

**A. ANALYSIS**

The air quality surrounding Seattle-Tacoma International Airport is affected by numerous sources and is of concern to the study area cities that are near the airport. The focus of this analysis is to evaluate changes in air quality from 1997 through present day. Three regulatory agencies are responsible for air quality issues in the Puget Sound region:

- **United States Environmental Protection Agency (US EPA)**
U.S. EPA has established the National Ambient Air Quality Standards (NAAQS) for criteria pollutants: ozone, carbon monoxide, nitrogen dioxide, particulate matter (PM_{2.5} and PM₁₀), sulfur dioxide and lead. Air quality standards specify the maximum short-term and long-term concentrations of air contaminants, and U.S. EPA sets aircraft emissions standards.
- **Puget Sound Clean Air Agency (PSCAA)**
PSCAA is the primary agency for air quality in the region; responsible for enforcement of federal, state and local air quality standards for stationary sources; and responsible for developing plans and programs to attain and maintain NAAQS.
- **Washington Department of Ecology (Ecology)**
In conjunction with PSCAA, Ecology has state and local ambient air quality standards (AAQS), which must be at least as stringent as the national standards (currently the standards are the same as the NAAQS). PSCAA and Ecology operate 25 permanent air quality/meteorology monitoring stations in the Seattle-Tacoma Puget Sound area. U.S. EPA, Washington state and Puget Sound AAQS for 1997 and current year are shown in Figures 6.1 and 6.2.

The Clean Air Act (CAA) requires establishment of NAAQS for criteria air pollutants across the U.S., including primary standards to protect the health of the citizens and secondary standards to protect other welfare-related values (Figures 6.1 and 6.2). The CAA requires existing and proposed emission sources to demonstrate compliance with those standards. The standards have become more stringent since 1997, and the U.S. EPA has promulgated some relatively recent shorter term averaging periods. Other changes include the removal of total suspended particulates and addition of particulate matter with a diameter of 2.5 microns or less (PM_{2.5}).

In ongoing review and regulatory actions, U.S. EPA and state governments designate areas as:

- **Attainment or Better Than NAAQS** – If monitored data demonstrate compliance with the standards.
- **Unclassifiable or Cannot Be Classified** – If monitored data are not available for such determinations.
- **Non-Attainment** (for either Primary or Secondary standards) – If monitored values of the criteria air pollutants exceed the NAAQS.

Non-Attainment areas for ozone may also be sub-classified from “marginal” to “extreme”, and Non-Attainment areas for particulate matter with an aerodynamic diameter of 10 microns or less (PM₁₀) and particulate matter with an aerodynamic diameter of 2.5 microns or less (PM_{2.5}) may be sub-classified as “moderate” or “serious” depending on the air quality levels. King County and the state of Washington are designated as in “Attainment” or “Unclassified” and are thereby in compliance with the NAAQS.

Figure 6.1
1997 Ambient Air Quality Standards (Federal, State, and Region)

Pollutant	Averaging Period	Unit	STANDARDS			
			FEDERAL		STATE	REGION
			Primary	Secondary	Washington State	Puget Sound
Ozone (O ₃) ¹	1 hour	ppm	0.12	0.12	0.12	0.12
Nitrogen Dioxide (NO ₂) ²	Annual	ppm	0.053	0.053	0.053	0.053
Sulfur Dioxide (SO ₂)	1 hour	ppm	n/a	n/a	0.40 ³	0.40 ²
	1 hour	ppm	n/a	n/a	0.25 ⁴	0.25 ⁴
	3 hours	ppm	n/a	0.05	n/a	n/a
	24 hours	ppm	0.14 ³	n/a	0.10 ³	0.10 ²
	30 days	ppm	n/a	n/a	n/a	0.04
	Annual	ppm	0.03	n/a	0.02	0.02
Carbon Monoxide (CO)	1 hour	ppm	35	n/a	9	9
	8 hour	ppm	9	n/a	150	150
Particulates (as PM ₁₀)	24 hour	µg/m ³	150	150	150	150
	Annual	µg/m ³	50	50	50	50
Particulates (as TSP)	24 hour	µg/m ³	n/a	n/a	150	150
	Annual	µg/m ³	n/a	n/a	50	50
Lead (Pb)	3 month rolling	µg/m ³	1.5	1.5	n/a	1.5

- Standard attained when the expected number of days per calendar year with maximum hourly average concentration above 0.12 ppm is equal to or less than one.
- Never to be exceeded
- Not to be exceeded more than once per year
- Not to be exceeded more than twice in seven consecutive days
- Standard attained when the expected annual arithmetic mean concentrations is less than or equal to 50 µg/m³
- Standard attained when the expected number of days per calendar year with a 24-hour average concentration above 150 µg/m³ is equal to or less than one.

Figure 6.2
Current National Ambient Air Quality Standards (Federal, Washington State and Regional)

Pollutant	Standard	Averaging Period	Concentration		Statistical Format
			ppb	µg/m ³	
Ozone (O ₃) ¹	Primary & Secondary	8 hour	70	137	3-year average of the annual fourth-highest daily 8 hour concentrations
Nitrogen Dioxide (NO ₂)	Primary	1 hour	100	188	3-year average of the annual 98 th percentile highest daily 1 hour concentrations
	Primary & Secondary	Annual	53	100	Annual mean
Sulfur Dioxide (SO ₂)	Primary	1 hour	75	196	3-year average of the annual 99 th percentile highest daily 1 hour concentrations
	Secondary	3 hour	500	1,300	Not to be exceeded more than once per year
Carbon Monoxide (CO)	Primary	1 hour	35,000	40,000	Not to be exceeded more than once per year
	Secondary	8 hour	9,000	10,000	
Particulates (as PM ₁₀)	Primary & Secondary	24 hour	n/a	150	Not to be exceeded more than once per year on average over 3 years
Particulates (as PM _{2.5})	Primary	Annual	n/a	12	Annual mean, averaged over 3 years
	Secondary	Annual	n/a	15	Annual mean, averaged over 3 years
	Primary & Secondary	24 hour	n/a	35	3-year average of the annual 98 th percentile highest daily average concentrations
Lead (Pb)	Primary & Secondary	3 month rolling	n/a	0.15	Not to be exceeded

Source: 40 CFR part 50 NAAQS Table <https://www.epa.gov/criteria-air-pollutants/naaq-table>

B. REGIONAL AIR QUALITY MONITORING

U.S. EPA finalized an amendment to the ambient air monitoring regulations on Oct. 17, 2006. As part of this amendment, the U.S. EPA added the following requirement for state, or where applicable local, monitoring agencies to conduct a network assessment once every 5 years, per 40 CFR 58.10(e):

“The State, or where applicable local, agency shall perform and submit to the US EPA Regional Administrator an assessment of the air quality surveillance system every 5 years to determine, at a minimum, if the network meets the monitoring objectives defined in appendix D [of 40 CFR 58.10(e)] to this part, whether new sites are needed, whether existing sites are no longer needed and can be terminated, and whether new technologies are appropriate for incorporation into the ambient air monitoring network.” The network assessment must consider the ability of existing and proposed sites to support air quality characterization for areas with relatively high populations of susceptible individuals (e.g., children with asthma), and, for any sites that are being proposed for discontinuance, the effect on data users other than the agency itself, such as nearby States and Tribes or health effects studies. For PM_{2.5}, the assessment also must identify needed changes to population-oriented sites. The State, or where applicable local, agency must submit a copy of this 5-year assessment, along with a revised annual network plan, to the Regional Administrator. The first assessment was due July 1, 2010.”

Ecology and PSCAA operates several air quality monitors throughout King County. A 15-mile radius was implemented to obtain monitoring data surrounding Seattle-Tacoma International Airport. All pertinent data was evaluated starting in 1997 through 2018. Most monitors were active for only a portion of the past 21 years. These include 13 monitors (Figure 6.3) that comprise various years of each criteria pollutant in and around King County. The six currently active monitors (as per the Washington Department of Ecology in 2019) are shown in Figures 6.4 through 6.9 (all images were obtained courtesy of the department) and include:

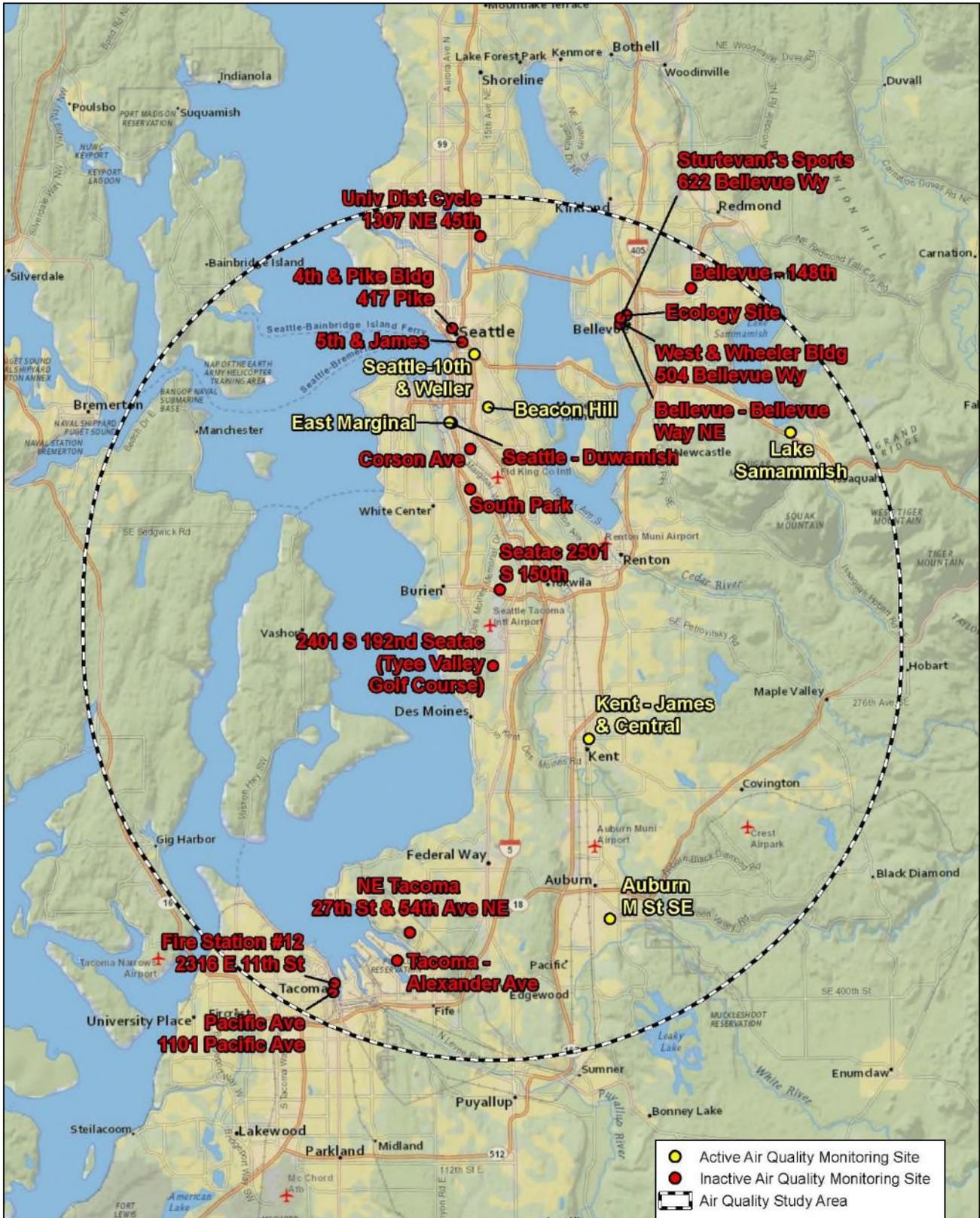
- Beacon Hill Monitoring Station.
- 10th & Weller Monitoring Station.
- East Marginal Way (Seattle-Duwamish) Monitoring Station.
- Lake Sammamish Monitoring Station.
- Kent-James & Central Monitoring Station.
- Auburn-M Street Monitoring Station.

Data were obtained in three-year intervals to best correspond to the appropriate standard. Figure 6.4 provides all the currently active or previously active monitoring sites from 1997-2019 within a 15-mile radius of the airport. As illustrated in this section, all standards are met during the years evaluated and, in several cases, the region has seen a reduction of pollutant effects. To further emphasize this reduction, Ecology does not operate two NO₂/PM₁₀ monitors in the city of SeaTac any longer. They were discontinued mainly due to decreasing trends as well as observed concentrations well below the NAAQS.

Each monitor within the Washington network falls under a spatial scale for which that monitor is intended to represent. A monitor can represent one of six spatial scales:

- Microscale – Area dimensions between several and 100 meters.
- Middle scale – Areas between 100 and 500 meters, typically several city blocks.
- Neighborhood scale – Areas between 0.5 and 4.0 kilometers with relatively uniform land use.
- Urban scale – Areas with city-like dimensions between 4 and 50 kilometers. Urban and neighborhood scales can overlap considerably. Heterogeneous urban areas may not have a single representative site.
- Regional scale – Areas from tens to hundreds of kilometers with relatively homogeneous geography and no large sources.
- National and global scale – Scales representing the nation or the globe as a whole.

