the three year period from 2007 through 2009. Monitors are listed by station name.

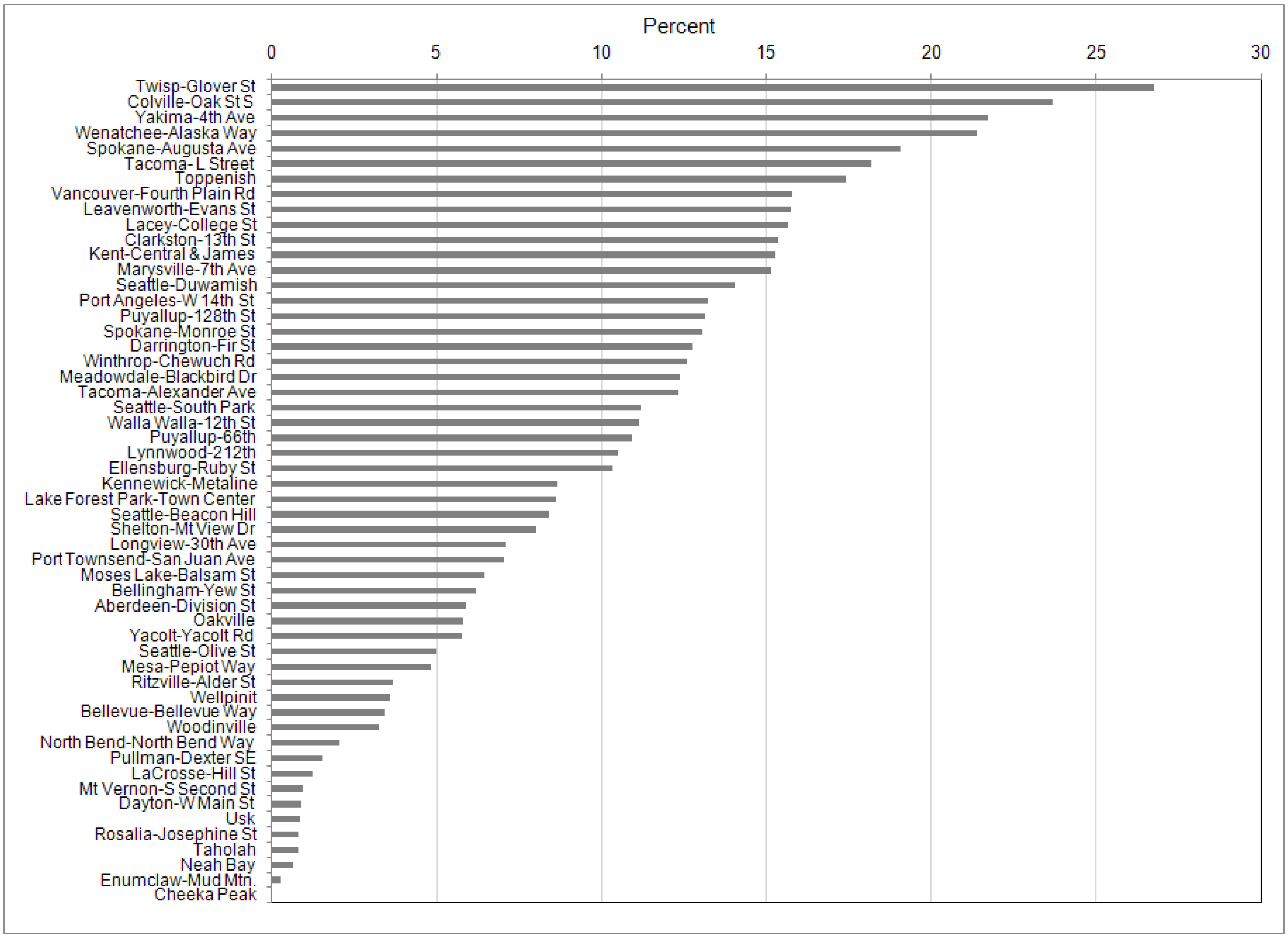

Figure 27: $PM_{2.5}$ Non-Good Days (2007-2009)

5. Forecasting/Curtailment Need?

Along with its partners at EPA, local air agencies and tribes, Ecology uses its network continuous $PM_{2.5}$ monitors for the forecasting of air quality and for making woodstove/outdoor burn curtailment calls during episodes of impaired air.

Making defensible curtailment calls is critical to Ecology and its partners' work of protecting public health, preventing exceedances and violations of the NAAQS, and ensuring our credibility with the public and the regulated community. Monitors that allow us to successfully conduct this work are very important. This analysis accounts for the importance of this need.

This is a yes or blank category. Any monitor that is used for forecasting/curtailment calls received a "Y". A "Y" (for yes) is worth 1 point.

6. Tribal Station?

Ecology partners with EPA to provide continuous $PM_{2.5}$ monitoring on tribal lands located within the boundaries of Washington State. These monitors are used by EPA and tribal nations to ensure compliance with Federal Air Rules for Reservations (FARR) and make curtailment calls. It should be noted that while these air monitors are located within tribal boundaries, they provide useful information for both those inside and outside the reservation.

These monitors are funded by EPA.

This is a yes or blank category. Any monitor that is part of Ecology's contractual agreement with EPA for conducting monitoring on tribal lands within Washington State received a "Y". A "Y" (for yes) is worth 1 point.

7. USFS Station?

Ecology partners with the U.S. Department of Agriculture Forest Service (USFS) to provide continuous $PM_{2.5}$ monitoring on USFS lands located within the boundaries of Washington State. These monitors are used by USFS to characterize smoke impacts associated with prescribed silvicultural burning. It should be noted that while these air monitors are located on USFS land, they provide useful public health information for those living in communities or recreating near national forests.

These monitors are funded by the USFS.

This is a yes or blank category. Any monitor that is part of Ecology's contractual agreement with the USFS for conducting monitoring on USFS lands within Washington State received a "Y". A "Y" (for yes) is worth 1 point.

8. Agricultural Burning Station?

As a result of a federal court case settlement, several years ago Ecology implemented a sub-network of 8 continuous $PM_{2.5}$ monitors to assist with smoke management associated with agricultural burning in Eastern Washington. Specifically, these monitors - along with information from meteorological monitors, field reports, burn permit applications and both meteorological and atmospheric dispersion models - are used on a daily basis by Ecology to make burn decisions. These monitors are both a vital resource for the proper implementation of the agricultural burn smoke management program and for evaluating the performance thereof.

This is a yes or blank category. Any monitor that is part of the agricultural burning network received a "Y". A "Y" (for yes) is worth 1 point.

