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DEPARTMENT OF
ECOLOGY

1998/1999 SeaTac Oxides of Nitrogen and Particulate Monitoring Study

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Prepared by:
Jim Frost
Doug Knowlton

Washington State Department of Ecology
Air Program

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Introduction

This report summarizes the results from the Oxides of Nitrogen and Particulate Monitoring Study that was conducted from January, 1998 to June, 1999 by the Department of Ecology (Ecology) Northwest Regional Office (NWRO) air monitoring staff. In April 1995, the Federal Aviation Administration (FAA) and the Port issued a joint Draft Environmental Impact Statement (EIS) for the proposed Master Plan Update Improvements at Seattle-Tacoma International Airport. In February 1996, the FAA and Port issued the Final EIS, which incorporated a draft air quality conformity determination. In response to comments on the EIS and to SeaTac area residents' concerns about air pollution originating from the SeaTac airport, a Memorandum of Agreement (MOA) between Ecology, the Port of Seattle, Puget Sound Clean Air Agency, and the US Environmental Protection Agency - Region X, was made to monitor carbon monoxide, oxides of nitrogen and deposition in the vicinity of the SeaTac Airport. There were two phases to this monitoring program. The first was a study of the carbon monoxide (CO) concentrations at major traffic intersections adjacent to the airport, conducted in the fall and winter of 1997-98. The CO study results are presented in a separate report (1996-1997 SeaTac Carbon Monoxide Saturation Study, Williamson, 1997). The second phase is the Oxides of Nitrogen and Particulate Monitoring for the SeaTac Area study.

EPA has established National Ambient Air Quality Standards (NAAQS) for air pollutants including nitrogen dioxide and particulate matter. The NAAQS for nitrogen dioxide (NO_2) is an annual standard of .053 parts per million (ppm). For an area to maintain compliance, the concentrations of NO_2 must not exceed an average of 0.053 ppm for any 12-month period. For an area to maintain compliance with the NAAQS for particulate matter with a cut size of less than 10 microns (PM_{10}), the annual average must not exceed 50 $\mu g/m^3$ and the 24–hour average must not exceed 150 $\mu g/m^3$.

Nitrogen dioxide is a yellowish brown, highly poisonous reactive gas. It forms when fuel is burned at high temperatures. Combustion engines (automobiles and aircraft) and stationary combustion sources are the two major sources of NO_2. In the Puget Sound region motor vehicles constitute the largest source of NO_2. Since 1968, when the Federal Clean Air Act first mandated motor vehicle emission controls, tailpipe emissions of oxides of nitrogen have decreased. The decreasing tailpipe emissions have produced a reduction of ambient NO_2 concentrations in the Puget Sound area.

NO_2 has significant human health effects. Nitrogen dioxide enters the blood stream through the lungs. Because it is a bronchoconstrictor it causes lung irritations, resulting in ciliary paralysis, bronchitis and pneumonia. NO_2 exacerbates influenza by impairing the body's defenses against bacterial and viral infections. Nitrogen dioxides are also factors in the generation of secondary pollutants such as ozone.

PM_{10} consists of tiny particles of dust, sand, cinders, soot, asbestos, smoke and liquids found in the atmosphere. PM_{10} often transports toxic elements such as lead, cadmium, arsenic, nickel, vinyl chloride, asbestos and benzene compounds throughout the body, often ending up in the respiratory, digestive and lymphatic systems. PM_{10} can aggravate chronic disease and heart and lung disease symptoms.

In accordance with EPA regulations, Ecology maintains an automated reference method NO_2 monitoring station at Beacon Hill. Data from this station is used to determine compliance with the NAAQS and to develop and evaluate control measures. Figure 1 depicts the annual average for NO_2 at Beacon Hill since 1995.