Figure 6.3



Monitoring Station Locations

Figure 6.4
Beacon Hill Monitoring Station



Figure 6.5
10th and Weller Monitoring Station



Figure 6.6
East Marginal Way (Seattle-Duwamish) Monitoring Station



Figure 6.7
Lake Sammamish Monitoring Station



Figure 6.8
Kent-James & Central Monitoring Station



Figure 6.9
Auburn-M Street Monitoring Station



(Source: Figure 6.4 through 6.9 photographs by Stantec)

Most criteria pollutants have an applicable scale micro through neighborhood. Only O₃ and PM₁₀ do not include a microscale. Additionally, O₃, SO₂ and PM_{2.5} are measured on a more macroscale. The six currently operating monitors within a 15-mile radius of the airport have scales that range from microscale to neighborhood (3) to urban (2).

Figure 6.10
Beacon Hill Monitoring Station Data

Pollutant	Averaging Period	Units	Station Data			NAAQS
			1997-1999	Mid-Years ^{1,2,3}	2016-2018	
O ₃	8-hr	ppb	42	42	46	70
NO ₂	1-hr	ppb	58.3	57.3	45.3	100
	Annual	ppb	19.3	18.1	11.4	53
SO ₂	1-hr	ppb	N/A	28.0	23.6	75
	3-hr	ppb	N/A	20.8	6.3	500
PM ₁₀	24-hr	µg/m ³	55	69	54	150
PM _{2.5}	Annual	µg/m ³	6.0	5.5	6.4	12
	24-hr	µg/m ³	17	20	26.8	35
CO	1-hr	ppb	N/A	1,600	1,100	35,000
	8-hr	ppb	4,800	1,300	800	9,000

1. Ozone mid-years were 2006-2008.
2. Nitrogen Dioxide mid-years was 2004-2006.
3. Sulfur Dioxide and Carbon Monoxide mid-years were 2007-2009.
4. "n/a" equates to data not available for that year.

All data shown in Figure 6.3, there is a swath of all active and inactive monitors within a 15-mile radius of Seattle-Tacoma International Airport from 1997 through 2018. (Note that 2019 data was not used in analysis because the calendar year was not complete at the time of data gathering.)

A full list of all currently active and active at one time during the study period is provided in Figure 6.12. It should be noted that per the U.S. EPA, King County has remained in attainment throughout the duration of the study period. Note, however, that the portion of the city of Seattle bounded on the east by IH-5/East Duwamish Greenbelt, on the south by 104th Street, on the west by the West Duwamish Greenbelt north to Fairmont Avenue SW, north on Fairmont to Elliott Bay, and Dearborn Street from Elliott Bay to IH-5 is considered to be in moderate maintenance for PM₁₀. In addition, the U.S. EPA identifies the Tacoma metropolitan area bounded on the north by Marine View Drive from Commencement Bay east to the 100-foot contour, southeast along the 100-foot contour to 64th Avenue East, south along 64th Avenue East extended to IH-5, IH-5 west to the 100-foot contour near Pacific Avenue, and north along the 100-foot contour to Commencement Bay to also be in moderate maintenance for PM₁₀.

On Aug. 7, 1987, U.S. EPA identified Kent and the industrial areas of Seattle and Tacoma as having greater than 95% probability of violating the 24-hour PM₁₀ average standard. By operation of law, all three areas were designated moderate PM₁₀ nonattainment areas upon enactment of the CAA on Nov. 15, 1990.

State Implementation Plan (SIP) submittals addressing PM₁₀ potential nonattainment in Kent and Seattle were submitted by Ecology to U.S. EPA in November 1990, followed by the submittal for Tacoma one year later. The principal control strategies in the PM₁₀ attainment plans for the three areas included a residential wood smoke control program, a fugitive dust control program, and a prohibition on outdoor burning.

Figure 6.11
Monitoring Data Within 15-Mile Radius (Other Than Beacon Hill Station)

Monitoring Site	Pollutant	Year	Averaging Period	Units	Amount	NAAQS
Tacoma – Pacific	CO	1997-1999	1-hr	ppb	9,900	35,000
			8-hr	ppb	7,000	9,000
		2004-2006	1-hr	ppb	5,433	35,000
			8-hr	ppb	3,833	9,000
Corson Avenue	CO	2000-2002	1-hr	ppb	6,000	35,000
			8-hr	ppb	4,600	9,000
5th & James	CO	1997-1999	1-hr	ppb	7,500	35,000
			8-hr	ppb	4,800	9,000
SeaTac-150th	NO ₂	1998-1999	1-hr	ppb	57	100
			Annual	ppb	21.9	53
	PM ₁₀	1998-1999	24-hr	µg/m ³	28	150
SeaTac-Tyee	NO ₂	1998-1999	1-hr	ppb	51	100
			Annual	ppb	14.4	53
	PM ₁₀	1998-1999	24-hr	µg/m ³	28.5	150
Bellevue-West & Wheeler	PM ₁₀	1997-1999	24-hr	µg/m ³	38.3	150
Bellevue-Bellevue Way	PM _{2.5}	2002-2004	24-hr	µg/m ³	18.7	35
			Annual	µg/m ³	8.5	12
Corson Avenue	NO ₂	2000-2002	1-hr	ppb	62.3	100
			Annual	ppb	20.6	53
South Park Site ¹	PM _{2.5}	1999-2001	24-hr	µg/m ³	32.5	35
			Annual	µg/m ³	13.5	12
East Marginal Way	PM _{2.5}	2016-2018	24-hr	µg/m ³	31.6	35
			Annual	µg/m ³	8.4	12
	PM _{2.5}	2010-2012	24-hr	µg/m ³	19.5	35
			Annual	µg/m ³	9.3	12
	PM ₁₀	2005-2007	24-hr	µg/m ³	62	150
SO ₂	1997-1999	1-hr	ppb	53	196	
		3-hr	ppb	37.7	500	
Kent-James & Central	PM _{2.5}	2010-2012	24-hr	µg/m ³	28.3	35
			Annual	µg/m ³	10.8	12
Lake Sammamish	O ₃	1997-1999		ppb	58	70
		2006-2008	8-hr	ppb	61	70
		2016-2018		ppb	66	70
10th & Weller	CO	2016-2018	1-hr	ppb	2,019	35,000
			8-hr	ppb	1,633	9,000
	PM _{2.5}	2016-2018	24-hr	µg/m ³	29	35
			Annual	µg/m ³	8.7	12
	NO ₂	2016-2018	1-hr	ppb	62.6	100
			Annual	ppb	20.5	53

(Note that the PM_{2.5} annual standard was 15 µg/m³ at that time. All data gathered from U.S. EPA.)

Figure 6.12
Department of Ecology and/or Puget Sound Clean Air Agency Monitors from 1997-2019

Monitor	Active Years	CO	NO ₂	Ozone	PM ₁₀	PM _{2.5}	SO ₂
10th & Weller	2014-2019	X	X			X	
Beacon Hill¹	1995-2019	X	X	X			
	2003-2006				X		
	2011-2015; 2018-19				X		
	2010-2019					X	
	1996-1999, 2005, 2007-2019						X
5th & James	1990-2001	X					
Corson Avenue	2000-2002	X	X				
SeaTac-150th	1998-1999		X		X		
SeaTac-Tyee	1998-1999		X		X		
Lake Sammamish	1990-2019			X			
Kent – James & Central	2004-2007				X	X	
	1999-2003; 2019					X	
South Park	1990-1998				X		
	1999-2002					X	
East Marginal Way	1990-1999						X
	2010-2019					X	
	2004-2007				X		
Auburn-M Street	2019					X	
4th & Pike	1990-2006	X					
University District	1992-2006	X					
Ecology Site	1994-2003	X					
Bellevue-Sturtevant's	1990-1999	X					
Bellevue-148th	1998-2009	X					
Bellevue-West & Wheeler	1990-1999				X		
Bellevue-Bellevue Way	2000-2004					X	
Tacoma-Alexander Avenue	2005-2007				X		
	1999-2003					X	
	1990-1999						X
Tacoma-27th Street and 54th Avenue	1990-1999				X		X
Tacoma - Pacific	1990-2006	X					
Tacoma-Fire Station	1990-2000				X		

1. The Beacon Hill monitor has been active for CO from 2000-2019, Ozone from 1997-2019; only NO₂ has been active since 1995.

The PM₁₀ attainment plan for Kent was fully approved by U.S. EPA on July 27, 1993 (58 FR 40059), and the plans for Tacoma and Seattle were fully approved by U.S. EPA on Oct. 25, 1995 and Oct. 26, 1995, respectively (60 FR 54599 and 60 FR 54812). The maintenance plan and request for re-designation from non-attainment to maintenance for Kent, Seattle, and Tacoma were approved on March 13, 2001 (66 FR 14492). The Second 10-Year Limited Maintenance Plan for PM₁₀ in Kent, Seattle, and Tacoma and is the last maintenance plan for these areas. This maintenance plan revision ensures compliance through 2020 and fulfills the second 10-year planning requirement of CAA Section 175A (b).

C. ACTIVE MONITORS SURROUNDING CASE STUDY AIRPORTS

Section 3 of this document identified three airports of similar size to Seattle-Tacoma International Airport that were analyzed as case studies – Boston Logan International Airport, Miami International Airport, and Phoenix Sky Harbor International Airport.

As discussed above, there are currently sox active monitors within a 15-mile radius of Seattle-Tacoma International Airport. Figures 6.13 through 6.15 detail the active criteria pollutant monitors within the same 15-mile radius of Boston, Miami and Phoenix airports. Figures 6.16 through 6.18 presents the locations of these monitors for each case study airport.

Figure 6.13
Active Area Air Quality Monitors: Boston Logan International Airport

Massachusetts Department of Environmental Protection	Boston Kenmore Square	2018-2019					
	Boston Kenmore Square	1999-2019					X
	Boston Kenmore Square	1990-2019		X			
	Dudley Square Roxbury ¹	1999-2019	X	X	X	X	X
	Lynn Water Treatment Plant	2014-2019					X
	Lynn Water Treatment Plant	1993-2019			X		
	Lynn Water Treatment Plant	2019		X			
	Von Hilern Street ²	2013-2019	X	X			X
	Blue Hill Observatory	2002-2019		X	X		

1. The Dudley Square monitor began measuring each pollutant at different times. SO₂: 2018, PM_{2.5}: 2014, PM₁₀: 2005, Ozone: 1999, NO₂: 2000 and CO: 2001.
2. The Von Hilern Street site began measuring PM_{2.5} in 2019.

Figure 6.14
Active Area Air Quality Monitors: Miami International Airport

Miami-Dade County Department of Environmental Resources	Lab Annex	1990-2019	X	X			
	Perimeter Road	2017-2019		X			
	Rosenstiel	1990-2019		X	X		
	Miami Fire Station	2018-2019				X	X
	Palm Springs Fire Station	2005-2019					X
	Pennsuco	2010-2019					
	Perdue	1990-2019			X		

Both Boston and Miami have five and seven active monitors, respectively. Phoenix by contrast has 20 active monitors, some of which have been operated since 1990. Not only is the total number of active monitors in Boston and Miami similar, but the number of monitoring per pollutant is comparable.

Figure 6.15
Active Area Air Quality Monitors: Phoenix Sky Harbor International Airport

Arizona Dept of Environmental Quality	JLG Supersite ¹	1996-2019	X	X	X	X	X	X
Maricopa County	West Phoenix ²	1990-2019	X	X	X	X	X	
	Central Phoenix ²	1990-2019	X		X	X		X
	South Phoenix ²	1999-2019	X	X	X	X	X	
	North Phoenix ²	1990-2019			X	X	X	
	Diablo	2014-2019	X	X			X	
	Mesa ³	1990-2019	X		X	X	X	
	Thirty Third	2015-2019		X				
	Tempe ⁴	2000-2019			X	X	X	
	South Scottsdale	1990-2019			X	X		
	Durango Complex ⁵	1999-2019				X	X	X
	West 43rd	2002-2019				X		
	Glendale ⁶	1990-2019			X	X	X	
	West Chandler	2000-2019	X		X	X		
Falcon Field	1997-2019			X				
Gila River Reservation	St. John's ⁷	2003-2019			X	X		
Salt River Reservation	Senior Center Station	2005-2019			X	X	X	
	High School Station ⁸	2006-2019			X	X		
	Red Mountain	2005-2019			X			
	Lehi ⁹	2005-2019			X	X		

1. The JLG Supersite monitor began measuring each pollutant at different times. SO₂: 2018, PM_{2.5}: 2011, PM₁₀: 2004, Ozone: 1996, CO & NO₂: 1999.
2. West Phoenix began measuring PM_{2.5} in 2010. Central Phoenix began measuring PM₁₀ in 1997. South Phoenix began measuring PM_{2.5} in 2010. North Phoenix began measuring PM_{2.5} in 2011.
3. The Mesa monitor began measuring PM_{2.5} in 2012.
4. The Tempe monitor began measuring both PM_{2.5} and PM₁₀ in 2012.
5. The Durango Complex monitor began measuring PM_{2.5} in 2012 and SO₂ in 2011.
6. Glendale monitor began measuring PM_{2.5} in 2011.
7. The St. John's monitor began measuring PM₁₀ in 2013.
8. The High School Station monitor began measuring PM₁₀ in 2012.
9. The Lehi Station monitor began measuring PM₁₀ in 2018.

The majority of the Phoenix sites measure multiple pollutants for an extended period of time. The Phoenix area has a much more comprehensive monitoring network surrounding its airport than do than airports in Boston, Miami, and Seattle. The following two tables and three figures provide further detail of the active monitoring system surrounding the three airports within a 15-mile radius. All active monitors surrounding Miami and Logan airports were compliant for all criteria pollutants in 2019. The Phoenix area (Maricopa County) is in attainment with all criteria pollutants except for ozone and PM₁₀. Ozone is considered in marginal nonattainment of the 2015 NAAQS, and PM₁₀ is considered in serious nonattainment (U.S. EPA 2019). Specifically, in 2019, the West 43rd monitor exceeded the PM₁₀ 24-hr standard, while six monitors within the 15-mile radius exceeded the 2015 ozone standard.