9. NCORE/Potential NCORE?

Ecology recognizes the importance of the EPA's National Core Monitoring (NCORE) and that NCORE status should be included as a factor in the prioritization of the $PM_{2.5}$ monitoring network. This category identifies monitors located at stations that are, or are pending designation as, NCORE pursuant to EPA's Core Monitoring Strategy.

This is a yes or blank category. Any monitor that is located at a station that is, or is pending, NCORE designation received a "Y". A "Y" (for yes) is worth 1 point.

10. Sole monitor Per Air shed?

Ecology sought to identify redundancies in its $PM_{2.5}$ monitoring network. Resource savings may be achieved in areas where monitors provide redundant information on air quality by the elimination of one or more of the redundant monitors.

To this end, Ecology examined several monitors that appeared to be close enough in spatial proximity to yield redundant information. It should be noted that the topography, meteorology and emissions in Washington, particularly Western Washington, are quite heterogeneous as compared to other areas of the country, such as the Midwest. For this reason, the guidance and tools provided by EPA for identifying redundancies in monitoring were not particularly useful for Washington State. Specifically, cross-comparing stations as suggested by EPA, and calculating correlation matrices was of little utility as many stations with high R^2 values nevertheless represented unique air sheds, including those within the same metropolitan statistical areas.

Therefore, Ecology examined a variety of factors for monitors that were believed to be in the same air shed to determine whether redundant information was being collected. Ecology looked at how well trends tracked each other as well as the magnitude of those trends in a variety of ways. Sites with $R^2 > 0.7$ from the EPA correlation matrices were also examined this way, even though many such site pairs were clearly located in separate air sheds. Ecology then ran the comparisons shown in Figure 28, and found that the majority of $PM_{2.5}$ monitoring stations in the Ecology network provided unique information.

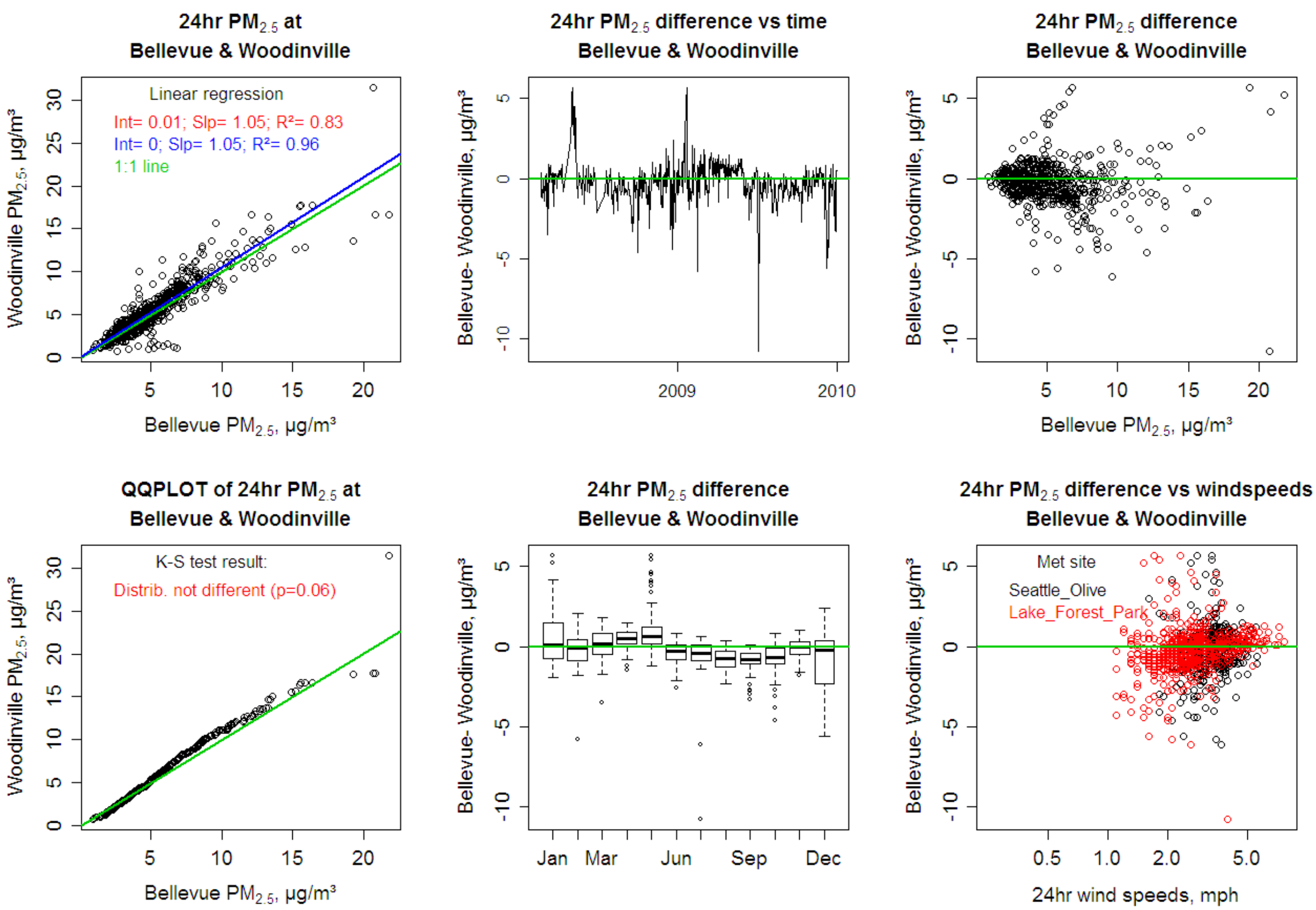

Figure 28: Inter-comparison of Bellevue and Woodinville $PM_{2.5}$

Figure 28 shows the inter-comparison of Bellevue and Woodinville nephelometers. (a) Shows a scatterplot, with different regression lines. Forcing the intercept to zero does not change the slope much. (b) $PM_{2.5}$ difference as a function of time suggests that differences are not confined to a particular period. (c) $PM_{2.5}$ difference as a function of Bellevue $PM_{2.5}$. The plot suggests the sites deviate randomly, and not when Bellevue is more/less polluted. (d) Quantile-quantile plot, suggesting data are similarly distributed, as confirmed by the Kolmogorov-

Smirnov (K-S) Test. (e) No clear seasonal dependence of differences between sites is seen. (f) While some data deviate at lower wind speeds (i.e. suggesting localized sources impact one site and not the other), for the most part the differences are not correlated with winds.

This is a yes or blank category. Any monitor that was identified as being the sole monitor for an air shed/area received a "Y". A "Y" (for yes) is worth 1 point.