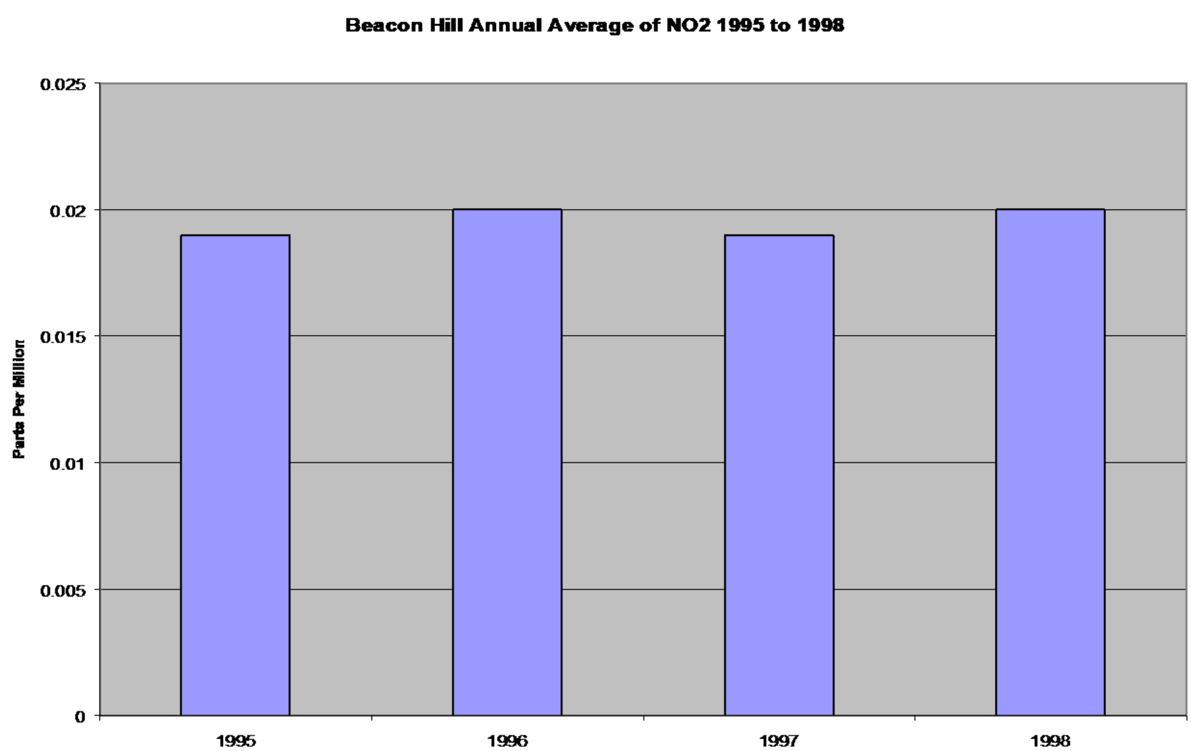
Background

For several years, residents in the vicinity of Seattle-Tacoma International Airport (SeaTac) have expressed concerns over concentrations of air pollutants emitted from Seattle-Tacoma International Airport. Several small-scale air pollutant sampling programs had been conducted by the Port of Seattle (Port), the Washington State Department of Ecology and Puget Sound Clean Air Agency.

In April 1995, the Federal Aviation Administration (FAA) and the Port issued a joint Draft Environmental Impact Statement (EIS) for the proposed Master Plan Update Improvements at Seattle-Tacoma International Airport. In February 1996, the FAA and Port issued the Final EIS, which incorporated a draft air quality conformity determination. These environmental documents address, among other issues, potential air quality impacts associated with various Master Plan Update improvement projects (facility developments and operational changes) to be phased in between 1996 and 2020 as part of the long range airport plan.

The Final EIS considered the available SeaTac air quality information from previous studies, updated the baseline and projection year emission inventories for five criteria pollutants of concern (nitrogen dioxide, particulate matter, carbon monoxide, sulfur dioxide, and ozone), performed area-wide dispersion screening modeling for volatile organic compounds (VOC) and oxides of nitrogen (both precursors to ozone) and conducted localized traffic intersection modeling analyses for carbon monoxide.

Figure 1



The Port and FAA identified probable future exceedences of the federal standard for CO resulting from the project. However, no monitored air quality data for the SeaTac vicinity existed with which to interpret the FEIS' worst case modeling results, which may overstate actual future air quality problems. Also, because the Master Plan Update project phase that caused the modeled CO exceedences does not occur until approximately 2010, the issue of specifying appropriate mitigation measures was prematurely raised.

In comments submitted by PSCAA, Ecology, and EPA to the Federal Aviation Administration on the FEIS draft conformity finding, it was noted that in order to demonstrate conformity with the Central Puget Sound State Implementation Plan (SIP), there must be firm commitments made at that time by the Port and FAA to either (1) mitigate the modeled standard exceedences for CO or (2) delay inclusion of certain projects until future environmental reviews are completed for those elements and firm commitments to new mitigation measures are made, if necessary. Several options for achieving this outcome were specified. The comments also recommended a funded 24-month SeaTac area air quality monitoring study.

In response to these comments and to SeaTac area residents' concerns about air pollution originating from the SeaTac airport, a Memorandum of Agreement (MOA) between Ecology, the Port of Seattle, Puget Sound Clean Air Agency, and the US Environmental Protection Agency - Region X, was made to monitor carbon monoxide, oxides of nitrogen and deposition in the vicinity of the SeaTac Airport. There were two phases to this monitoring program. The first was a study of the CO concentrations at major traffic intersections adjacent to the airport, conducted in the fall and winter of 1997-98. The CO study results are presented in a separate report (1996-1997 SeaTac Carbon Monoxide Saturation Study, Williamson, 1997). The second phase is the Oxides of Nitrogen and Particulate Monitoring for the SeaTac Area study.

The Oxides of Nitrogen and Particulate Monitoring for the SeaTac Area project had two parts. The first part was to determine and quantify any spatial or temporal variations of NO_2 concentrations throughout areas of the SeaTac community. This part became known as the "SeaTac Airport Spatial Nitrogen Dioxide Study". The second part was to provide accurate measurements of ambient concentrations of NO, NO_2 and particulate matter. This part became known as the "Oxides of Nitrogen and Particulate Monitoring Study"

Study Design

The Oxides of Nitrogen and Particulate monitoring Study was conducted in the SeaTac area. The study area was defined as being bounded by South 136th to the north, I-5 to the east, 1st Avenue South to the west, and South 200th to the south.

SeaTac Airport Spatial Nitrogen Dioxide Study

The SeaTac Airport Spatial Nitrogen Dioxide Study was designed and conducted by Ecology. The University of Washington (UW) was contracted to analyze the badge samplers, to analyze the data and to issue a summary report. Sampling was conducted by Ecology staff, Jim Frost and Doug Knowlton. Doug Urry, from UW, analyzed the samples and issued a report to Ecology (see appendix C).