Figure 6.16
Air Quality Monitoring Station Locations: Boston Logan International Airport



Figure 6.17
 Air Quality Monitoring Station Locations: Miami International Airport

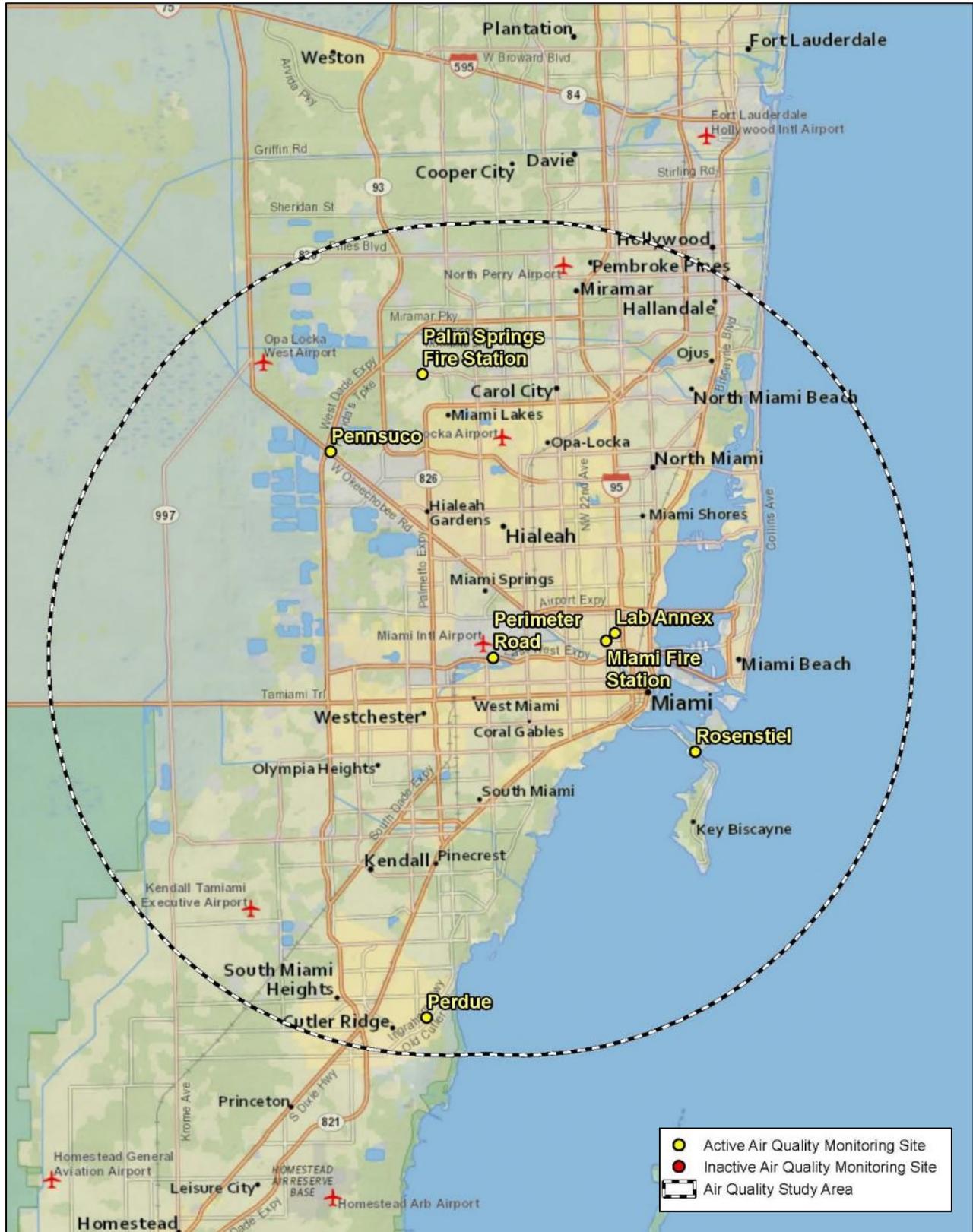
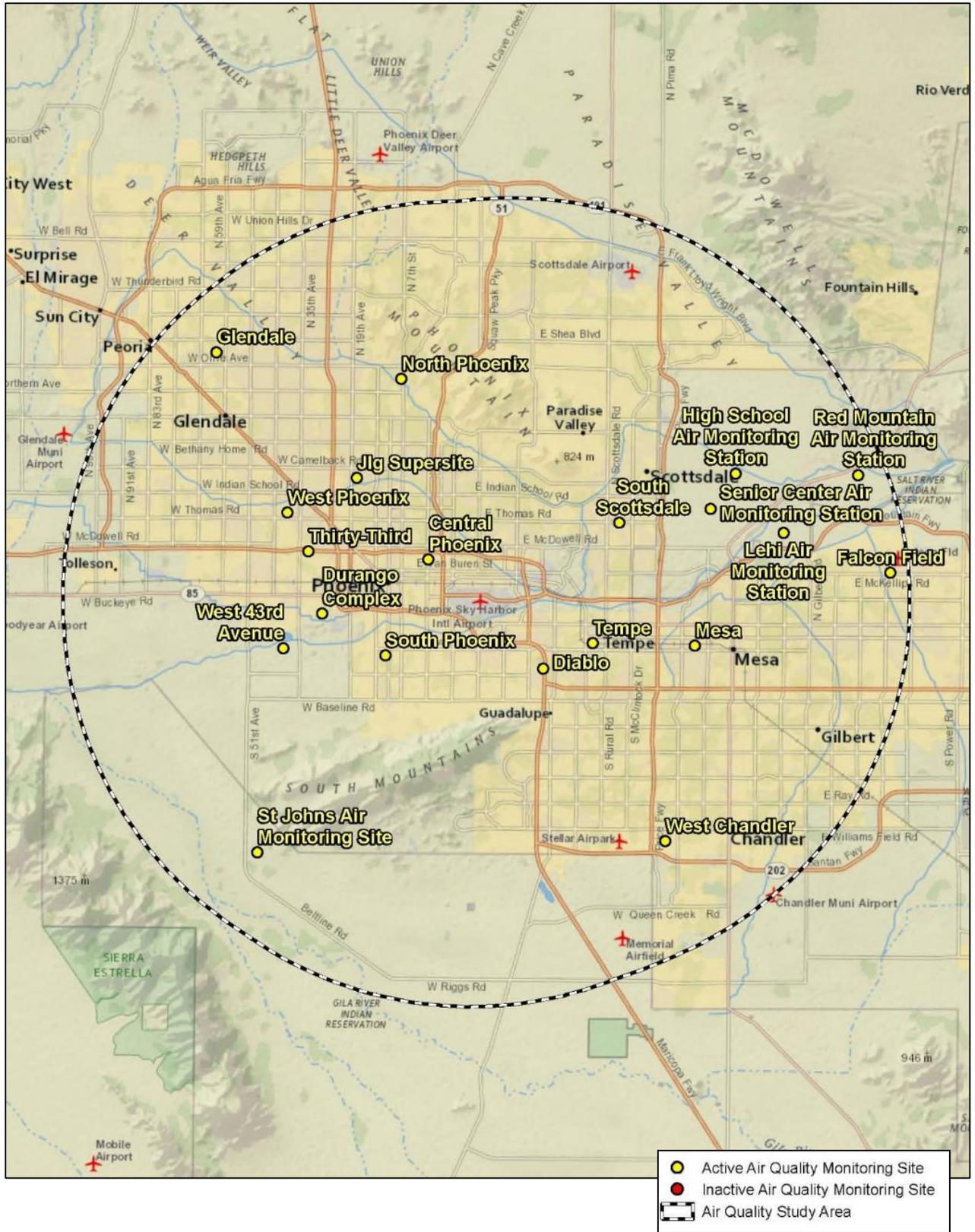


Figure 6.18
Air Quality Monitoring Station Locations: Phoenix Sky Harbor International Airport



D. FEDERAL REFERENCE/EQUIVALENT METHOD AND NAAQS COMPARISON

U.S. EPA requires that all monitors used to evaluate NAAQS compliance meet federal reference method (FRM) or federal equivalent method (FEM) standards when sampling. FRM means a method of sampling and analyzing the ambient air for an air pollutant that is specified as a reference method in an appendix to 40CFR § 50.1, or a method that has been designated as a reference method in accordance with part 53 of 40CFR § 50.1. This ensures that all data collection is consistent among states and agencies.

U.S. EPA has defined FRMs for the measurement of various criteria pollutants, such as CO, O₃, NO₂, PM₁₀, and PM_{2.5}. These methods are described in detail in 40 CFR §50. For example, both PM₁₀ and PM_{2.5}, the FRM is based on manual sampling techniques where a pre-weighed filter is installed into a sampling device, ambient air is sampled for 24 hours, and then the filter is retrieved, equilibrated and reweighed in order to determine the concentration of particulate on the filter. Only the measurement techniques defined in 40 CFR §50 can be FRMs.

To foster innovation and advance new technologies, U.S. EPA also reviews, tests, and approves other FEMs, which are based on different sampling and/or analyzing technologies than FRMs, but are required to provide the same decision-making quality when making NAAQS attainment determinations (Gilliam and Hall 2016). All monitors evaluated for this study are FRM or FEM.

E. NATIONAL EMISSION INVENTORIES FROM SEATTLE-TACOMA INTERNATIONAL AIRPORT: 1997 -2017

U.S. EPA compiles comprehensive and detailed air emissions for criteria and hazardous air pollutants called National Emissions Inventories (NEI). The NEI data are developed every three years. Data comprises point, nonpoint, on-road and non-road sources. Point sources in the NEI include large industrial facilities and electric power plants, airports, and smaller industrial, non-industrial and commercial facilities. NEI on-road sources include emissions from vehicles that use gasoline, diesel, and other fuels. These sources include light-duty and heavy-duty vehicle emissions from operation on roads, highway ramps, and during idling. All emissions are based on the U.S. EPA transportation emissions model known as MOVES. NEI non-road sources include off-road mobile sources that use gasoline, diesel, and other fuels. Source types include construction equipment, lawn and garden equipment, aircraft ground support equipment, locomotives, and commercial marine vessels. For many nonroad sources, the U.S. EPA uses the MOVES-NONROAD model, and these sources are included in the EIS nonroad Data Category. Aircraft engine emissions (occurring during landing and takeoff operations) and the ground support and power unit equipment are included in the EIS Point Data Category at airport locations (U.S. EPA 2018).

The estimates from Seattle-Tacoma International Airport’s operations were obtained from the Emissions Inventory System through discussion with the Washington Department of Ecology. Figure 6.19 outlines the criteria pollutant emissions associated with Seattle-Tacoma International Airport for each NEI year.

Figure 6.19
NEI Criteria Pollutant Totals from Seattle-Tacoma International Airport

CO	2,111.95	2,272.80	2,500.63	3,242.51	3,318.47	3,045.04	8,066.16
NO_x	1,287.98	1,485.13	1,215.22	2,222.20	2,334.86	2,489.08	3,704.20
VOC	410.90	350.85	232.39	280.39	447.81	479.98	1,177.63
SO₂	122.04	144.57	115.46	191.62	242.97	260.68	506.01
PM₁₀	17.92	19.70	102.41	38.28	47.92	61.93	76.43
PM_{2.5}	15.03	16.36	93.98	36.42	47.04	61.07	75.40
CO	2,111.95	2,272.80	2,500.63	3,242.51	3,318.47	3,045.04	8,066.16

In Figure 6.19, 1997 and 2000 PM_{2.5/10} data does not have commercial aircraft emissions, as it was not available. Also, the 1997 and 2000 airport pollution emissions were estimated using King County totals and multiplied by the average percentage attributable to the airport from 2005-2017. Even so, there is a large increase for most gaseous pollutants.

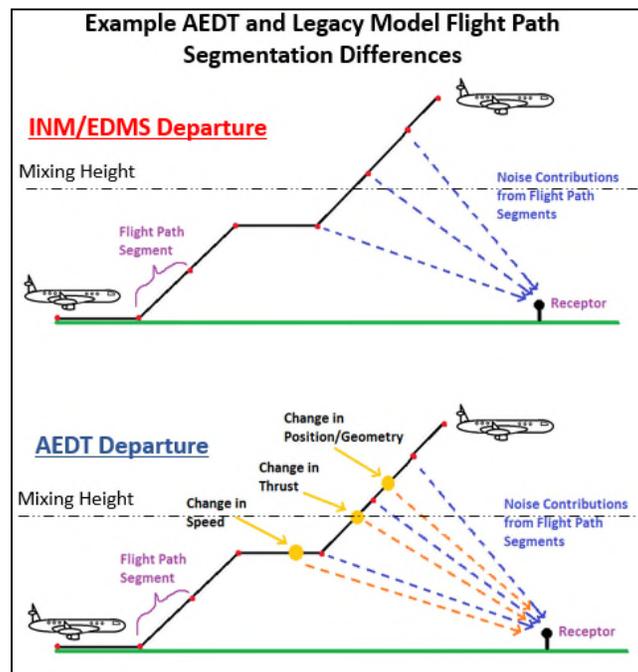
Nitrogen oxides are more of a gradual increase over the last 21 years. The increases are likely due, in part, to increased aviation operations and more landing and takeoffs specifically by commercial aircraft. For example, 2014 commercial aviation data suggested 162,713 landing/takeoffs (LTOs) and 2017 was 240,525 LTOs. Also, the model used by the Federal Aviation Administration (FAA) and the U.S. EPA when calculating aircraft-related emissions changed after 2014 – therefore, the majority of the increased CO and other pollutants is primarily due to a change in aviation modeling. The Federal Aviation Administration stopped using the Emissions and Dispersion Modeling System (EDMS) and began using the Aviation Environmental Design Tool (AEDT).