11. Percentage of Individuals Living Below the Federal Poverty Level

Ecology believes it is important to consider issues of environmental justice when evaluating its air pollution monitoring network. EPA defines environmental justice as follows:

> Environmental Justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, culture, education, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair Treatment means that no group of people, including racial, ethnic, or socioeconomic groups, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal environmental programs and policies. Meaningful Involvement means that: (1) potentially affected community residents have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; (2) the public's contribution can influence the regulatory agency's decision; (3) the concerns of all participants involved will be considered in the decision-making process; and (4) the decision-makers seek out and facilitate the involvement of those potentially affected (EPA, 2010).

Ecology analyzed the value of its $PM_{2.5}$ monitors in terms of environmental justice. Ecology determined the appropriate representative zip code for each monitor and used the US Census Bureau's American Fact Finder website to determine the percentage of individuals living below the federal poverty level (FPL) within the zip code in which each monitor was located.

There are some caveats that accompany this analysis:

- The metric of percentage of individuals living below the FPL may or may not be the best indicator of environmental justice but was considered a reasonable surrogate for the purposes of this analysis.
- Zip codes vary in size and shape, monitors may straddle more than a single zip code, and zip codes may encompass only a portion of the air shed that the monitor represents. Nevertheless, for the purposes of this analysis, zip codes were seen as a reasonable surrogate for spatial coverage of a monitor. In addition, this information was easily obtained via the US Census Bureau American Fact Finder website.
- Because recent poverty estimates were unavailable for many monitor-zip codes statewide, Ecology used 2000 Census poverty information only. This means that the information is somewhat out of date. However, for the purposes of this analysis, it was believed that 2000 data would provide reasonable information, even though the magnitudes of individuals living in poverty may have changed.

Areas with higher percentage of individuals living in poverty received higher scores

Scores for this category were determined as follows: The monitor located within the zip code with the highest percentage of individuals living in poverty received a top score of "1" while all other monitors received relative scores as determined by the relationship of the percentage of individuals living in poverty for a given monitor-zip code to the maximum percentage individuals living in poverty (percentage of individuals in poverty/maximum percentage). Figure 29 presents the percentage of individuals living in poverty by monitor-zip code. Monitors are listed by station name.

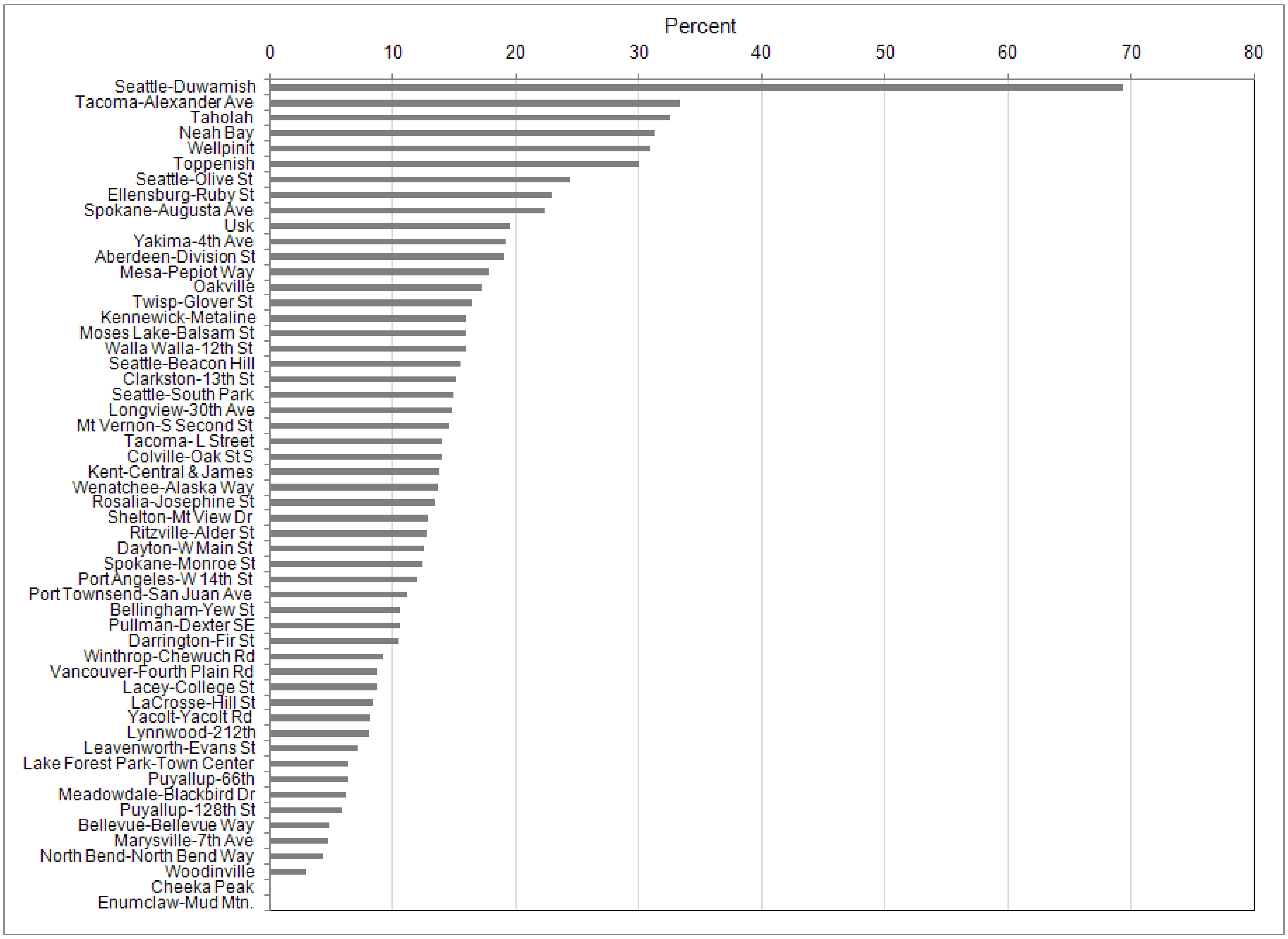

Figure 29: Percentage of Individuals Living Below FPL by Zip Code

12. Length of Historical Record

Monitors with long historical records are particularly useful for characterizing air quality over time and tracking efficacy of control measures. Likewise, monitors with long records can provide sound historical pollution information for future policy choices.

Ecology evaluated the length of the historical record length for each of its network $PM_{2.5}$ monitors. Monitors with longer records received higher scores. Ecology downloaded monitor start dates from AQS for this analysis.

Scores for this category were determined as follows: The monitor with the longest record received a top score of "1" while all other monitors received relative scores as determined by the relationship of the length of given monitor's record to the longest record (length of record/maximum record length).