Passive NO_2 samplers were deployed at 16 locations (see Figure 2). The badge samplers consisted of five layers of hydrophobic fiber filter as a diffusion barrier and a cellulose fiber filter soaked with triethanol amine (TEA). Palmes et al. (1976) developed the diffusion sampler to measure NO_2 using TEA as the absorbing reagent. TEA was selected because it captures NO_2 very efficiently, has a high viscosity and low vapor pressure making it stable on coated surfaces, and forms a very stable complex with NO_2 enabling considerable storage periods between sampling and analysis. The samplers were housed inside a short segment of ABS pipe mounted on ten foot conduit which was attached to fences or fence posts. Samples were collected following a three-week exposure and analyzed at the University of Washington. Collected NO_2 mass was quantified by extracting the TEA coated filter in azodye-forming reagent and analyzing colorimetrically (Saltzman, 1954).

The sampling period began January 3, 1998 and ran through December 1998. The study design called for sampling to begin simultaneously at all sites. Co-locating samplers allowed for direct comparison of sampling methods and local badge transfer rates were determined based on co-location sample results. Due to equipment procurement delays and problems securing sites, the automated sites were not operational at the beginning of the study. Co-located sampling was also performed at Beacon Hill Reservoir (BHR). The three-week passive sampling results at Beacon Hill were also used as a means for comparing SeaTac measurement results with Seattle urban NO_2 levels. This site was determined to be representative of the Seattle area on an urban scale (Norris, 1994). The BHR monitoring site was operational throughout the duration of the study; continuous monitoring was performed at Sites 1(SeaTac North) and 16 (Tyee Valley Golf Course) beginning in April and June, respectively.

Oxides of Nitrogen and Particulate Monitoring Study

The Oxides of Nitrogen and Particulate Monitoring Study was designed and conducted by Ecology. Sampling was performed by Jim Frost and Doug Knowlton. Federal Reference Method (FRM) oxides of nitrogen continuous automated analyzers were deployed at these two sites. In addition, High Volume Air Samplers, for the measurement of particulate matter with a cut size of 10 microns (PM_{10}), were located at each site along with meteorological sensors.

One of the concerns of the citizens in the SeaTac area was deposition of small particles. With the resources and sampling technology available, it was not possible to analyze the composition of these particles. Ecology elected to monitor the concentrations of small particulate matter with High Volume Air Samplers, in conjunction with Integrating Nephelometers (Model M 903), which were also deployed at the two automated sites. The physical geometry of the integrating nephelometers used in this study measures the optical light scattering caused by fine particulate matter and produces an output signal proportional to the scattering extinction coefficient (Bscat). This extinction coefficient due to light scattering has been found to correlate well with the mass concentration of fine particles.

The High Volume Air Samplers were set to sample on a one-day in six schedule. The Nephelometers operated continuously. The nephelometer data was used to estimate PM_{10} concentrations for the days between scheduled PM_{10} sampling.