F. AVIATION MODEL COMPARISON

AEDT was developed to replace the Federal Aviation Administration modeling tools as it relates to noise, air emissions and fuel consumption. AEDT incorporated all elements from EDMS and the Integrated Noise Model (INM) into one comprehensive architecture and common interface. Many updates and corrections representing the best available science have been incorporated into AEDT, which will result in differences when comparing results from AEDT with the legacy tools.

During AEDT development, extensive work of verification and validation was performed against both the legacy tools and gold standard data, such as cockpit flight data recorder data to ensure AEDT is capturing the aircraft performance and positioning correctly. These types of validation exercises are captured as part of the AEDT documentation to build confidence that AEDT is a more accurate model than legacy tools. Figure 6.20 illustrates flight path and emission calculation point differences between EDMS and AEDT models.

Figure 6.20
EDMS and AEDT Comparison Flight Paths



AEDT and the legacy tools model aircraft along a flight path. AEDT and INM/EDMS break up flight paths into smaller pieces, called flight path segments. Each flight path segment contains specific aircraft data including engine power setting, aircraft state (bank angle, flap setting, etc.), aircraft speed, and position. These values are used to compute noise, fuel burn and emissions.

AEDT flight paths typically have more segments, which have shown to better approximate changes in aircraft states. Aircraft performance modeling improvements also directly affect time in a particular mode (i.e., take-off, climb-out, and approach) and fuel burn. These improvements cause differences in fuel burn and emissions, which vary by aircraft. For example, a Boeing 747-200 spends fewer seconds in take-off mode, but 10 times longer in climb-out mode per AEDT than EDMS. As a result, the total amount of fuel burned increases tenfold during that mode. Modeled fuel consumption from AEDT correlates better to measured values than EDMS. AEDT is a robust improvement regarding noise and emissions modeling as compared to EDMS.

G. HAZARDOUS AND TOXIC AIR POLLUTANTS

Hazardous air pollutants (HAPs) are pollutants known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects and comprised in a list of 187 toxic pollutants per the Clean Air Act. Most HAPs originate from stationary sources (e.g., factories, refineries, power plants) and mobile sources (e.g., cars, trucks, buses, airplanes), as well as indoor sources (building materials and cleaning solvents).

All aviation data for HAPs and criteria pollutants is allocated to a specific source classification code (SCC) by the U.S. EPA, as follows:

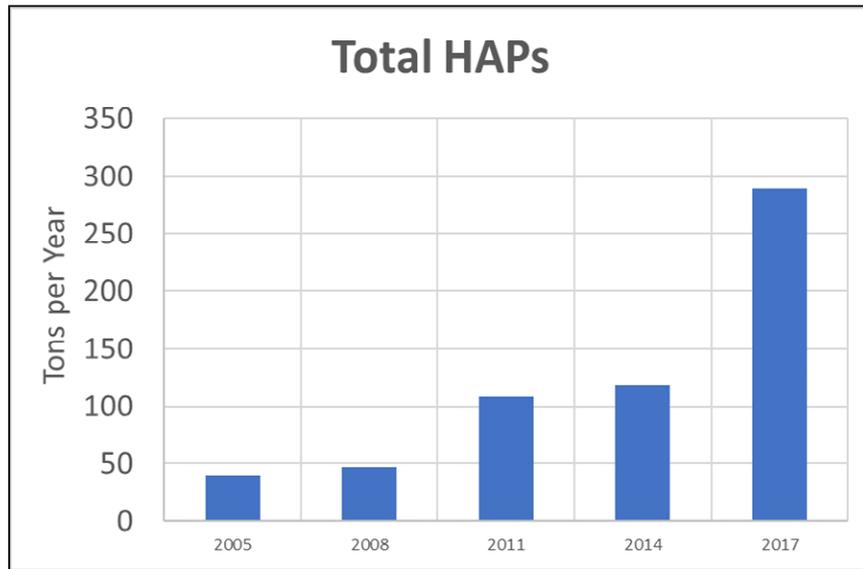
- Military aircraft (2275001000).
- Commercial aircraft (2275020000).
- General aviation – piston engine (2275050011).
- General aviation – turbine engine (2275050012).
- Air taxi – piston engine (2275060011).
- Air taxi – turbine engine (2275060012).

Non-aviation emissions at airports are primarily ground support equipment and auxiliary power units.

NEI data from Seattle-Tacoma International Airport from 2005-2017 is illustrated in Figure 6.21. Note that there is a large increase in 2017. Aviation-related emissions are determined using AEDT for known engine types, while generic emission factors are applied on a ton-per-LTO basis.

From 2008-2014 there was steady increase of overall HAPs emissions attributed to the airport, with a substantial increase in 2017. Formaldehyde contributes approximately 126 tons (43.6%) of the total in 2017. This is because the formaldehyde tons/LTO emission factor is an order of magnitude or greater than most other HAPs (Eastern Research Group, Inc. 2019). The overall increase is attributable to the change from EDMS to AEDT along with increased LTOs, primarily commercial aviation, at Seattle-Tacoma International Airport.

Figure 6.21
Seattle-Tacoma
Airport HAPs



International
Emissions

H. TOXIC AIR POLLUTANT STUDIES

In 2003, the Puget Sound Clean Air Agency conducted a monitoring study for toxic emissions at six locations around Seattle. The purpose of the study was to characterize air emissions and to identify those air toxics and sources that may pose the greatest risks to residents of the Puget Sound area. The analysis uses results from a monitoring study conducted in the greater Seattle/King County area.

The study evaluated 17 toxic pollutants including wood smoke and diesel particulate matter (DPM). Two of the monitoring locations selected were Beacon Hill and Georgetown. Beacon Hill represents a typical urban residential area with a mix of urban sources. Georgetown was chosen because it represents potential maximum concentrations near an industrial area, as it is affected by large industries and a regional airport. Additionally, U.S. Highway 99 and residential wood burning affected the site. The other four sites were Lake Sammamish for an urban background site, Maple Leaf for a typical urban residential site, the City of SeaTac for a site that is highly affected by mobile sources (airport, etc.), and Lake Forest Park for an area affected by wood smoke and mobile sources.

The 2003 study suggests that DPM has a higher potential to a cancer risk than the air toxics measured. Wood smoke has the potential to contribute to the region's cancer risk. Those toxics that are higher are most likely from volatile organic compounds from mobile sources, which the airport is a subset. However, the overall results do not reflect significantly higher pollutant levels at the city of SeaTac location when compared with other sites. In fact, the City of SeaTac's potential risks appear slightly lower than Beacon Hill.

Formaldehyde and other toxics health risks are similar to the average of six sites. The city of SeaTac site cancer risk is 67.5 per 1 million, and the hazard index (HI) is 0.55. The average is 73.4 per 1 million (70 year lifetime and exposure) and 0.57 HI.

Toxics were again assessed in a PSCAA 2017 Air Quality Data Summary (Puget Sound Clean Air Agency, 2018). The Beacon Hill Washington Department of Ecology monitoring site is one of the 27 U.S. EPA National Air Toxics Trends locations. Annual average potential cancer risks were calculated for the air toxics collected from 2000 to 2017 at Beacon Hill.

For many air toxics, the analysis of the trends shows a statistically significant decrease in annual average concentrations. While Ecology using the Acceptable Source Impact Levels (ASIL) for stationary source toxics compliance, there is not an explicit standard for non-stationary sources like the airport or motor vehicles.

That being said, a potential exceedance of an ASIL does not necessarily mean that a source is not compliant, but rather that a further health risk assessment is required per Ecology regulations. The potential effect from the Seattle-Tacoma International Airport from toxics is not explicitly known, but general trends indicate a significant reduction over the past 10-15 years. The 2018 report for 2017 emissions did, however, suggest that the mean hazard index for non-cancerous toxics were exceeded for one pollutant, acrolein. Acrolein irritates the lungs, eyes, and nose, and is a combustion by-product. Unfortunately, acrolein is one of the most difficult pollutants to monitor, and its measurements have large uncertainty. Therefore, for acrolein, PSCAA did not explore a trend analysis as the results are likely all within the historical uncertainty of the measurement.

I. GREENHOUSE GAS EMISSIONS

The primary natural and synthetic greenhouse gases (GHGs) in the Earth's atmosphere are water vapor, carbon dioxide (CO₂), methane, nitrous oxide, and fluorinated gases. GHGs allow heat from the sun to pass through the upper atmosphere and warm the Earth by blocking some of the heat that is radiated from the Earth back into space. As GHG concentrations increase in our atmosphere, they affect the global climate by further decreasing the amount of heat that is allowed to escape back into space.

Many GHGs are naturally occurring in the environment; however, human activity has contributed to increased concentrations of these gases in the atmosphere:

- Carbon dioxide (CO₂) is emitted from the combustion of fossil fuels (i.e., oil, natural gas, and coal), solid waste, trees and wood products, and as a result of chemical reactions (such as manufacture of cement).
- Methane (CH₄) results from livestock, other agricultural practices, decay of organic waste in municipal solid waste landfills and is also emitted during the production and transport of coal, natural gas, and oil.
- Nitrous oxide (NO₂) is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.
- Fluorinated gases, while not abundant in the atmosphere, are powerful GHGs that are emitted from a variety of industrial processes and are often used as substitutes for ozone-depleting substances (e.g., chlorofluorocarbons, hydrochlorofluorocarbons, and halons).

The majority of GHGs from airport operations are associated with CO₂ and not the other GHG pollutants. For example, kerosene-based jet fuel CO₂ emission factors are usually measured in kilograms per gallon, while methane and nitrous oxides are measured in grams per gallons and typically an order lower in magnitude. All subsequent GHG emissions-related discussion will be in reference to CO₂ only.

Contribution from Airport Operations

GHG emissions are a global concern and from aircraft are primarily CO₂ emissions. Though there is no ambient standard for CO₂ emissions, there are reporting requirements and general commitment to reduce emissions in the U.S. and worldwide.

This report researched at CO₂ emissions from two perspectives. One is from the contribution from a local perspective, where landing and take-off are taken into consideration. The other is from a global perspective where although aircraft flies over other regions of the country, the original source of the CO₂ emissions are from refueling at Seattle-Tacoma International Airport.

The landing/take off emissions are based on U.S. EPA emission factors and Federal Aviation Administration models such as EDMS and ADET discussed earlier. Total aviation emissions from Seattle-Tacoma International Airport in 2014 were 525,357 tons of CO₂. That amount increased to 1,195,636 tons in 2017. All emissions are associated with only the SCC values described in Section 1.3 and contribute to only the area within 3,000 feet of elevation surrounding Seattle-Tacoma International Airport. This is a restriction of the EDMS/AEDT. The increase of CO₂ totals is most likely due to the increase of landing and take-off cycles (165,567 in 2014 and 204,121 in 2017) and a move from EDMS to AEDT.

In 2014, CO₂ other mobile source emissions associated with King County (on-road and non-road light and heavy-duty vehicles and equipment) was 11,031,736 tons. Seattle-Tacoma International Airport contributed only approximately 4.55% of the total.

It should be noted that the airport's contribution covers only the area within airport property and 3,000 feet above its ground, while the county emissions are spread out throughout the various roads and highways of King County. This potentially dilutes the effect, but the airport's contributions tend to be more concentrated. Therefore, it is possible for the smaller emission totals to potentially have a greater effect on the surrounding areas.

GHG Emissions in King County: 2003-2017

King County developed a report update in 2018 that compared countywide GHG emissions by sectors in 2003, 2008, 2015 and 2017. Total GHG emissions from all sectors increased from 18,719,700 Megagrams of carbon dioxide equivalent (MgCO₂e) in 2003 to 20,108,400 MgCO₂e in 2017. However, the peak emissions were seen in 2008 and have decreased since. Emissions from commercial aviation increased from 525,600 MgCO₂e in 2003 to 716,800 in 2017. Note that the emission calculation methodology used for aviation in this study was based on U.S. EPA emission factors from 2015 and total fuel consumed, which differs from Seattle-Tacoma International Airport specific data developed by the U.S. EPA via EDMS/AEDT.

The overwhelming majority of GHG emissions from King County are derived from two sectors: built environment and transportation/mobile Sources. Built environment consists of energy consumption such as electricity, natural gas and petroleum. They are broken down into three general categories: residential, commercial and industrial. 61.7% of 2017 emissions totals are derived from these sources. Similarly, the transportation sector comprises on-road vehicles (passenger vehicles, transit and freight), rail, marine vessels, commercial aviation (Seattle-Tacoma International Airport and Boeing Field) and other miscellaneous mobile equipment. Total transportation emissions have stayed relatively constant by percentage since 2003: 36.6% to 35.9% in 2017. As a result, 97.6% of 2017 GHG emissions are associated with these two sectors. Aviation-specific emissions in King County have seen a slight uptick in total amount and percentage. The aviation percentage of total emissions is 3.6% in 2017 and approximately 10% of total transportation emissions. By contrast, on-road vehicles makeup approximately 87% of all transportation emissions. The percentage of aviation-related GHG emissions is similar to the worldwide percentage described by the International Civil Aviation Organization (ICAO). The ICAO states that aviation emissions comprise approximately 2% of global GHG emissions.