13. Number of Collocated Network Parameters

Cost-savings are leveraged at stations with multiple monitors. At these stations, operators can perform maintenance or quality control checks on several instruments during the same visit, resulting in operational and maintenance cost savings per-monitor. Therefore, Ecology evaluated the total number official network monitors at each station equipped with a network $PM_{2.5}$ monitor. Ecology used AQS to count the number of network parameters per station for this analysis.

Scores for this category were determined as follows: The monitor collocated with the greatest number of network monitors received a top score of "1" while all other monitors received relative scores as determined by the relationship of a given monitor's number of collocated network monitors to the maximum number of collocated monitors (number of collocated monitors/maximum number of collocated monitors).

14. Population Represented By Monitor

Exposure increases as a function of population for a given area. In other words, more people are likely to be exposed to a given pollution concentration in a relatively densely populated area than in a less-densely populated one.

While it would have been ideal to determine exposure using air sheds, doing so for each monitor was deemed to be too resource-intensive and was therefore not pursued. Instead, as a surrogate for human exposure, Ecology used Office of Financial Management (OFM) 2007 Washington population estimates at the 12 km grid resolution to determine the population represented by a given monitor.

In general, this analysis provided reasonable estimates of the number of people represented by a given monitor. It should be noted, however, that the vast majority of Ecology's $PM_{2.5}$ monitors are designated Neighborhood Scale and therefore are technically only representative of air quality conditions within a 4 km radius from the monitor. In addition, estimates of represented population in urban areas such as Seattle were complicated by the fact that one 12 km grid cell contained three monitors. In such cases, each monitor within the grid cell was estimated to represent the population for the entire grid cell and thus population exposure is probably overestimated for these monitors. However, because these monitors are located in densely populated areas, Ecology believed that its analysis nonetheless provided reasonable approximations of relative exposure by monitor and was a reasonable surrogate for more precise estimates.

Ecology used the Environmental Benefits Mapping & Analysis Program (BenMAP) to compile monitor-represented population estimates from the OFM census data at the 12 km grid resolution.

Scores for this category were determined as follows: The monitor representing the largest population was awarded a score of "1" and all other monitors received a relative score as determined by the relationship of the population represented by the monitor (monitor-population) to the maximum represented population (monitor-population/maximum monitor-population). As mentioned previously, there were three monitors that fell within the same 12 km grid cell. This grid cell had the maximum population and therefore, there were three monitors with a score of "1". Figure 30 presents the estimated population represented by each $PM_{2.5}$ monitor. Monitors are listed by station name.

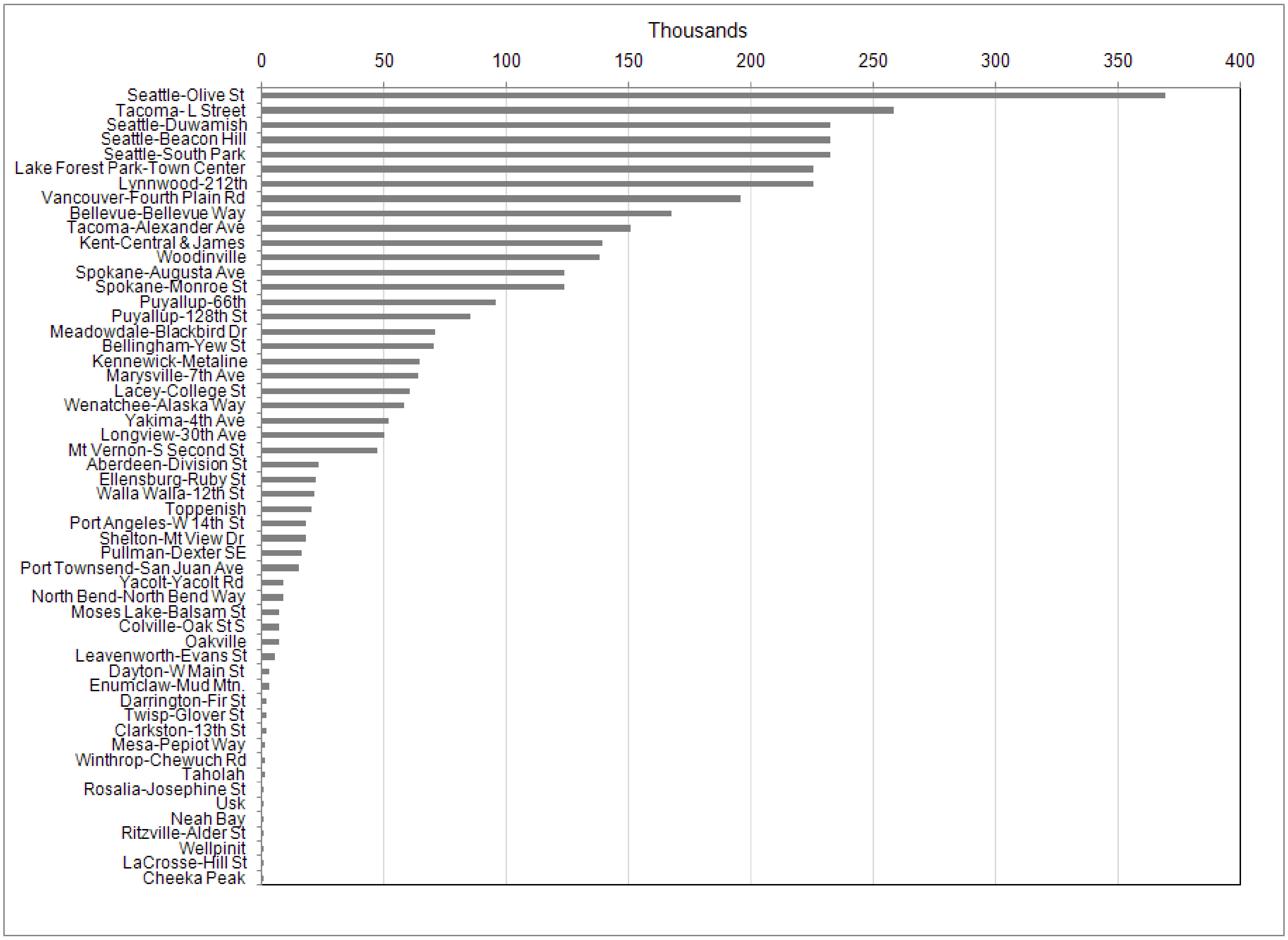

Figure 30: Population Represented by $PM_{2.5}$ Monitor

15. Population Trend

Communities with rapidly growing populations may be at higher risk of worsening air quality conditions over time due to increases in vehicle traffic, industry, and other factors.