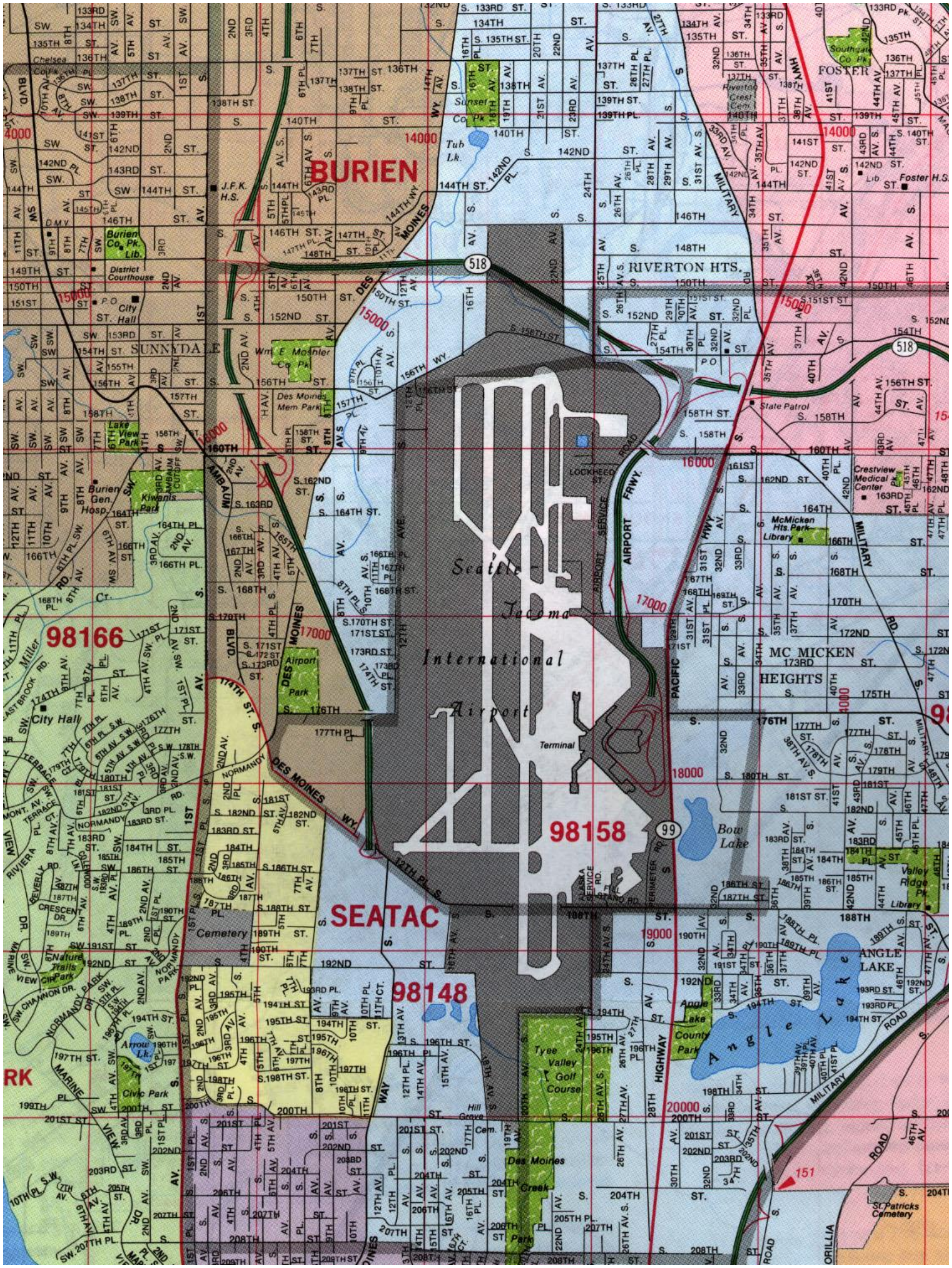


Figure 2 – Map of Site Locations

Site Selection

The general objective in selecting the passive sampling locations at SeaTac was to encompass the communities north and south of the airport where the highest aircraft impacts had been predicted. The goal was to identify NO_2 "hotspots" by sampling at a large number of locations. Ideally, the sites would have been laid out in a systematic grid, however the lack of acceptable locations prohibited this approach. Ecology generated a list of potential sites based on past sampling efforts, wind roses and a canvassing of the community. The University of Washington researchers worked with Ecology staff to narrow the list down to the best sites that would be spread as evenly as possible throughout the areas of concern.

Earlier modeling exercises (FAA and Port of Seattle, 1996) had identified the areas at each end of the runways for potential exceedences of National Ambient Air Quality Standards for NO_2. Based upon the resources available, the number of passive sampling sites for the annual study was set at sixteen. Seven sites were located in both the communities directly north (Sites 1 – 7) and south (Sites 10 – 16) of the airport. Table 1 presents predicted concentrations at selected sample locations for 1994 airport operations. These concentrations were obtained from NO_X concentration isopleths; 0.020 ppm was added to each to account for the background NO_2 level.

Table 1. Predicted concentrations for selected sites

Site #	Worst-case annual conc. (ppm)[a]	Worst-case hourly conc. (ppm)[b]
1	0.05	-
3	0.07	-
5	0.12	19
6	0.06	-
11	0.07	-
14	0.03	-
16	0.13	12

[a]FAA and Port of Seattle, 1996
[b]WDOE, 1991

Site 8 was located as close as possible to the runways at an airport viewing area, 370 meters west of the westernmost runway. This location was selected for the purpose of evaluating concentrations of NO_2 to the west of the airport. Site 9 was located in Normandy Park approximately 2.5 km west of the runways. This location is normally upwind and further away from local vehicle, airport, and other NO_X emission sources; therefore, it was selected as a background site.

Two sites were selected by Ecology for Federal Reference Method automated analyzer sites, one located in an area adjacent to a neighborhood north of the runway (site 1) and one in a public golf course south of the runway (site 16). Continuous sampling was conducted at sites 1 and 8 beginning April 8, 1998,and June 8, 1998, respectively. These sites were selected because they lie within the areas predicted to have the highest concentrations of NO_2 in areas open to the public. Passive samplers were also co-located at these sites to determine mass transfer rates for the badge and method precision.

Sites were selected following rationale discussed in Appendix D of 40 CFR Part 58 (EPA, 1996 (3)), titled "Network Design for State and Local Air Monitoring Stations (SLAMS), National Air Monitoring Stations, and Photochemical Assessment Monitoring Stations (PAMS)". We followed the four basic objectives as outlined in SLAMS requirements:

1) To determine highest concentrations expected to occur in the area covered by the network.
2) To determine representative concentrations in areas of high population density.
3) To determine the impact on ambient pollution levels of significant sources or source categories.
4) To determine general background concentration levels.

All samplers were sited to meet the criteria set forth in the Code of Federal Regulations 40 CFR 58 Appendix A. Adherence to these siting criteria is necessary to ensure the uniform collection of comparable air quality data.

The purpose of the Oxides of Nitrogen and Particulate Monitoring for the SeaTac Area study was to better determine conditions at and around the airport; to evaluate model results; to provide accurate ambient air quality information with which to respond to public air quality concerns, and to evaluate the impact of aircraft operations on local NO_2 levels. In addition the study would help Ecology determine if a NO_2 or PM_{10} State and Local Air Monitoring Station was necessary to further study the air quality in the SeaTac area. Consequently, the desired scale of representativeness was middle-scale, which defines the concentrations typical of areas up to several city blocks in size with dimensions ranging from about 100 meters to 0.5 kilometer.

- Horizontal and Vertical Probe Placement. Because of the importance of measuring population exposure to NO_2 concentrations, air should be sampled at average breathing heights. However, for security reasons the probes were located higher. The required height of the inlet probe for NO_2 monitoring and for Nephelometers is between 3 and 15 meters above ground level. The probes were located at 3.5 meters +/-½ meter. The air intakes for the PM_{10} samplers were located at 2.5 meters +/- ½ meter.
- Spacing from Obstructions. Buildings and other obstacles may possibly scavenge NO_2. To avoid this interference, airflow must be unobstructed for at least 90% of the monitoring path and the probe must be located away from obstacles so that the distance from the probe is at least twice the height that the obstacle protrudes above the probe.
- Spacing from Roads. Neighborhood sites are intended to provide measurements of the pollutant exposure of the population representing an area of approximately several city blocks. In order to provide some reasonable consistency and comparability in air quality data, the samplers inlet probe must be located at a minimum distance from roadways. That distance varies according to the traffic count from a minimum of 10 meters for less than 10,000 vehicles per day to a minimum of 250 meters for less than 110,000 vehicles per day.