Global Contribution from Seattle-Tacoma International Airport

In 2007 (and updated on March 17, 2008), the Port of Seattle developed its own CO₂ emission estimates associated with the airport for the 2006 GHG Inventory. It was calculated that the airport, through a variety of sources, emitted 4.7 million metric tons of CO₂ in 2006. The total was allocated to sources directly controlled by

the Port, such as hotel/parking lot shuttles and facility power, at 1.4%. Eight percent was from publicly controlled sources like passenger vehicles and employee commuting. The remaining 90.6% of the emissions was derived from aircraft operated by various airlines and tenants.

The 2007 report also indicated that over 90% of the aircraft emissions occurred when the planes were operating above 3,000 feet or cruising. This is consistent with the more recent U.S. EPA data. Appendices within the 2007 report identify methods used to calculate the various emission sources. For example, cruising emissions were determined by calculating total fuel dispensed and subtracting off the LTO (less than 3,000'). Seattle-Tacoma International Airport used only Jet fuel A in 2006 with a conversion rate of 21.095 pounds of CO₂ per gallon dispensed.

Aircraft Emissions Certification and Compliance

Tier 4 and earlier engines manufactured before July 18, 2012 must meet HC, CO, smoke, and NO_x standards prescribed in 40 CFR 87.21. Tier 6 and 8 engines manufactured on or after July 18, 2012 must meet HC, CO, smoke, and NO_x standards prescribed in 40 CFR 87.23.

General certification requirements are contained in title 14 of the Code of Federal regulations. Engine manufacturers must submit compliance reports to U.S. EPA. Manufacturers holding U.S. FAA-type certificates are required to submit exhaust emission data (NO_x, HC, CO, Smoke and CO₂) to U.S. EPA to comply with the terms of the reporting requirements.

J. WHAT WE HEARD FROM THE PUBLIC

During this study, the consultant team heard comments from the public through public meetings, stakeholder interviews, and monthly Technical Advisory Committee meetings. The following is a summary of this citizen input.

▪ **Community Data Evaluation**

Throughout the development of this review of air quality-related data, numerous members of the community provided data for consideration. A question was raised regarding the NEI CO₂ data associated with the airport and the Port of Seattle report from 2006 discussed previously in this section. The 2006 report identifies approximately 4.7 million metric tons emitted, when compared to the NEI data stating that 525,357 short tons (476,596 metric tons) were emitted from aviation-related activities at the Seattle-Tacoma International Airport in 2014. The report also indicates that 90.6% of the total emissions were derived from fueling estimates and occur during cruising (above 3,000 feet). Because the NEI data accounts only for activity under 3,000 feet, such as landing, take-off and taxiing, it is reasonable to assume that the cruising emissions are excluded or emissions are reduced by approximately 90%. When compared to each other, 2014 NEI data comprises approximately 10.1% of the 2006 totals, which would suggest that the CO₂ emissions under 3,000 feet are similar for the two years. The Port of Seattle also provided CO₂ estimates for 2017, which suggested a total of 714,010 metric tons from Scope 3 sources (aviation-related sources) and the NEI data from 2017 was 1.08 million metric tons. There is somewhat of a discrepancy, but there is not an underestimation of the NEI data as previous suggested by community members.

A community member also sent information pertaining to a 2015 New Jersey of Institute of Technology study indicating that emissions and air toxics from airports are “significant and growing.” The consultant team was unable to obtain a copy of this study after numerous requests from the community member and an internal search. All data reviewed for this study does also suggest that emissions associated with Seattle-Tacoma International Airport are also increasing, but as discussed throughout this report, the

general trend of measured concentrations of both criteria and toxic pollutants at the nearest monitors continue to illustrate a downward trend and/or meet appropriate federal standards.

Regional impacts associated with the airport air pollution emissions are likely not fully reflected by the current air quality monitoring network because of geographic distribution of the monitors.

LTO cycle emission factors were also provided by the community. These data appeared to derive from a few different legitimate sources at the time of publication. They included: U.S. EPA Procedures for Emission Inventory Volume IV: Mobile Sources, September 1981; a Seattle-Tacoma International Airport emissions inventory EIS in 1994-95 that used version 994 of EDMS and a 1991 Ecology study for King County.

All sources were reviewed for comparison between the most recent information and calculation methodologies or models. As with other models, the EDMS has been updated over time and replaced by AEDT to further its accuracy. Because the NEI data and other Port of Seattle calculation methods are more recent and most representative of the operations of the airport during the time of this study (1997-present), the suggested data sources were deemed less reliable when compared to newer approaches.

- **Ultrafine Particulates and Aircraft Wakes**

Community members were curious as to whether UFPs that become entrained in the wake of aircraft are pushed down because of a vortex-like effect. The most recent University of Washington MOV-UP report references a 2006 study that evaluated when aircraft emissions within the wake of airplanes tend to descend under induction of vortices. This conserves emissions which leads to higher mean concentrations at ground level, except under moderate or very stable atmospheric conditions. Because of this effect, UFPs from descending aircraft reach the ground within a few minutes nearest the airport and up to 15-20 minutes 15-kilometers downwind. The shorter timeframe doesn't allow the UFPs to coagulate into larger particles. Additionally, the UFPs associated with aircraft tend to be smaller than mobile sources from highways, and their affected areas tend to be larger with the potential to affect more people, but at lower concentrations.

- **SO₂ Emissions from Seattle-Tacoma International Airport**

During a public meeting, the community expressed concern over the amount of SO₂ emissions associated with the airport as they compare to other surrounding SO₂ sources. As previously discussed, the 2017 NEI data suggested that the total annual SO₂ emissions attributable to the airport was 506 short tons. When compared to other King County sources identified in the NEI, Seattle-Tacoma International Airport is a significant contributor of SO₂. The second largest emission source was Ardah Glass, Inc. at 98.6 tons. Additionally, Seattle-Tacoma International Airport was the fifth-largest individual source in the state of Washington. The most recent U.S. EPA emissions data does bear out Seattle-Tacoma International Airport as being a large emitter of SO₂ within its surrounding area. It should be noted, however, that the region is still within the SO₂ NAAQS. Regional impacts associated with the airport air pollution emissions are likely not fully reflected by the current air quality monitoring network because of geographic distribution of the monitors.

There was also concern about whether compliance correlates to health effect. The NAAQS have been rigorously analyzed regarding human health and are constantly reviewed. The review and determination process includes updates to planning documentation, integrated science assessments, risk and exposure and policy amendments. All primary standards are human health-based.

- **Particulate Residue on Plants and Other Surfaces**

Several community members inquired as to the source of the residue they are seeing on their plants. Aircraft engines emit water vapor, CO₂, small amounts of NO_x, hydrocarbons, carbon monoxide, sulfur gases, and PM/soot. Soot makes up a very small percentage of the overall emissions from aircraft, but

97% of the soot is composed of black carbon. While it is uncertain what percentage of the residue is directly attributable to the aircraft, it is very likely that most of the residue seen on plants is carbon-based soot from the combustion of jet fuel and nearby traffic. It should also be noted that PM_{2.5} that tends to linger in the atmosphere for an extended period of time travel long distances and have secondary formation. Thus, deposition of soot is not likely to come from solely one source.

▪ **World Health Organization Guidelines**

The 2020 study has illustrated that the region surrounding Seattle-Tacoma International Airport is technically in compliance with the NAAQS. However, to provide further context and compare other air pollution guidelines, a recent May 2018 World Health Organization (WHO) document was reviewed. The following data are for informational purposes only and do not supersede the NAAQS as it pertains to air quality compliance in King County and the surrounding areas. Rather its intent is to provide the reader with an understanding of how some in the international community evaluate human health standards. Figure 6.22 compares the criteria pollutant standards in the U.S. and health guidelines according to the WHO.

**Figure 6.22
NAAQS and WHO Guidelines Comparison**

Ozone (O₃)	8-hr	100	137
Nitrogen Dioxide (NO₂)	1-hr	200	188
	Annual	40	100
Sulfur Dioxide (SO₂)²	1-hr	500	196
	3-hr	20	1,300
Carbon Monoxide (CO)	1-hr	N/A	40,000
	8-hr	N/A	10,000
Particulates (as PM₁₀)	24-hr	50	150
	Annual	20	N/A
Particulates (as PM_{2.5})	Annual	10	12
	24-hr	25	35
Lead (Pb)	3-month rolling	N/A	0.15

1. Ambient (Outdoor) Air Quality and Health Fact Sheet (World Health Organization 2018).
2. The WHO SO₂ guideline averaging periods are 10 minutes and 24-hr.

▪ **Jet Fuel Odor Concerns**

Community members were concerned about the potential health effects from jet fuel odor and subsequent inhalation. The New Jersey Department of Health (NJDOH) has a hazardous substance fact sheet that outlines odor thresholds and potential adverse health effects from inhalation of kerosene-based jet fuel. As per NJDOH, the odor threshold is 0.1 ppm, meaning the lowest concentration at which an odor can be detected by the human sense of smell. Inhalation of kerosene can irritate the nose, throat and lungs. Higher exposure has the potential to affect the nervous system causing headaches, dizziness, nausea and vomiting. It also has the potential through the skin but requires direct contact. Note that the odor threshold is primarily focused on workers in close proximity to the aircraft, but there is still a potential to affect the general public to a lesser degree.

- **Indoor Air Quality and Absenteeism**

Community members discussed a potential correlation between poor indoor air quality and absenteeism from work and school. Per the U.S. EPA there are numerous sources of indoor air pollution, such as inadequate ventilation. Pollution sources include fuel-burning appliances, tobacco products, various building materials, household cleaning supplies or outdoor sources such as radon, pesticides and outdoor air pollution. Outdoor air pollution can infiltrate buildings and homes via open windows and doors, as well as poor window seals and cracks. Older houses and building are more susceptible because they are less airtight and often more damaged by age and weather.

According to the U.S. EPA, recent studies reinforce previous conclusions that Indoor/Outdoor (I/O) relationships are sensitive to particle size, with I/O typically decreasing in the PM_{2.5-10} range. New studies add to the literature base for UFP, where I/O was found to decrease with decreasing particle size. Unlike larger particles, UFP movement is more influenced by Brownian diffusion, which likely caused more UFP to diffuse to building surfaces instead of being transported indoors. Additional studies added to the characterization of indoor-outdoor relationships for different seasons and times of day. For most studies, I/O was higher during summer than winter and higher during daytime than nighttime.

Poor indoor air quality can create Sick Building Syndrome (SBS). This occurs when occupants of a building experience acute health and comfort effects that are correlated to time spent in the building. SBS can cause more absenteeism among the workforce. There is a plausible correlation between outdoor air pollution and increased absenteeism. However, there is nothing that specifically indicates that aviation emissions have a greater effect than any other outdoor source.

K. AIR QUALITY EFFECTS ATTRIBUTABLE TO AVIATION ACTIVITY

Positive Effects on Air Quality

There are some positive aspects of air quality to report:

- **Air Quality is in Attainment in King County**

King County technically meets all applicable standards through the full time period. King County has had a couple of areas in maintenance for PM₁₀, but both areas are improving and working toward full attainment. As noted in this section, the lack of close-in monitors to Seattle-Tacoma International Airport and the number of inoperable monitors warrant further study and analysis to determine if King County's air quality standards are affected.

- **Some Air Monitors Show Improvement in Air Quality**

Throughout the past 22 years, some air monitors have shown a decline in overall ambient concentrations. The Beacon Hill station shows that CO, NO₂ and SO₂ have decreased since 1997. However, the lowest SO₂ was seen between 2010 and 2012 (Puget Sound Clean Air Agency 2018). CO has seen a steady decline across the entire region and state since 1997 (Puget Sound Clean Air Agency 2015).

- **Toxic Emissions Showing a Downward Trend**

The PSCCA 2017 toxics data summary shows a distinct decrease since 2000 for the majority of pollutants. The 2003 study illustrates that the toxics surrounding the city of SeaTac did not demonstrate a significant difference compared to any of the other five sites evaluated. The city of SeaTac site produced a lower ambient concentration than the average of the six sites for most toxic pollutants.

- **Emissions Reduction Initiatives**

The airport has installed nearly 300 electric ground support equipment vehicles. The goal is to have them available at every gate by 2021 for a total of 561. These vehicles save nearly 1 million gallons of petroleum each year and 10,000 metric tons of GHGs per year. Seattle Tacoma International Airport has

also installed pre-conditioned air (PC air) at all gates. PC air was a project that constructed a centralized plant that pumps hot and cold fluids through 15 miles of pipes to each of the airport's 73 jet gates, where a unit then pre-conditions warm or cool air blown into the aircraft. The central plant houses four 300-ton chillers that fill 16 ice storage tanks with ethylene-glycol solution cooled by electricity provided by the airport. Four secondary pumps circulate the chilled liquid through pipes to the gates for cooling. Alternately, the airport's steam plant heats water that is piped to gates for heating.

A heat exchanger at the gate directs the conditioned air through a telescoping duct on the jet bridges, to a ventilation hose and directly into the aircraft's cabin. The plant has the potential to expand to 100 gates in the future. It is estimated that the PC air saves five million gallons of fuel per year, which equates to 40,000 metric tons of GHGs and 73 tons of NO_x.