Ecology evaluated population trends by city in an attempt to identify areas of rapid population growth using data available through the Washington State Office of Financial Management (OFM) website. Ecology used OFM's 2009 estimates (2000 baseline), for the purposes of this analysis.

Cities with rapidly growing populations received higher scores.

Scores for this category were determined as follows: The monitor located within the city (station-city) with the fastest growing population received a top score of "1" while all other monitors received relative scores as determined by the relationship of a given monitor-city's population growth to the maximum population growth (pop. growth/maximum pop. growth).

Appendix B – Ozone Decision Matrix

Table 9: Ranking criteria for each Ozone monitoring site

AQS Number	Site Name	Network Parameter	1	2	3	4	5	6	7	8	9
530330023	Enumclaw-Mud Mtn.	O3	1.00	1.00	1.00	0.31	0.72	1.00		1.00	6.03
530330010	Issaquah-Lake Sammamish	O3	0.80	0.11	0.20	0.06	1.00	1.00		1.00	4.18
530330017	North Bend-North Bend Way	O3	0.81	0.22	0.31	0.31	0.34	1.00		1.00	4.01
530330080	Seattle-Beacon Hill	O3	0.62	0.00	0.00	1.00	0.38		1.00	1.00	4.00
530110011	Vancouver-Blairmount Dr	O3	0.83	0.11	0.31	0.31	0.35	1.00		1.00	3.91
530531008	LaGrande-Pack Forest	O3	0.89	0.44	0.71	0.06	0.72	1.00			3.83
530630046	Spokane-Greenbluff	O3	0.82	0.00	0.31	0.06	0.58	1.00		1.00	3.78
530670005	Yelm-Northern Pacifc	O3	0.79	0.11	0.20	0.06	0.37	1.00		1.00	3.54
530090013	Cheeka Peak	O3	0.70	0.00	0.00	0.56	0.11		1.00	1.00	3.38
530530012	Mt Rainier-Jackson Visitors Ctr	O3	0.74	0.00	0.14	0.06	0.34	1.00		1.00	3.29
530630001	Cheney-Turnbull	O3	0.78	0.00	0.00	0.06	0.32	1.00		1.00	3.16
530730005	Custer-Loomis	O3	0.63	0.00	0.00	0.06	0.61			1.00	2.30

Ranking criteria

1. **Estimated 2009 Design Value** (normalized category)
2. **Number of 8-hour Exceedances (2007-2009)** (normalized category)
3. **Number of 8-hour Daily Maximums Above .060 ppm** (normalized category)
4. **Number of Collocated Network Parameters** (normalized category)
5. **Historical Record Length** (normalized category)
6. **Forecasting/Action Day Need?** ("Y" or blank where "Y" =1)
7. **NCORE/Potential NCORE?** ("Y" or blank where "Y" =1)
8. **Non-redundant Monitor?** ("Y" or blank where "Y" =1)
9. **Total Score**

Ozone Decision Matrix Detail

This section describes the analyses that were conducted on the ozone monitoring network and were subsequently incorporated into the decision matrix to determine the final ranking in Table 9 above.

1. Estimated 2009 8-hour Design value

Ecology estimated 2009 8-hour design values (3-year average of the annual 4th-highest daily maximum 8-hour average from the years 2007, 2008, and 2009) for ozone network monitors that met the 75% annual data completeness criteria. Ecology used validated data exclusively for this analysis as downloaded from EPA's Air Quality System (AQS). The statistical package "R" was used to calculate design values.

Scores for this category were determined as follows: The monitor with the maximum design value was given a top score of "1" and all other monitors received a relative score as determined by the relationship of a given monitor's design value to the maximum design value (given design value/maximum design value). Figure 31 presents the relative ranking for the estimated design value analysis. Monitors are listed by station name.