The individual site maps are documented in Appendix D showing the exact location of each sampler.

Site Location Descriptions

Site 1. S 150th and 26th Ave. S. This site, known as SeaTac North, was the automated site to the north of the runway. A federal reference method NO_2 analyzer, Nephelometer, PM_{10}, meteorological sensors and co-located passive sampler duplicate were located here. It was assumed that this site would likely measure some of the highest concentrations outside the airport operations area (AOA).

Site 2. S 148th and 28th Ave. S. 28th Ave. S was in a residential driveway. It was located northeast of the north end of the runway.

Site 3. S 150th and 24th Ave. S. This site was located on a fence surrounding a water reservoir. After the beginning of the project, the Port began construction of a parking lot on the adjacent property.

Site 4. S 136th and 16th Ave. S. This site was located in a city park directly north of the runways. The sampler was located on a fence a hundred feet north of Sunset High School.

Site 5. S 154th. This site was located on Port property on the north side of S. 154th, inside the fence. There is a gate just east of the FAA towers. This site was the closest to the runways.

Site 6. S 150th and 12th Ave. S. This site was located inside a fence on Port property just east of Des Moines Memorial Dr. S. The sampler was on a post in a grassy area.

Site 7. S 152nd and 6th Ave. S. This site was located in the center of a parking lot across the street from the Highline Performing Arts Center. The sampler was strapped to a street light pole.

Site 8. S 170th off 12th Ave S. This site was located in the northeast corner of the Runway View Point Park. The sampler was on the fence post.

Site 9. 801 SW 174th. This site was at the Normandy Park City Hall. The sampler was on a fence next to the driveway near the play fields. This site was intended to serve as a background site.

Site 10. 19030 8th Ave. S. This site was located behind Prince of Peace Church. The sampler was on a fence post along the north property line.

Site 11. S 188th and 16th Ave S. This site was located at the Avis lot. The sampler was on the fence behind the office.

Site 12. 1410 B S 200th. This site was located at Maywood School. The sampler was on a fence post behind the building.

Site 13. 19631 Pacific Highway S. This site was located in the parking lot of Holiday Inn. The sampler was on the fence at the north end of the parking lot.

Site 14. S 188th and 28th Ave. S. This site was in the Budget parking lot. The sampler was on the fence in the southeast corner of the lot.

Site 15. 3312 S. 189th. This site was at a private residence. The sampler was on a fence in the front yard.

Site 16. S 200th. This site was located in the middle of Tyee Valley Golf Course, directly south of the main runway. A federal reference method NO_2 analyzer, Nephelometer, PM_{10}, meteorological sensors and co-located passive sampler and duplicate were located here. It was assumed that this site would likely measure some of the highest concentrations outside the airport Area of Operations.

Summary of Results

SeaTac Airport Spatial Nitrogen Dioxide Study

Sampling was conducted from January 2, 1998 through June 8, 1999. At the 16 passive sampler sites, data was collected from January 2, 1998 to December 31, 1998. Automated data was collected at the SeaTac North site from April 8, 1998 to June 8, 1999, and at the Tyee Valley Golf Course site from June 8, 1998, to June 8, 1999.

Table 2 lists the location, annual mean, and standard deviation of the three-week integrated NO_2 concentration measurements for each sample location. The average annual mean NO_2 concentration of all 16 sampling sites was 33 $\mu g/m^3$ (.017 ppm). The highest annual average concentration observed at any site was 41$\mu g/m^3$ (.021 ppm) at Site 3; the lowest was 22 $\mu g/m^3$ (.011 ppm) at Site 9.

The highest measured three-week NO_2 concentration was 49 $\mu g/m^3$ (.026 ppm) at Site 14 from September 10 to October 1, 1998; the lowest was 12 $\mu g/m^3$ (.006 ppm) at Site 9 from May 28 to June 18, 1998. All measurement results were less than half of the annual NAAQS of 100 $\mu g/m^3$ (.053 ppm) (EPA, 1996(1)). Detailed results for each site are included in Appendix B of the SeaTac Airport Spatial Nitrogen Dioxide Study Final Report.

Table 2. NO_2 badge measurement results summary

Site #	**Location**	**Annual NO_2 Mean Conc. (μg/m^3)**	**NO_2 Meas. Std. Dev. (μg/m^3)**
1	150th St. / 26th Ave. S (analyzer co-location site)	39	5.2
2	148th St. / 28th Ave. S	38	5.2
3	146th St. / 146th Ave. S (Water Dept.)	41	5.3
4	140th St. / 18th Ave. S (Sunset School)	30	5.2
5	154th St. S (Port property)	38	5.6
6	150th St. S (Port property Gate B-6)	28	5.5
7	152nd St. / 6th Ave. S (Performing Arts parking)	33	5.4
8	170th St. / 12th Ave. S (runway viewpoint)	34	7.0
9	SW 174th St.(Normandy Park City Hall)	22	4.9
10	192nd St. / 8th Ave. S (Prince of Peace Church)	30	5.8
11	188th St. / 16th Ave. S (Avis)	33	5.7
12	200th St. / 4th Ave S (Maywood School)	28	5.6
13	28th Ave. S / 196th Pl. (Holiday Inn)	35	6.7
14	188th St. / 28th Ave. S (Budget parking lot)	40	6.5
15	3212 S. 189th Pl.	34	5.2
16	Tyee Valley Golf Course (analyzer co-location site)	30	5.7
BHR	Beacon Hill Reservoir, Seattle	38	5.4