- **Sustainable Aviation Fuels**

The Port of Seattle has a goal to power all flights fueled at Seattle-Tacoma International Airport with a minimum of 10% blend of sustainable aviation fuels (SAF) by 2028. This initiative has been spearheaded by the Port of Seattle Commission as part of the SAF Northwest initiative. The Port has been working with the Washington State Aviation Biofuels Work Group since 2012. In 2017 the workgroup provided recommendations to the state legislature that identified a statewide clean fuel standard. This standard was introduced as House Bill 1110. On March 12, 2019 the House of Representatives passed the bill, which directs Ecology to adopt a rule that establishes a Clean Fuels Program. The rule is to limit GHG emissions per unit of transportation fuel to 10% below 2017 levels by 2028 and 20% below 2017 levels by 2035. The bill is currently going back and forth between the Senate and House.

Neutral Effects on Air Quality

Despite some positive gain as described above, air quality concerns remain:

- **Neutral Effect #1: Limited Airport-Area Air Quality Monitors**

As discussed previously in this section, while regional air quality has been improving over the past several years, there are very few active monitors close to Seattle-Tacoma International Airport. Therefore, it may be necessary to evaluate the need to include more FRM/FEM monitors downwind of Seattle-Tacoma International Airport to ensure all standards are truly being met.

Over the past 20 years, air quality monitors operated by PSCAA or Ecology have come and gone. The primary reason is because of ambient pollutant trends declining over time and the agencies believing that they are no longer necessary because standards are being easily met. However, there are not many active monitors very near the study area cities.

- **Neutral Effect #2: PM_{2.5} is Regulated but not UFPs**

It is evident through recent studies that UFPs are present and may cause health concerns, yet they are not currently regulated by the U.S. EPA, Ecology or PSCAA. PSCAA has indicated that it does not foresee any federal standard within the next few years. The earliest may be 10 or more years out. PSCAA indicated that further study is needed as well.

Negative Effects on Air Quality

Despite positive gains described above, air quality concerns remain:

- **Negative Effect #1: Ultrafine Particulate Pollution**

Ultrafine particulates (UFPs) are defined as less than 0.1 microns in aerodynamic diameter or 100 nanometers. UFPs are not currently regulated in the U.S. and include combustion sources as well as secondary aerosols formed through atmospheric chemistry reactions. Very high concentrations of UFPs

have been reported near and on freeways as well as in proximity to airports. Several studies were reviewed:

- Mobile Observations of Ultrafine Particles (MOV-UP) Study – The University of Washington (UW) conducted a seasonally sampling study from February 2018 through March 2019 to assess UFP concentrations associated with air traffic and other sources. The UW study (“Mobile Observations of Ultrafine Particles”, abbreviated as MOV-UP) used mobile and stationary sampling methods. Two hybrid vehicles were equipped with a condensation particle counter (CPC, Model 3007) and the P-Trak Model 8525 condensation nuclei particle counter. Mobile monitoring occurred along defined routes (“transects”) that were designed to sample in an East-West direction at fixed latitudes north and south of the airport. Because of terrain and roadway considerations, some transects deviate slightly from the target latitude. UW monitored transects 10 miles north (5 transects) and 10 miles south (6 transects) of Seattle Tacoma International Airport. Fixed site monitoring was conducted at four locations, also equipped with the same equipment as described above. The MOV-UP primarily found that UFPs derive from both roadway traffic and aircraft sources, with the highest UFP counts found nearest major roadways (Interstate 5). Total concentrations of UFP alone (10 to 1000 nm) did not distinguish between roadway and aircraft features. However, key differences exist in the particle size distribution and the black carbon concentration for roadway and aircraft features. These differences can help distinguish between the spatial effect of roadway traffic and aircraft UFP emissions using a combination of mobile monitoring and standard statistical methods.

Fixed-site monitoring confirms that aircraft landing activity is associated with a large fraction of particles in the range of 10-20 nm (ultra UFP). Mobile-derived fuel-based emissions factors (the number of ultra UFP per kilogram of fuel) are consistent with differences in emissions between aircraft and roadway vehicles.

The MOV-UP study findings demonstrate two clear and consistent spatial features of ultrafine particles independently associated with vehicle traffic and aircraft emissions.

- Boston Logan Airport UFP Study – Tufts University conducted a UFP study related to aviation emissions in Boston surrounding Logan International Airport. The study was sample-based, similar to the University of Washington study, however their methods were slightly different. Sampling was conducted at residential homes and inside the Central Business District of Boston. The focus was whether aviation-related particle number concentrations (PNC) increased downwind of Logan. Seven residences were sampled in the Chelsea area (4 to 5 kilometers from the airport) and another nine in Boston (5 to 6 kilometers away). During winds from the direction of the airport, an increase in outdoor and indoor PNC was evident at all areas in Chelsea and in three of the nine in Boston. The median increase during impact-sector winds compared to other winds was 1.7-fold for both outdoor and indoor PNC. Across all residences during impact-sector and other winds, median outdoor PNC were 19,000 and 10,000 particles/cm³ in Chelsea and Boston, respectively. The median indoor PNC were 7,000 and 4,000 particles/cm³, respectively. Overall, the results indicate that aviation-related outdoor PNC infiltrate indoors and result in significantly higher indoor PNC. Results also suggest that aviation-related outdoor PNC do get inside and significantly increase indoor PNC values.
- LAX/ATL UFP Study – The University of Washington measured UFP number and distribution downwind of the Los Angeles International Airport (LAX) and Atlanta Hartsfield-Jackson International Airport (ATL) in 2016 using mobile monitoring along transects similar to the MOV-UP study detailed above. Measurements were also taken at 43 urban neighborhood locations along freeways. The study found a three to five-fold increase in UFP number concentrations in the transects under the approach path to both airports compared to the surrounding area. Additionally, the ultrafine particles observed below the airport descent paths were distinct by being smaller in diameter than

particles measured in other neighborhoods and freeways within the same city. Elevated black carbon and NO₂ correlated well with the area airport transects as well. Note that the two UW studies as well as the Tufts study show similar results regarding particle size number measurements and elevated values along airport transects. All studies also suggest further evaluation and study is necessary to truly understand the health effects of aircraft-related UFP.

- Washington Department of Health Literature Review – The Washington State Legislature convened the study of ultrafine particle concentration that included a call for a literature review. The Port of Seattle pledged money to that study while the legislature was considering the proposal, at the request of Rep. Tina Orwall, who then asked that the Port of Seattle work with Department of Health on the literature review portion of the UW’s MOV-UP study. The review indicated that it is difficult to determine the effect of UFP exposure on human health. Animal evidence indicates that UFP exposure is associated with adverse health effects, including neurological effects. There is strong and consistent animal data linking long-term UFP exposure with nervous system effects, and these effects are often correlated with multiple markers of neurotoxicity in animals. While much is known about PM_{2.5} and its health effects, there is a lot more uncertainty about the number, mass or concentration of UFP constituents within PM_{2.5}. UFPs are not evenly distributed in the atmosphere and have unique physical and chemical properties compared to larger particles that lead to differences in how they affect health.

The Department of Health could not conclude from PM_{2.5}-specific human studies whether UFPs are a major contributor to observed neurological and other adverse health effects. Currently toxicological and epidemiological human studies do not provide evidence that UFPs are more problematic than other PM size fractions. Enhanced modeling methods will allow for improvements in estimating the effect of UFPs on human health. The evidence on health effects in humans associated with UFP exposure remains inconclusive or insufficient for most health outcomes.

The Department of Health suggests further study is needed to identify toxicity characteristics such as particle number concentration, chemical composition and surface area, in addition to UFP monitoring across the county as part of NAAQS compliance and standardizing methods.

- Los Angeles International Airport UFP Study – University of Southern California – The University of Southern California (USC) Department of Preventive Medicine conducted a short-term UFP exposure study to evaluate potential effects on walkers in the vicinity of Los Angeles International Airport (LAX). Twenty-two randomly selected non-smoking adults (zero cigarettes in the past month) with mild to moderate asthma participated in the study in winter 2014 and summer 2015. Participants were asked to walk for two hours with short resting periods every 15 minutes at two public parks, one outside the high LAX UFP zone. The study suggested UFP numbers were four to five higher than background levels in downwind communities. They concluded that UFP related to airport emissions demonstrated increased acute inflammation. Note that the sample size is very small but does indicate potential adverse health effects for compromised populations.
- Bay Area Air Quality Management District Study – The Bay Area Air Quality Management District (BAAQMD) is the regulation body surrounding San Francisco and San Jose, California. The study began in 2011 and was most recently updated in 2016 where PM_{0.1} was measured from a variety of sources using a TSI model 3031 along with regional dispersion modeling (CMAQ-MADRID) and emission inventory data from 2015. Their findings suggested that approximately 8% of all non-road sources were attributable to nearby airports. During the winter 2015, all PM_{0.1} sources were determined to emit an average daily amount of 5.809 tons with aircraft comprising 0.021 tons.
- U.S. EPA Particulate Matter Integrated Science Assessment (ISA) – The SA is an evaluation and synthesis of policy-relevant science to characterize exposures to ambient PM and associated health and welfare effects. Ambient UFPs originate from two distinct processes: primary emissions and new

particle formation. Primary UFPs originate from a large variety of sources, such as transportation (road traffic, ships, and aircraft), power plants, municipal waste incineration, construction and demolition, vegetation fires, domestic biomass burning, cooking, and cigarette smoke. UFP consists mainly of nucleation-mode particles. However, nucleation-mode particles often have short atmospheric lifetimes because they coagulate to form the larger particles that make up the accumulation mode.

Soluble material can move rapidly from the alveolar surface into the blood, but poorly soluble particles generally remain in the lung for an extended period of time. Several human studies are available confirming that the majority of poorly soluble UFP deposited in the alveolar region undergo slow clearance and do not rapidly enter circulation. However, animal studies (primarily of rats) show that UFPs cross cell membranes by mechanisms different from larger (~1 µm) particles, and that a small fraction of these particles enter capillaries and distribute systemically. Some evidence suggests that a small degree of pulmonary inflammation increases in resulting in a flux of fluid and any associated particles or fibers into pulmonary capillaries.

Studies examined hospital admissions for respiratory-related diseases, with the majority presenting associations with short-term PM_{2.5} exposure in analyses of all ages. A recent study that examined associations with PM sizes smaller than 2.5 µm, but larger than UFP supports a positive association with respiratory-related emergency department visits observed for PM_{2.5}.

Short-term UFP exposure may lead to respiratory health effects via a pathway involving respiratory tract inflammation and allergic responses, which are linked to asthma exacerbation. Another pathway involves the activation of sensory nerves in the respiratory tract leading to lung function decrements.

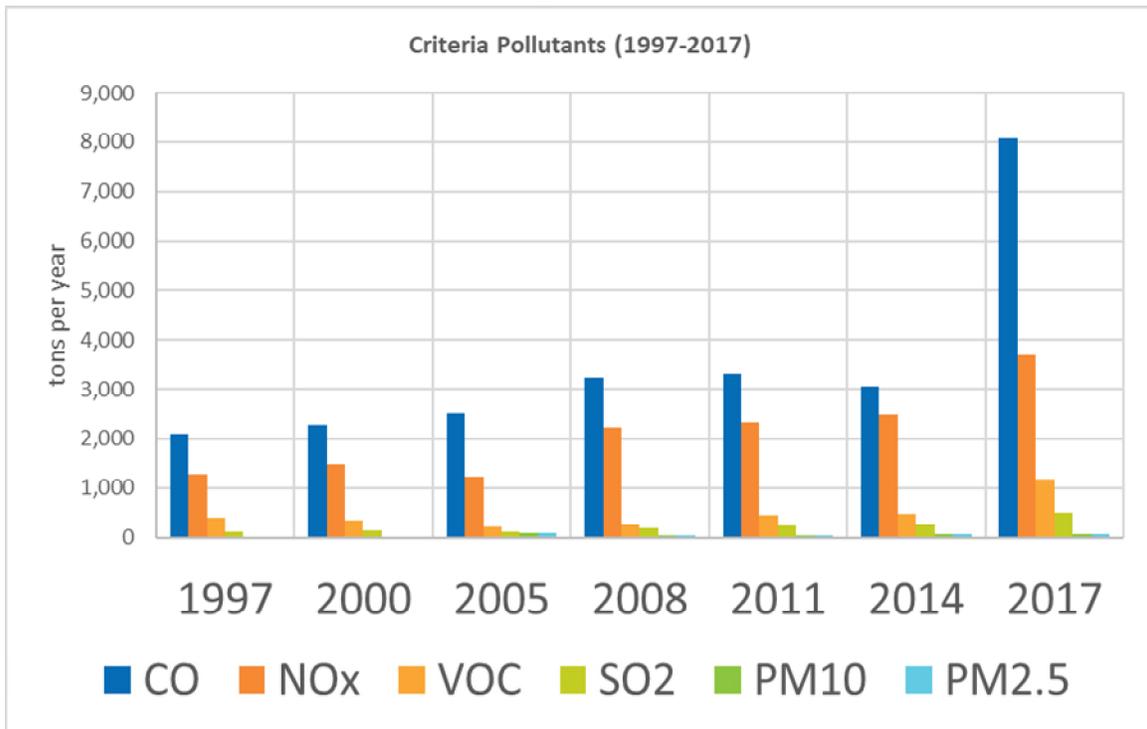
- **Negative Effect #2: Increased Operations Negatively Affect Air Quality**

Overall, Seattle-Tacoma International Airport operations (twice LTO values) have steadily increased from 2011 through 2018 (314,944 to 438,391). Prior to 2010, operations declined from 2000 (from 445,667 to 313,954). Figure 6.22 illustrates those fluctuations since 1997. NEI total emissions, as previously discussed, increase or decrease, in part, due to the total airport operations. Note that while the total operations are increasing in recent years, the emissions increase is not directly correlated, only partially. This is because engines' fuel efficiency has been increasing, and the distinctive emissions increase from 2014 to 2017 is also significantly affected by the change in Federal Aviation Administration model from EDMS to AEDT. While emissions are increasing, general ambient air concentrations at the Beacon Hill monitor (active through the full time period) have mostly declined. This may suggest that airport emissions do not have a great effect compared to other emission sources surrounding that monitor. Regional impacts associated with the airport air pollution emissions are likely not fully reflected by the current air quality monitoring network because of geographic distribution of the monitors.