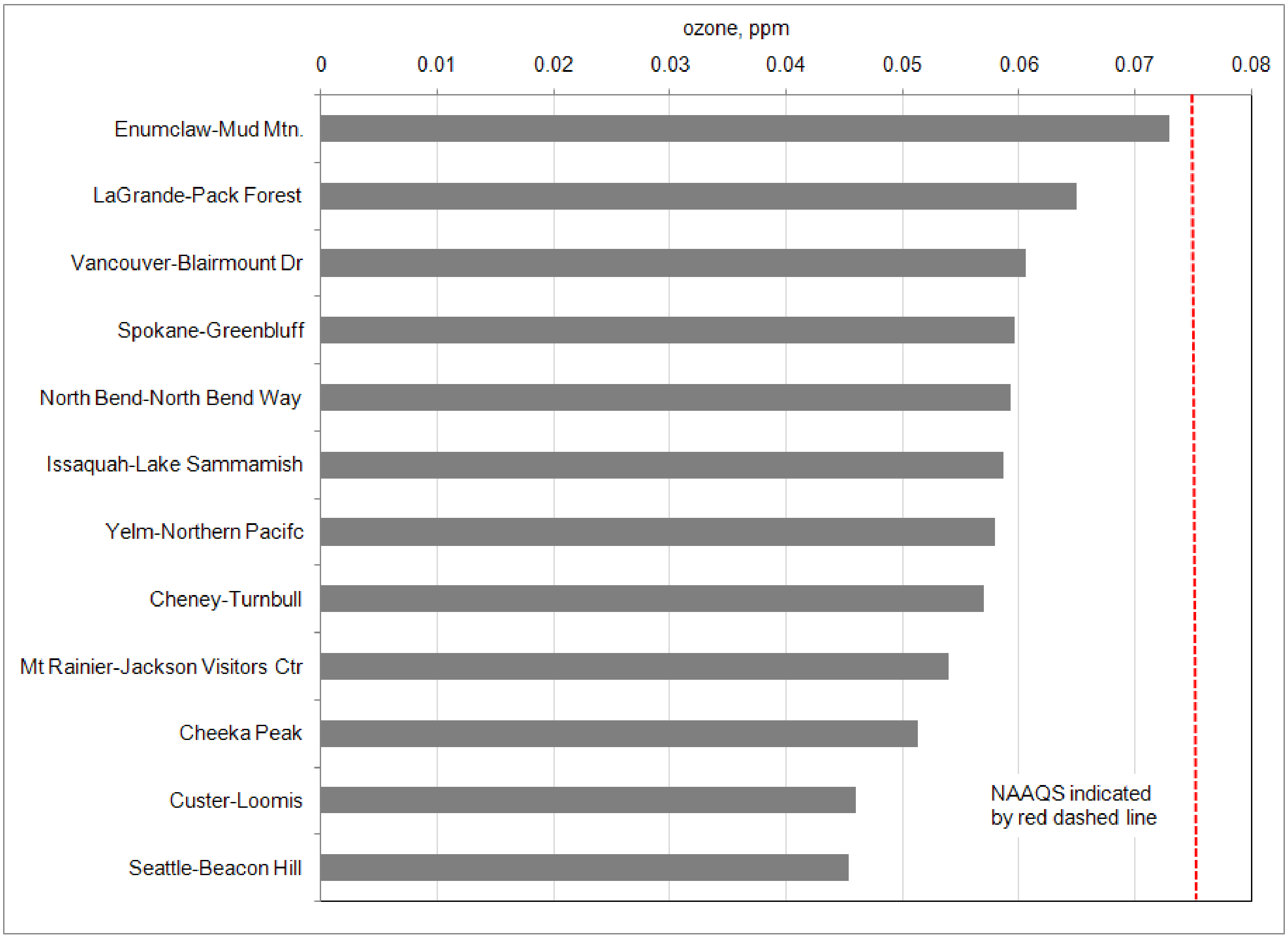

Figure 31: Estimated 2009 8-hour Ozone Design Values

2. Number of 8-hour NAAQS Exceedances (2007-2009)

Ecology determined the number of exceedances of the 8-hour ozone National Ambient Air Quality Standard (NAAQS) of .075 ppm for the 3 year period from 2007 through 2009 for each network monitor. Ecology used validated data exclusively for this analysis as downloaded from EPA's Air Quality System (AQS). The statistical package "R" was used to count the number of 8-hour NAAQS exceedances.

Like design values, this analysis is an attempt to rank monitors in terms of the 8-hour NAAQS and weight them accordingly. However, it is different from the design value analysis in one important regard: Monitors that have high 8-hour NAAQS design values are very likely to record many exceedances above the 8-hour NAAQS. However, some monitors that have lower design values may nevertheless record several exceedances a year, exposing people to high levels of ozone pollution. This analysis attempts to account for those monitors.

Scores for this category were determined as follows: The monitor with the maximum number of exceedances was given a top score of "1" and all other monitors received a relative score as determined by the relationship of the count of a given monitor's exceedances compared to the maximum number of exceedances (# of exceedances/maximum # of exceedances). Figure 32 presents the number of 8-hour ozone NAAQS exceedances by monitor. Monitors are listed by station name.

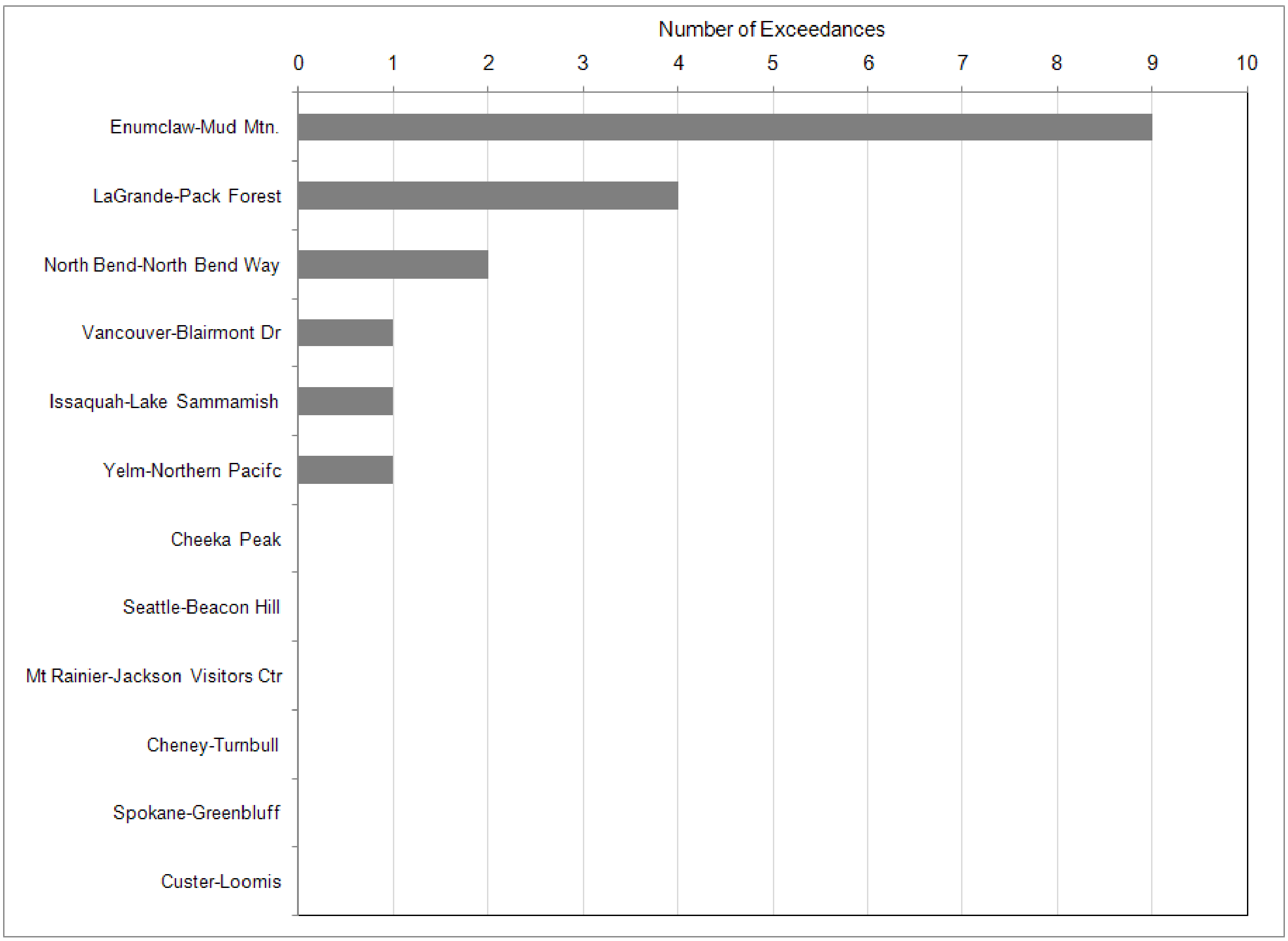

Figure 32: Ozone Monitor 8-hour NAAQS Exceedances (2007-2009)

3. Number of Daily Maximum 8-hour Concentrations Above .060 ppm (2007-2009)

Ecology analyzed the ozone network to determine when ozone pollution levels were anything other than Good as defined by EPA's Air Quality Sub-index for ozone (the breakpoint of which is .060 ppm). This analysis attempts to identify monitors that, while not necessarily recording pollution levels high enough to exceed the NAAQS, are representative of areas where people are nevertheless being exposed to unhealthy air. Currently, EPA has proposed a revised 8-hour ozone standard between .060 and .070 ppm. This analysis therefore also ranks monitors in terms of the lower end of EPA's proposed standard range.