A two-way analysis of variance test performed on the annual data set (17 sample periods) indicates that statistically significant variations ($p \leq 0.001$) in NO_2 concentration occur with respect to both sample location and sample period. The variations in concentration at each site are therefore not merely due to random variations in measured concentrations. Rather there are systematic differences in NO_2 levels between the sites. Figure 3 presents the annual mean concentration at each site. Figure 4 shows the 95% confidence interval (CI) of the average concentration of all sites for each sample period; here the NO_2 concentration fluctuation throughout the year is evident. The NO_2 level was notably lower during sample periods 7 through 9, corresponding to the months of May and June.

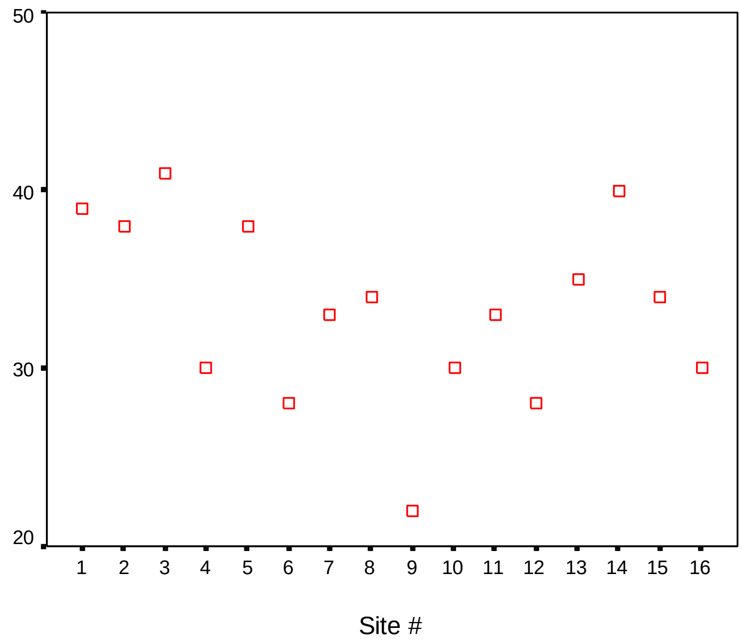


Figure 3. Spatial NO2 concentration data, annual mean by site

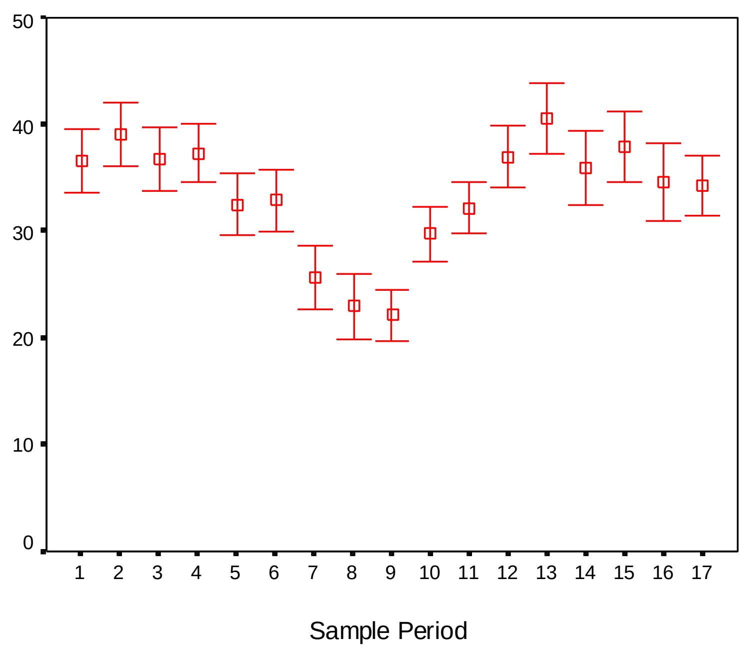


Figure 4. Spatial NO_2 concentration data, spatial mean by sample period

Oxides of Nitrogen and Particulate Monitoring Study

Sampling of PM_{10} began in June 1998 and ran through June 1999. Nephelometer sampling was conducted at SeaTac North from April 8, 1998 to June 8, 1999, while sampling began at Tyee Valley Golf Course September 1, 1998 and ran through June 8, 1999. Sampling of NO_X began April 8, 1998 at SeaTac North and June 8, 1998 at Tyee Valley Golf Course. Both sites collected NO_X data through June 8, 1999.

Sampling was also conducted at Beacon Hill. Data from Beacon Hill was collected for the entire duration of the study. This site was used for comparing SeaTac measurements with Seattle urban NO_2 levels and as a co-located site for the badge study.

The data is summarized in Appendix E. It is organized by site number, parameter, and date. NO_X concentrations are presented in parts per million (ppm) and represent hourly averages. PM_{10} data was collected on the one day in six sampling schedule. Concentrations are presented in micrograms per cubic meter (μ/m3) and represent 24 hour periods from midnight to midnight. Nephelometer data is presented in backscatter (Bscat) for each hour.

Temperature is presented in degrees Fahrenheit. Wind direction is presented in degrees of azimuth. Wind speed is presented in miles per hour. Excluding PM_{10}, all data represent hourly averages.