Figure 6.23
Seattle-Tacoma International Airport Annual Operations



Figure 6.24



Seattle-Tacoma International Airport NEI Annual Criteria Pollutant Emissions

- **Negative Effect #3: Black Carbon Emissions from Aircraft**

Particulate emissions, specific PM_{2.5}, comprise a series of elements, one of which is black carbon. They are a byproduct of incomplete combustion with a variety of size ranges. Some are visible to the naked eye. The global distribution of black carbon aviation emissions is shown to be higher across the standard airline flight paths throughout the U.S. and Europe. Most emission inventories of black carbon for jet engines extrapolate data from wind tunnel or staged nonrealistic engine tests. A recent study attempts to use data from in-use aircraft as well as a new model to better estimate the global black carbon inventory from aircraft during takeoff, landing, and while cruising. The study concluded that the warming effects these particles exhibit (by absorbing incoming solar radiation in the atmosphere) are approximately 1/3 as large as the warming effect from the CO₂ emitted from the jet engine combustion itself.

Data Gaps

- **PM_{2.5} Regulated but not UFPs**

It is evident through recent studies that UFPs are present and may cause health concerns, yet they are not currently regulated by the U.S. EPA, Ecology or PSCAA. PSCAA has indicated that it does not foresee any federal standard within the next few years. The earliest may be 10 or more years out. PSCAA indicated that further study is needed as well.

- **Lack of Access to EDMS versus AEDT Data for Comparison**

As illustrated throughout this study, Seattle-Tacoma International Airport aviation emissions drastically increased from 2014 to 2017. The 2017 dataset was the first year where AEDT was instituted. While there is general discussion of changes made from EDMS to AEDT, U.S. EPA was unable to provide 2014 data using AEDT to do a complete “apples to apples” comparison.

- **2016 Emissions vs 2017 NEI Emissions**

A community commenter asked the consultant team to address emissions differences between a 2017 Landrum & Brown Air Quality Baseline Report outlining 2016 aviation emissions from the Port of Seattle as part of the Sustainable Airport Master Plan (SAMP) and 2017 U.S. EPA NEI emissions data. The 2016 Port emissions is significantly lower than the 2017 NEI emissions with the exception of Ground Support Equipment (GSE). 2016 Port emissions are based on the following:

- Aircraft emissions: 412,170 operations (from Federal Aviation Administration ATADS) broken down into five subcategories. Based on those operations, emissions were calculated using AEDT.
- All auxiliary power unit (APU) emissions were established via AEDT default assumptions.
- GSE total emissions were then calculated from known pollutant-specific emission factors, load factors, horsepower and overall usage.

The 2017 U.S. EPA NEI emissions are based on the following:

- Numerous sources are used as input values, including Federal Aviation Administration ATADS, state-provided data and generic emission factors for unknown engine-types. All known engine types were used as input to AEDT.
- Data and emission factors are based on LTO cycles rather than operations. U.S. EPA used 495,636 operations (247,818 LTOs) based on approximately two LTOs/operations. However, 2017 Federal Aviation Administration ATADS data suggests 416,136 operations.
- All emissions associated with unknown engine types were directly carried over from the 2014 NEI.

Both datasets implemented AEDT on some level, but there are different input factors as outlined above. However, there is not sufficient evidence to confirm that one method is more accurate than the other. To definitively determine whether one dataset is more representative an in-depth review

of all AEDT input parameters is required. The consultant team does not have access to that information at this time.

▪ **Follow-Up to UFP Studies**

The majority of UFP studies reviewed indicated that the next step is to continue data study and determine how health effects are affected by aircraft UFPs. The UW study suggests the need to determine if short-term health responses to roadway traffic and aircraft particles differ, if there are long-term health effects of exposure to traffic and aircraft UFPs, and if exposures change over time. To fully understand UFPs and their relationship to human health, more studies are needed.

▪ **Dated Environmental Impact Statement**

In September 2006, CH2MHill (now Jacobs Engineering) conducted an air quality analysis as part of the 2007 Seattle-Tacoma International Airport Comprehensive Development Plan NEPA Environmental Assessment. The report states that aviation-related emission estimates in 2006 were based on 207,320 LTOs (414,640 operations) and projected 2024 emissions on 274,895 LTOs (549,790 operations). Both inputs and emission results were established using EDMS. The 2024 operation estimates are reasonable, but use of EDMS is outdated. Because of the differences between EDMS and AEDT, it is likely that the 2024 estimates conducted by CH2MHill would be lower.

A conformity analysis was also conducted using CAL3QHC for off-airport motor vehicles, and a CO hot spot analysis was conducted at four intersections surrounding the airport. Modeling compliance with the NAAQS was obtained for the CO one-hour and eight-hour standards. However, a cumulative assessment was not conducted because of the temporary nature of construction and varying schedules. While monitoring data illustrated NAAQS compliance for other criteria pollutants, it did not appear that other facility-wide modeling was conducted beyond the CO hot spot analysis. Because of this, the lack of a cumulative analysis and that AEDT has replaced EDMS, it may be worthwhile to reevaluate the contents of the 2007 report with a newer report to confirm or update emission effects. The Port of Seattle is in the process of developing an updated SAMP. The Near-Term projects environmental review has been through scoping, and as of December 2019, the review period was extended to incorporate feedback during the scoping period. The current schedule estimates that the SAMP Environmental Review final document and decision will be completed by September 2021.

▪ **Toxic Concentration Information**

Toxic studies that are referenced in this section suggest that the overall toxic concentrations are mostly on the decline since 2000. However, the Ecology study is based only on the Beacon Hill monitor and the 2003 PSCAA study covers only two years' worth of data at the city of SeaTac monitor. The PSCAA study suggests that the airport's contribution may not be more than any other sources, but it is uncertain. The lack of confirmed data does not allow for 100% confidence that Seattle-Tacoma International Airport does not have a greater toxic effect on the surrounding communities. Also, the PSCAA study was conducted prior to the installation of the third runway in 2008. Increased toxic monitoring nearer the airport would provide more data to validate or disprove that concentrations from aviation sources do not greatly differ from others.

Summary of Air Quality Effects Attributable to Aviation Activity

Air quality has been an ongoing community concern in most of the study area. Air quality concerns reported by study area residents include smell and possible toxins deposited on area structures, surfaces, yards, etc. Most recently, concerns regarding UFP's were heightened through reports released from the World Health Organization and through a parallel and separate study conducted by the University of Washington.

The graphs and tables in this section present various aspects of air quality and its associated elements. There are also concerns that in lieu of a working and close-in monitoring network, reports of air quality attainment may be inaccurate. However, Figure 6.25 presents a general assessment of air quality effects in the study area attributable to aviation activity, categorized into four effect types:

- Positive effect attributable to aviation activity
- Negative effect attributable to aviation activity
- Neutral or no effect attributable to aviation activity
- Inconclusive data/needs additional study.

Figure 6.25
Summary of Air Quality Effects Attributable to Aviation Activity – 1997 to 2019

 Positive effect attributable to aviation activity	 Neutral/no effect attributable to aviation activity
 Negative effect attributable to aviation activity	 Inconclusive data/needs additional study

AIR QUALITY METRIC	STUDY AREA CITY																	
	Burien			Des Moines			Federal Way			Normandy Park			SeaTac			Tukwila		
	1997	2009	2019	1997	2009	2019	1997	2009	2019	1997	2009	2019	1997	2009	2019	1997	2009	2019
CO	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
HC	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
NO _x	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
SO ₂	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
VOC	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
PM ₁₀	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
PM _{2.5}	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
UFP's	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Due to the need for improved air quality monitoring and ongoing research into UFPs in the study area, a definitive assessment cannot be offered in the 2020 study regarding the positive, neutral, or negative effects on air quality. While the region is technically in attainment with U.S. EPA air quality standards, concerns regarding location and operability of the air quality monitoring network warrant further study, modelling and analysis beyond the scope of the 2020 study. As such, the effects from carbon monoxide, hydrocarbons, nitrogen and sulfur dioxides, volatile organic compounds, and particulate matter (PM₁₀, PM_{2.5}, and UFP's) should be further modelled and evaluated in a follow-up study.

L. RECOMMENDATIONS

To address the issues identified in this section, the following recommendations are proposed.

- **Air Quality Recommendation #1: Current Monitoring Network**

The current monitoring network surrounding Seattle-Tacoma International Airport is somewhat limited. Over the past 15-20 years various locations have started to be shut down in areas that have shown a steady decline and well within applicable standards. However, there are areas that potentially could warrant more monitors nearby the airport. Other networks were also evaluated at three other airports of similar size. These were Boston, Miami and Phoenix. Boston and Miami have a similar number of monitors when compared to Seattle. However, Arizona DEQ and Maricopa County operate a significant number of monitors greater than Seattle. Most of them are measurements of ozone and particulate-based.

▪ **Air Quality Recommendation #2: Monitoring Guidelines for New Location**

The location of a new monitoring site initially depends on the objective. In this case, the objective is likely to determine most pollutants at the neighborhood or middle scale. Other criteria to evaluate are nearby sources (Seattle-Tacoma International Airport), prevailing wind direction, uniform land use and nearby population density. Other factors that are involved in site consideration include:

- Economics – Access/cost to property, installation of power lines, excavation and installation of concrete pads, fencing, other site specific costs
- Security – A particular site may not be appropriate for the establishment of an ambient monitoring station simply due to problems with the security of the equipment in a certain area. If the problems cannot be remedied via the use of standard security measures such as lighting, fences, electronic surveillance, etc., then attempts should be made to locate the site as near to the identified sector as possible while maintaining adequate security.
- Logistics – Full knowledge of data collection, including planning, training, scheduling, and staffing
- Atmospheric Considerations – Atmospheric considerations may include the spatial and temporal variability of the pollutants and its transport to the monitoring site. Effects of buildings, terrain, and heat sources or sinks on the air trajectories can produce local anomalies of excessive pollutant concentrations. Meteorology must be considered: wind speed, wind direction, wind variability, topography.
- Pollution Considerations – A sampling site or an array of sites for one pollutant may be appropriate for another pollutant species because of the configuration of sources, the local meteorology, or the terrain. Pollutants undergo changes in their compositions between their emission and their detection; therefore, the effect of that change on the measuring system should be considered.

None of the factors stands on its own, but they depend in part on each other. Should any new sites be considered, all of the above will be accounted for by PSCAA or Ecology. At a minimum, criteria set forth in 40 CFR Part 58, Appendix D should be used.

In addition to adding more monitors, it may be possible to relocate a current monitor to a more desirable site. That may mean closer to the airport or more directly under the flight path when flying at lower altitudes. The key to relocation is to identify the intent of the monitor (i.e., to potentially better evaluate effects within the communities nearest the airport). Along with intent, it is necessary that any relocation effort meets all the site criteria discussed above.

▪ **Air Quality Recommendation #3: Purple Air Monitors**

PurpleAir.com is a company that sells particle monitors to individual users that allow them to measure particles ranging from 0.3 microns to 10. Those data are then used to calculate mass concentrations for PM_{1.0}, PM_{2.5} and PM₁₀. While these units are helpful to the user and provides Air Quality Index (AQI) at various averaging periods, the data gathered is not consistent with FRM/FEM monitors. AQI values are informative for daily air quality and are correlated to the NAAQS. For example, an AQI rating of 100 corresponds to a concentration equivalent to the federal standard for a specific pollutant and averaging period. The measuring methods of PM and the averaging time of data collected also differ from regulatory monitors.

As discussed previously in this section, the Purple Air monitoring network is helpful for AQI and to provide general interpretation of NAAQS correlation. It provides a general understanding of particulate matter surrounding the monitor but does not explicitly mean the area is non-compliant or shows negative effects. Individual exceedances of even FRM monitors does not mean the area is violating a specific standard. Complete data over a given averaging period must be reviewed by the applicable agency (i.e., PSCAA or Ecology), submitted to the U.S. EPA and then designated as such. It is recommended that consideration be given to deploying more Purple Air monitors throughout the study area cities (100 to

200 monitors, for example) in areas of concern to get a general sample of air quality trends. A quality assurance program should be part of this effort to ensure the monitors are deployed, placed, and maintained correctly. This, in turn, may assist in indicating which areas should receive future FRM/FEM monitor in the future.

▪ **Air Quality Recommendation #4: Ultrafine Particles and Health Effects**

The most recent UFP studies have demonstrated that there is a correlation to high UFP particle numbers and flight paths. It has also shown that aviation-specific UFPs can be distinguishable from other sources, such as highway traffic. There is even a correlation of UFPs to animals experiencing adverse neurological effects. However, there are very limited study on how UFPs affect human health. The current stance is that further study is necessary to establish a definitive link. If a link can be established, that may be the first step toward future regulation.