Ecology determined the number of times each monitor recorded a daily maximum 8-hour average in excess of .060 ppm during the 3-year period from 2007 through 2009. Ecology used validated data exclusively for this analysis as downloaded from EPA's Air Quality System (AQS). The statistical package "R" was used to count the number of non-Good days.

Scores for this category were determined as follows: The monitor with the maximum number of daily maximum 8-hour concentrations greater than .060 ppm was given a top score of "1" and all other monitors received a relative score as determined by the relationship of the count of a given monitor's daily maximums above .060 ppm as compared to the maximum number of daily maximums above .060 ppm (# of daily maximums > .060/maximum # of daily maximums > .060 ppm). Figure 33 presents the number of days that monitors recorded a daily maximum 8-hour concentration in excess of .060 ppm (i.e., a day that was other than Good). Monitors are listed by station name.

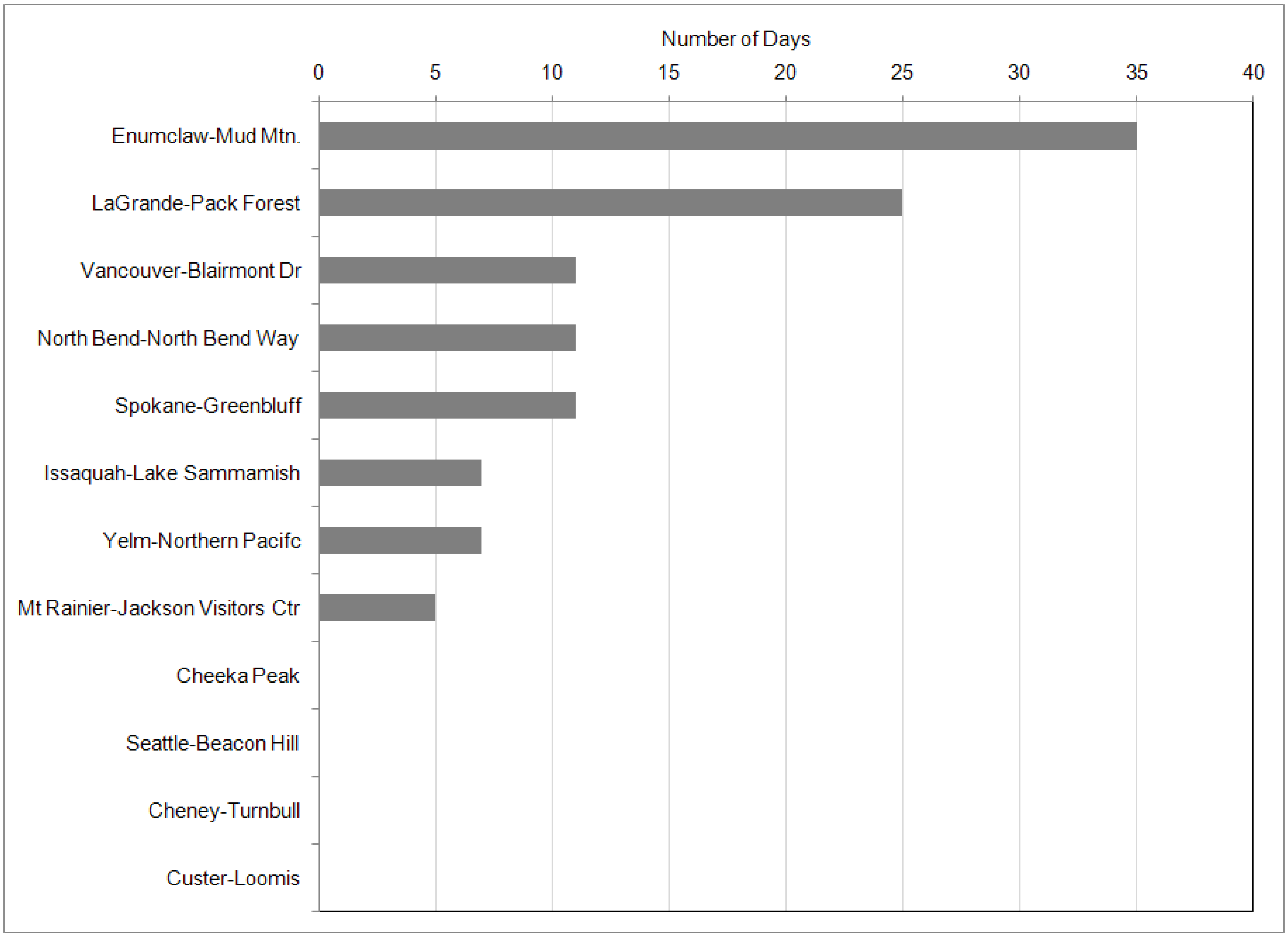

Figure 33: Ozone 8-hour Daily Maximum Concentrations Above .060 ppm (2007-2009)

4. Forecasting/Action-Day Need?

Ecology and its partners use the network ozone monitors for the forecasting of air quality and for announcing ozone action days during summertime episodes.

Making defensible action-day calls is critical to Ecology and its partners' work of protecting public health, preventing exceedances and violations of the NAAQS, and ensuring our credibility with the public. Monitors that allow us to successfully conduct this work are very important. This analysis accounts for the importance of this need.

This is a yes or blank category. Any monitor that is used for forecasting/action-day calls received a "Y". A "Y" (for yes) is worth 1 point.

5. NCORE/Potential NCORE?

Ecology recognizes the importance of the EPA's National Core Monitoring (NCORE) and that NCORE status should be included as a factor in the prioritization of the ozone monitoring network. This category identifies monitors located at stations that are, or are pending designation as, NCORE pursuant to EPA's Core Monitoring Strategy.

This is a yes or blank category. Any monitor that is located at a station that is, or is pending, NCORE designation received a “Y”. A “Y” (for yes) is worth 1 point.

6. Length of Historical Record

Monitors with long historical records are particularly useful for characterizing air quality over time and tracking the efficacy of control measures. Likewise, monitors with long records can provide sound historical pollution information for future policy choices.

Ecology evaluated the length of the historical record length for each of its network ozone monitors. Monitors with longer records received higher scores. Ecology downloaded monitor start dates from AQS for this analysis.

Scores for this category were determined as follows: The monitor with the longest record received a top score of “1” while all other monitors received relative scores as determined by the relationship of the length of given monitor’s record to the longest record (length of record/maximum record length).