Conclusions

SeaTac Airport Spatial Nitrogen Dioxide Study

The single most important goal of this study was to measure annual NO_2 concentrations throughout areas of the SeaTac community to assess compliance with the NAAQS. This required several sampling sites because previous modeling efforts indicated that the airport, was potentially impacting local concentration levels. Therefore, significant spatial variation was anticipated. The NO_2 badge measurements provided excellent accuracy for assessing compliance with the .053 ppm annual standard at each measurement location. Measurement results for every 3-week sample period at all locations were below one-half the annual standard. Therefore, a false determination of compliance in this study could occur only if badge measurement error consistently exceeded 100 percent. The average badge measurement error was determined to be no greater than five percent.

Secondly, adequate sensitivity was achieved to quantify spatial and temporal concentration variations. Annual mean concentrations by site ranged from 22 $\mu g/m^3$ (Site 9, Normandy Park) to 41 $\mu g/m^3$ (Site 3, Water Dept.). Temporally, the average concentration of all sites for each sample period also ranged from 22 $\mu g/m^3$ (sample period 9, June) to 41 $\mu g/m^3$ (sample period 13, September). Measured NO_2 concentrations varied by 58 percent of the combined site annual mean (33 $\mu g/m^3$) both spatially and temporally. Therefore, measurement errors averaging 5 percent did not prohibit quantification of variations that occurred with respect to both location and time.

Aircraft impacts are difficult to measure because of the nature of their operation; traveling both horizontally and vertically. A significant portion of aircraft NO_X emissions occur as planes climb; ground level effects from such emissions would not necessarily be close the airport. Ideally, this type of study should be conducted near an airport that is well removed from other industrial and mobile combustion sources. This would allow for an accurate assessment of airport NO_2 contribution by performing upwind and downwind measurements.

This study was confounded by additional NO_2 sources including freeways, heavily trafficked roads, and numerous industrial sources throughout the southern Seattle region. Therefore, it was not possible, within the scope of this study, to precisely quantify the impact the airport has on community NO_2 levels. If the background annual mean concentration (Site 9) is subtracted from the annual concentration average of all sites near the airport the impact of the airport could be estimated to be less than 13 $\mu g/m^3$ (.007 ppm). However, motor vehicle traffic is responsible for some portion of this difference; the ratio of airport to traffic sources is unknown.

Attempts were made to investigate spatial pollutant concentration gradients and concentration variations with respect to wind direction, both of which could provide evidence of airport impacts. Discussions of both spatial and wind direction analyses results are provided below.

Of the spatial parameters tested for association with NO_2 concentration variations (see Table 3), longitude showed the strongest correlation (-0.75). NO_2 concentration decreases from east to west across the study region. This relationship is logical, because vehicular traffic is much greater on the east side of SeaTac, particularly from Interstate 5 and Highway 99. Roadways on the west side of SeaTac have smaller traffic volumes with local traffic only. NO_2 concentrations are also strongly correlated with elevation. This is the same spatial association just discussed because elevation generally decreases to the west, towards the Puget Sound.

NO_2 levels tend to decrease with distance from both freeways and also from the airport runways. The correlation with freeway distance (-0.42) is slightly stronger than with runway distance (-0.30), but neither association is particularly strong. This does, however, provide some evidence that both these sources impact local NO_2 levels. The traffic impact parameter is a more sophisticated means of assessing vehicle source impacts than simply using distance from a freeway. This parameter accounts for non-freeway traffic, is weighted by traffic volume, and assumes an exponential decay in concentration with respect to distance from the source. Therefore, I would expect this correlation to be greater than the simple distance correlation; however it is not (ρ=0.39). Nonetheless, this correlation provides additional evidence that automobile sources cause increased local NO_2 concentrations.

As demonstrated by the Beacon Hill Reservoir temporal correlation tests, SeaTac NO_2 levels are highly affected by regional levels. SeaTac air quality is strongly influenced by regional pollutant levels and meteorological conditions.

Table 3 Site Data

Site #	Annual NO_2 Average ($\mu g/m^3$)	Location Latitude (N) deg.	Location Latitude (N) minutes	Location Longitude (W) deg.	Location Longitude (W) minutes	Elevation (m)	Dist. to Runway (m)	Dist. to Road (m)	Dist. to Freeway (m)
1	39	47	28.097	122	17.963	137	805	31.7	274
2	38	47	28.248	122	17.706	134	1030	32.6	499
3	41	47	28.215	122	18.257	131	772	191	257
4	30	47	28.706	122	18.447	94	1609	NA	885
5	38	47	27.985	122	18.428	110	306	40.2	177
6	28	47	28.154	122	19.004	82	708	27.4	193
7	33	47	28.014	122	19.619	98	1287	49.1	290
8	34	47	27.010	122	18.847	119	370	NA	531
9	22	47	26.760	122	20.640	34	2527	194	1609
10	30	47	25.940	122	19.356	107	1094	101	756
11	33	47	25.989	122	18.867	94	467	42.7	821
12	28	47	25.455	122	18.887	113	966	97.5	1706
13	35	47	25.606	122	17.771	128	982	49.1	982
14	40	47	26.060	122	17.722	101	885	72.2	1545
15	34	47	25.989	122	17.323	122	1368	11.0	1159
16	30	47	25.612	122	18.380	82	451	235	1577

Wind direction NO_X impact analyses at Sites 1 and 16 provided critical information for understanding SeaTac ambient NO and NO_2 source characteristics at the two sites. NO concentration levels at these sites are strongly affected by wind direction. NO concentrations are high at both sites with eastern winds, however this wind direction is infrequent. NO mass flux shows distinct differences between the two sites. The greatest impacts at Site 1 appear to be from local traffic sources, including the 518 freeway, while peak NO flux values at Site 16 only come from the direction of the airport runways. The differences by wind direction and site demonstrate that NO at these sites is strongly controlled by local sources.