▪ **Air Quality Recommendation #5: Aviation Emissions Rise and Effect Decline**

U.S. EPA NEI data has shown a general increase over the past decade that correlates well to a rise in airport operations. Additionally, the Federal Aviation Administration/U.S. EPA modified its model (EDMS to AEDT) to calculate engine-specific emissions, which illustrated a large increase from 2014 to 2017. Although airport-related emissions have been on the rise in recent years, the region and county have demonstrated compliance with all NAAQS and are moving out of maintenance for PM₁₀. Additionally, most of the toxic pollutants measured at Beacon Hill have shown a steady decline since 2000. Also, the PSCAA 2003 study demonstrated that measurements in the city of SeaTac were comparable to all other monitoring locations evaluated in the study. The overall regional reduction of effects may suggest that the airport has a smaller contribution than other sources in the area or, as discussed above, more monitors nearer the six communities would be helpful to gauge a more direct effect from the airport.

M. THE FUTURE

As noted previously, technological change is a near-constant, especially in transportation. In 2020, there is an increased interest by almost every automobile manufacturer to create vehicles that no longer rely on conventional internal combustion engines. At present, the near-future appears to be battery-powered vehicles, which will help reduce mobile-source air pollution (ozone and hydrocarbons). However, in the absence of external forces (rebate programs, drastic fuel price spikes, etc.), it will likely take years for these vehicles to reach market penetration to see measurable improvements in air quality.

Other previously noted changes – in aviation technology, a potential new airport, new modes (Hyperloop), or even new disruptive technology (autonomous cars, flying taxi services, etc.) remain future possibilities, but there are no market-ready alternatives (yet). Should any of these potential futures become a reality, an update to this study would be warranted.

N. SUMMARY

Next to noise, air quality also tends to be a common concern surrounding airports. More stringent air quality standards have improved measurable air quality since the enactment of the National Environmental Policy Act in 1970. This has been accompanied by improvements in aircraft design and power plant technology that have made today's aircraft more efficient, less polluting, and quieter than those flying decades earlier.

But in the minds of the public, meeting the standards or being in "attainment" is not a true measure of the concerns surrounding air quality. For example, the operation and location of working air quality monitors may not

be truly representative of airborne emissions surrounding Seattle-Tacoma International Airport. And emerging research into currently unregulated pollutants – specifically UFPs – raises further concerns about effects on human health.

While more study is warranted to understand potential epidemiological effects of UFPs and other pollutants, improvements to the study area’s air quality monitoring program is something that can be done almost immediately. Technically being “in compliance” with state and federal air quality standards may not be an accurate representation of air pollution levels when the devices that sample and monitor the air are either not functioning or are not close to inhabited portions of the study area.

O. REFERENCES

Austin, Elena, Jianbang Xiang, Tim Gould, Jeffry Shirai, Sukyong Yun, Michael Yost, Timothy Larson, and Edmund Seto. 2019. Mobile Observations of Ultrafine Particles (MOV-UP) Study Final Report. Report, Seattle: University of Washington.

CH2MHill. 2007. Seattle-Tacoma International Airport Comprehensive Development Plan – POS SEPA No. 07-09 Environmental Review NEPA Environmental Assessment. Report, Seattle: CH2MHill.

Department of Ecology. 2019. 2019 Ambient Air Monitoring Network Plan. Annual Report, Olympia: Washington Department of Ecology.

Diaz, Elmer, Koenraad Marien, Lillian Manahan, and Julie Fox. 2019. Summary of Health Research on Ultrafine Particles. Report, Olympia: Washington Department of Health.

Eastern Research Group, Inc. 2019. 2017 National Emissions Inventory: Aviation Component.

Technical Document, Ann Arbor: ERG.com.

Federal Aviation Administration. 2016. “AEDT & Legacy Tools Comparison.” Aviation Environmental Design Tool. June 3. Accessed Oct. 22, 2019. https://aedt.faa.gov/Documents/Comparison_AEDT_Legacy_Summary.pdf.

Federal Aviation Administration. 2019. Air Traffic Activity Systems - Airport Operations. October. Accessed Oct. 1, 2019. <https://aspm.faa.gov/opsnet/sys/Airport.asp>.

Friedman, Beth. 2019. Monitor Site Questions Email. October 1.

Gettelman, A., and C. Chen. 2013. “The Climate Impact of Aviation Aerosols.” Geophysical Research Letters 2785-2789.

Gilliam, J., and E. Hall. 2016. Reference and Equivalent Methods Used to Measure National Ambient Air Quality Standards (NAAQS) Criteria Air Pollutants - Volume I. US EPA/600/R-16/139, Washington DC: U.S. Environmental Protection Agency.

Graham, A., and D.W. Raper. 2006. “Transport to Ground of Emissions in Aircraft Wakes. Part I: Processes.” Atmospheric Environment 40 (29): 5574-5585.

Habre, Rima, Hui Zhou, Sandrah Eckel, Temuulen Enebish, Scott Fruin, Theresa Bastain, Edward Rappaport, and Frank Gilliland. 2018. “Short-term Effects of Airport-Related Ultrafine Particle Exposure on Lung Function and Inflammation in Adults with Asthma.” Environment International 48-59.

- Hudda, N, M.C. Simon, W. Zamore, and J.L. Durant. 2018. "Aviation-Related Impacts on Ultrafine Particle Number Concentrations Outside and Inside Residences Near an Airport." *Environmental Science & Technology* 1765-1772.
- International Civil Aviation Organization. 2016. Aircraft Engine Emissions. Accessed Jan. 9, 2020. <https://www.icao.int/environmental-protection/Pages/aircraft-engine-emissions.aspx>.
- Keill, Leslie, and Naydene Maykut. 2003. Final Report: Puget Sound Air Toxics Evaluation. Agency Report, Seattle: Puget Sound Clean Air Agency.
- Landrum & Brown. 2017. Air Quality Baseline (2016) Condition Report - SAMP Seattle-Tacoma International Airport. Preliminary Draft, Landrum & Brown.
- Leitte, A, U. Schlink, O Herbarth, A Wiedensohler, X Pan, M Hu, M Richter, et al. 2011. "Size segregated particle number concentrations and respiratory emergency room visits in Beijing, China." *Environmental Health Perspectives*.
- Miserocchi, G., G. Sancini, F. Mantegazza, and G. Chiappino. 2008. "Translocation Pathways for Unhaled Asbestos Fibers." *Environmental Health*.
- Mok, Hoi-Fei, Michael Steinhoff, Eli Yewdall, and Matt Kuharic. 2019. GHG Emissions in King County: 2017 Inventory Update, Contribution Analysis and Wedge Analysis. Report, Seattle: King County & ICLEI, USA.
- New Jersey Department of Health. 2016. "Hazardous Substance Fact Sheet – Kerosene." July 2016. Accessed Jan. 8, 2020. <https://nj.gov/health/eoh/rtkweb/documents/fs/1091.pdf>.
- Parent, P, C. Laffon, I. Marhaba, D. Ferry, T.Z. Regier, I.K. Ortega, B. Chazallon, Y. Carpentier, and C. Focsa. 2016. "Nanoscale characterization of aircraft soot: A high-resolution transmission electron microscopy, Raman spectroscopy, X-ray photoelectron and near-edge X-ray absorption spectroscopy study." *Carbon* 86-100.
- Port of Seattle. 2019. Climate and Air Quality. Accessed Oct. 21, 2019. <https://www.portseattle.org/environment/climate-air-quality>.
- Port of Seattle. 2019. CO2 From Scope 3 Sources at Sea-Tac Airport (2017-18). Seattle, December 2019.
- Port of Seattle. 2019. Pre-Conditioned Air. Accessed Oct. 21, 2019. <https://www.portofseattle.org/projects/pre-conditioned-air>.
- Port of Seattle. 2019. Sustainable Airport Master Plan Near-Term Projects Environmental Review. December. Accessed Jan. 13, 2020. <https://sampntpenvironmentalreview.org/>.
- Port of Seattle. 2019. Sustainable Aviation Fuels. Accessed Dec. 12, 2019. <https://portofseattle.org/page/sustainable-aviation-fuels>.
- Puget Sound Clean Air Agency. 2018. 2017 Air Quality Data Summary. Annual Report, Seattle: PSCAA.
- Puget Sound Clean Air Agency. 2015. "Puget Sound Clean Air Agency." 2015 Air Quality Data Summary. August. Accessed Dec. 31, 2019. <https://pscleanair.gov/DocumentCenter/View/2294/Air-Quality-Data-Summary-2015PDF>.
- Puget Sound Clean Air Agency. 2013. The Kent, Seattle and Tacoma, WA Second 10-yr Limited Maintenance Plan for PM10. Maintenance Plan, pscleanair.org.
- PurpleAir. 2020. PurpleAir Frequency Asked Questions. Accessed Jan. 2, 2020.

<https://www2.purpleair.com/community/faq#!hc-how-do-purpleair-sensors-compare-to-regulatory-particulate-matter-sensors-1>.

Raffuse, Sean M., Dana C. Sullivan, Michael C. McCarthy, Bryan M. Penfold, and Hilary R. Hafner. 2007. Ambient Air Monitoring Network Assessment Guidance. 454/D-07-001, Washington, DC: U.S. Environmental Protection Agency.

Riley, Erin, Timothy Gould, Kris Hartin, Scott Fruin, Christopher Simpson, Michael Yost, and Timothy Larson. 2016. "Ultrafine Particle Size as a Tracer for Aircraft Turbine Emissions." *Atmospheric Environment* 20-29.

Stephens, B. 2015. "Infiltration of outdoor pollutants: How building airtightness and pollutant characteristics affect the transport of outdoor air pollution into the indoor environment." *Home Energy*, May/June: 10-16.

Stettler, Marc E.J., Adam M. Boies, Andreas Petzold, and Steven R. H. Barrett. 2013. "Global Civil Aviation Black Carbon Emissions." *Environmental Science & Technology* 10397-10404.

Synergy Consultants Inc. 2007. Greenhouse Gas Emissions Inventory - 2006. Emissions Report, Seattle: Port of Seattle.

Tanrikulu, Saffet, and Cuong Tran. 2012. Ultrafine Particulate Matter Emissions Inventory Prepared for the San Francisco Bay Area. Research Report, San Francisco: Bay Area Air Quality Management District.

United States Environmental Protection Agency – EIS Report. 2019. Corrected SeaTac Compare_20191022.xlsx. Washington, D.C., October 10.

United States Environmental Protection Agency. 2019. Air Data Air Quality Monitors. Accessed Oct. 15, 2019. <https://www.epa.gov/outdoor-air-quality-data/interactive-map-air-quality-monitors>.

United States Environmental Protection Agency. 2000. Aircraft Contrails Factsheet. September. Accessed Jan. 3, 2020. https://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/contrails.pdf.

United States Environmental Protection Agency. 2018. "Emission Factors for Greenhouse Gas Inventories." Environmental Protection Agency. March 9. Accessed Dec. 30, 2019. https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf.

United States Environmental Protection Agency. 2010. "EPA Schools Monitoring Initiative Fact Sheet." Assessing Outdoor Air Near Schools. Accessed Dec. 30, 2019. <https://www3.epa.gov/air/sat/pdfs/acroleinupdate.pdf>.

United States Environmental Protection Agency. 1991. "Indoor Air Facts No. 4 - Sick Building Syndrome." US EPA. February. Accessed Jan. 9, 2020. https://www.epa.gov/sites/production/files/2014-08/documents/sick_building_factsheet.pdf.

United States Environmental Protection Agency. 2009. Integrated Science Assessment for Particulate Matter Final Report. Assessment, Research Triangle Park: Office of Research and Development.

United States Environmental Protection Agency. 2019. Integrated Science Assessment for Particulate Matter. Assessment, Research Triangle Park: Office of Research and Development.

United States Environmental Protection Agency. 2019. "Introduction to Indoor Air Quality." U.S. EPA. October 3. Accessed Jan. 9, 2020. <https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality#causes>.

United States Environmental Protection Agency. 2017. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015. Report, Washington, D.C.: U.S. EPA.

- United States Environmental Protection Agency. 2018. "Mobile Source Emissions – King County." 2014 National Emissions Inventory Data. July. Accessed Nov. 23, 2019. <https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data>.
- United States Environmental Protection Agency. 2018. NEI Data and Documentation. Accessed Sept. 2, 2019. <https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei>.
- United States Environmental Protection Agency. 2019. Nonattainment Areas for Criteria Pollutants (Green Book). December 31. Accessed Jan. 10, 2020. <https://www.epa.gov/green-book>.
- United States Environmental Protection Agency. 2017. Quality Assurance Handbook for Air Pollution Measurement Systems Volume II - Ambient Air Quality Monitoring Program. Handbook, Research Triangle: United States Environmental Protection Agency.
- United States Environmental Protection Agency. 2017. Sulfur Dioxide (SO₂) Primary Air Quality Standards. August 24. Accessed Jan. 8, 2020. <https://www.epa.gov/naaqs/sulfur-dioxide-so2-primary-air-quality-standards>.
- Washington Department of Ecology. 2019. Air Quality Monitoring Network. Accessed Nov. 8, 2019. <https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Air-quality-monitoring-network>.
- Washington Department of Natural Resources. 2016. Air Quality Review of Industrial PM_{2.5} Emissions From Stationary Sources in Wisconsin. Guidance, Madison: Washington Department of Natural Resources.
- World Health Organization. 2018. "Ambient (Outdoor) Air Quality and Health." World Health Organization. May 2. Accessed Aug. 23, 2019. [https://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health).

This page intentionally left blank