7. Number of Collocated Network Parameters

Cost-savings are leveraged at stations with multiple monitors. At these stations, operators can perform maintenance or quality control checks on several instruments during the same visit, resulting in operational and maintenance cost savings per-monitor. Therefore, Ecology evaluated the total number official network monitors at each station equipped with an ozone monitor. Ecology used AQS to count the number of network parameters per station for this analysis.

Scores for this category were determined as follows: The monitor collocated with the greatest number of network monitors received a top score of “1” while all other monitors received relative scores as determined by the relationship of a given monitor’s number of collocated network monitors to the maximum number of collocated monitors (number of collocated monitors/maximum number of collocated monitors).

8. Non-redundant Monitor?

Ecology sought to identify redundancies in its ozone monitoring network. Resource savings may be achieved in areas where monitors provide redundant information on air quality by the elimination of one or more redundant monitors.

To this end, Ecology examined several monitors that would reasonably be expected to yield redundant information. It should be noted that the topography, meteorology and emissions in Washington, particularly Western Washington, are quite heterogeneous as compared to other areas of the country, such as the Midwest. For this reason, the guidance and tools provided by EPA for identifying redundancies in monitoring were not particularly useful for Washington State.

Of the eleven ozone site pairs that were compared, Figure 34 suggests that the North Bend and La Grande sites may depict similar trends.

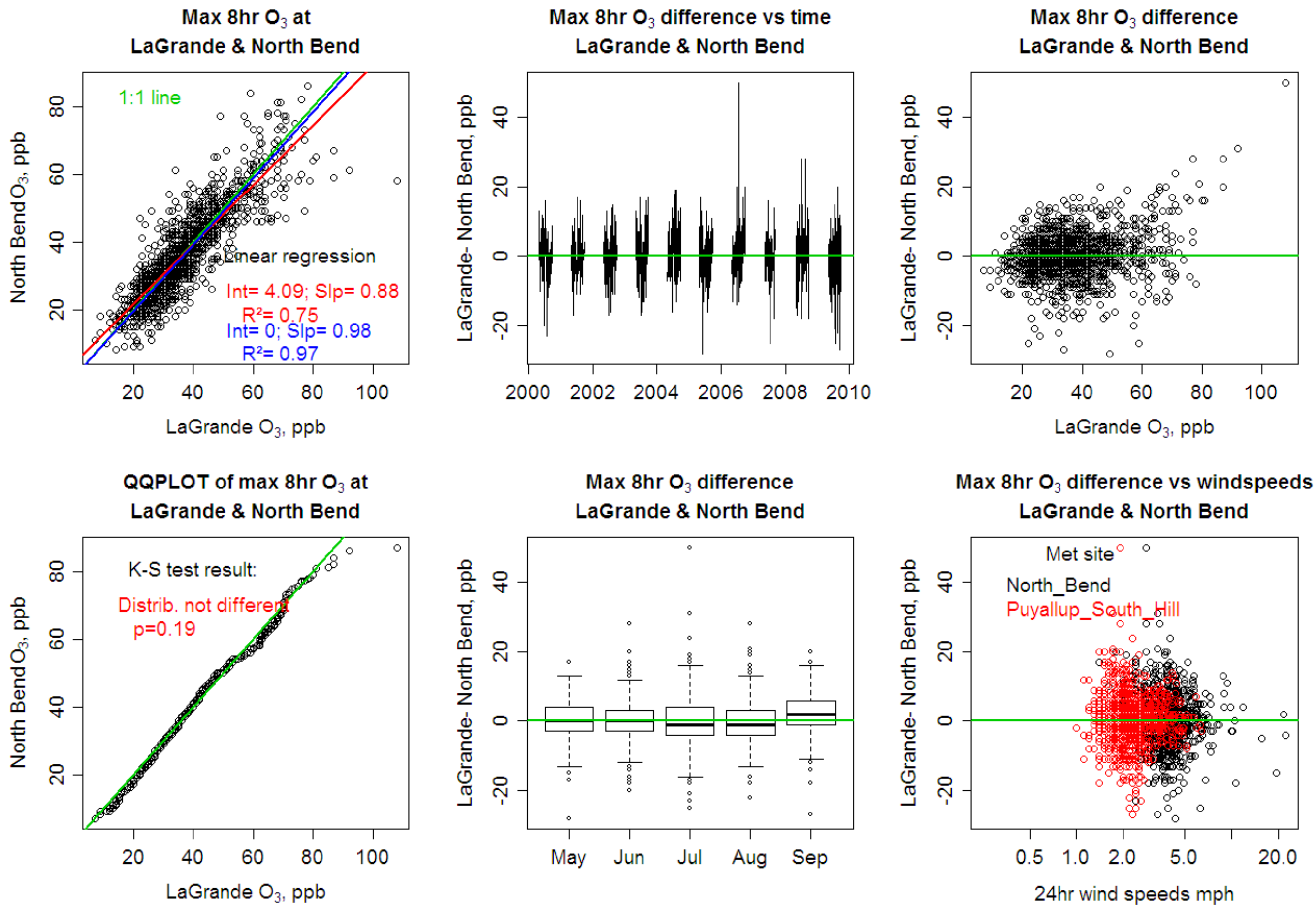

Figure 34: Intercomparison of North Bend and La Grande Ozone

Figure 34 presents the intercomparison of North Bend and La Grande ozone monitors. (a) Shows a scatterplot, with different regression lines. Data appear somewhat similar. (b) Ozone difference as a function of time. Other than a few events, the differences are not pronounced during a particular period. (c) Ozone difference as a function of La Grande ozone. The plot suggests that there are a few instances (27 days in 10 years) when high ozone events recorded at La Grande are not captured in North Bend*. Otherwise, most of the differences between sites appear to be random in nature. (d) Quantile-quantile plot, suggesting data are similarly distributed. The K-S test can be considered close to significant, if a probability of <95% is acceptable. (e) Differences between sites by month shows no clear monthly dependence. (f) Differences by wind speeds recorded at nearest met sites. Other than the extreme events recorded at La Grande, which occurred during moderate easterly winds*, for the most part the differences are not correlated with winds.

* Days when La Grande was over 60 ppb and North Bend lagged by at least 5 ppb. These events were characterized by easterly cross-Cascade flow, which, coupled with the northerly regional flow, drives the ozone plume toward the south/southwest of the Puget Sound lowlands and away from North Bend. Depending on the strength of the easterly gradients, this pattern gives rise to comparable or higher ozone levels either at the Yelm or Enumclaw monitors. It is felt that little information will be sacrificed by shutting down the standalone ozone station at La Grande, as comparable concentrations are expected either at Enumclaw, North Bend or Yelm on most high ozone days.

This is a yes or blank category. Any monitor that is considered to provide non-redundant data/information received a “Y”. A “Y” (for yes) is worth 1 point.