As seen in Figure 5, NO_2 concentrations are not highly sensitive to wind direction. NO_2 is less variable than NO (see Figure 6), and is more controlled by regional levels than local sources. This is because NO_2 is primarily produced in the atmosphere by oxidation of directly emitted NO. However, Site 1 does experience NO_2 concentration peaks from the southeast (freeways). Both sites show NO_2 peaks from the NNW direction. This is more evident when looking at NO_2 flux. While Site 16 shows stronger NO_2 flux, both sites are impacted from the NNW direction. This is potentially caused by sources upwind of both sites, specifically heavy industrial sources located in South Seattle.

It is likely that aircraft emissions are partially responsible for the strong NO and NO_2 peaks observed at Site 16 because the wind direction is focussed directly from the runways, and the levels exceed those observed at Site 1 from the same wind direction. However, these peaks do not cause a high time-averaged concentration at this site; rather it has one of the lowest annual mean NO_2 concentrations. Site 1 did not experience NO or NO_2 peaks from the direction of the runways that were as great as observed at Site 16, but time averaged concentrations for both pollutants were higher. This demonstrates that average concentration levels are more influenced by proximity to automobile sources than aircraft operation.

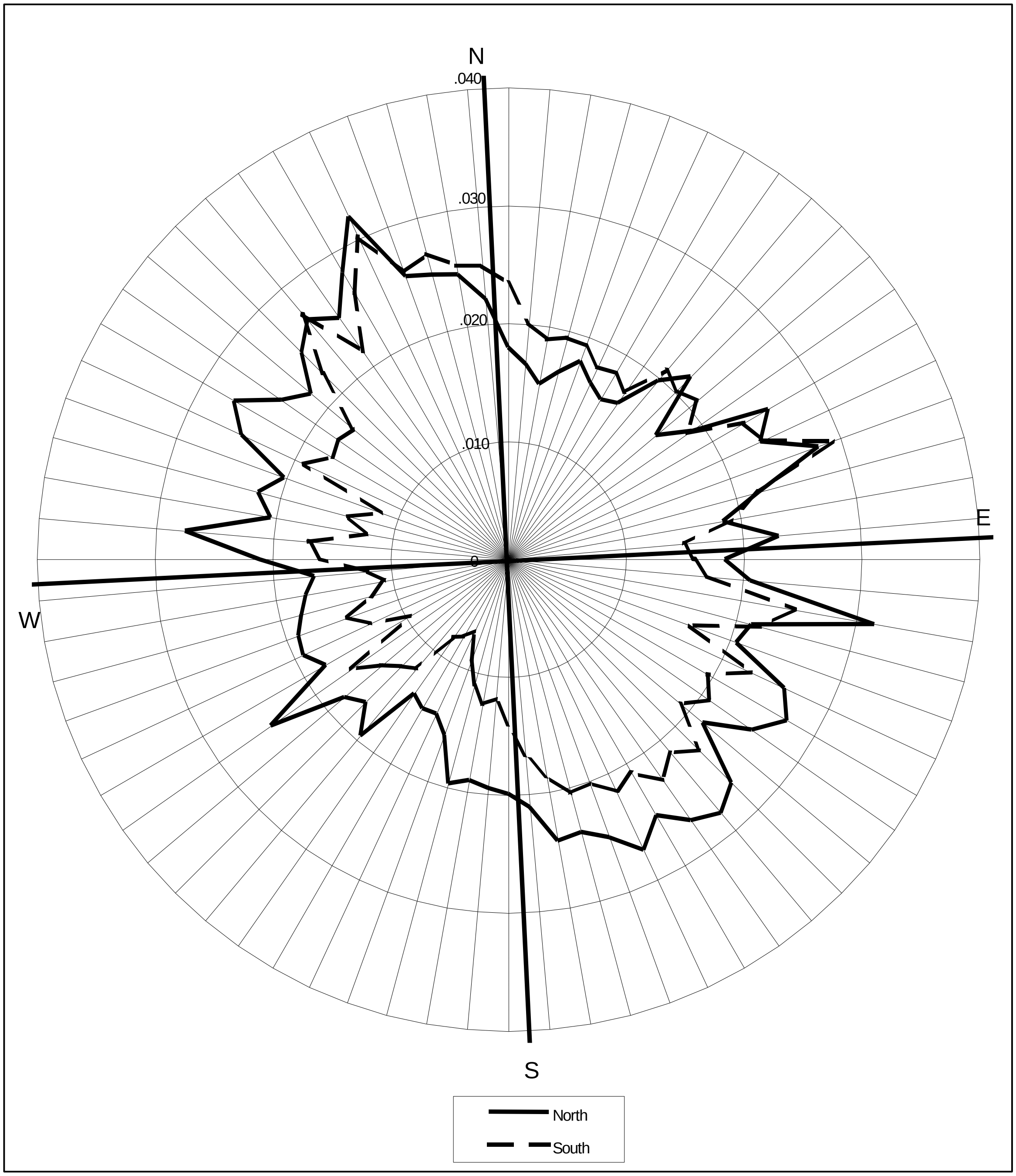


Figure 5. Average NO_2 concentration (ppm) by wind direction. Hourly data (July – September 1998) from Sites 1 (North) and 16 (South)

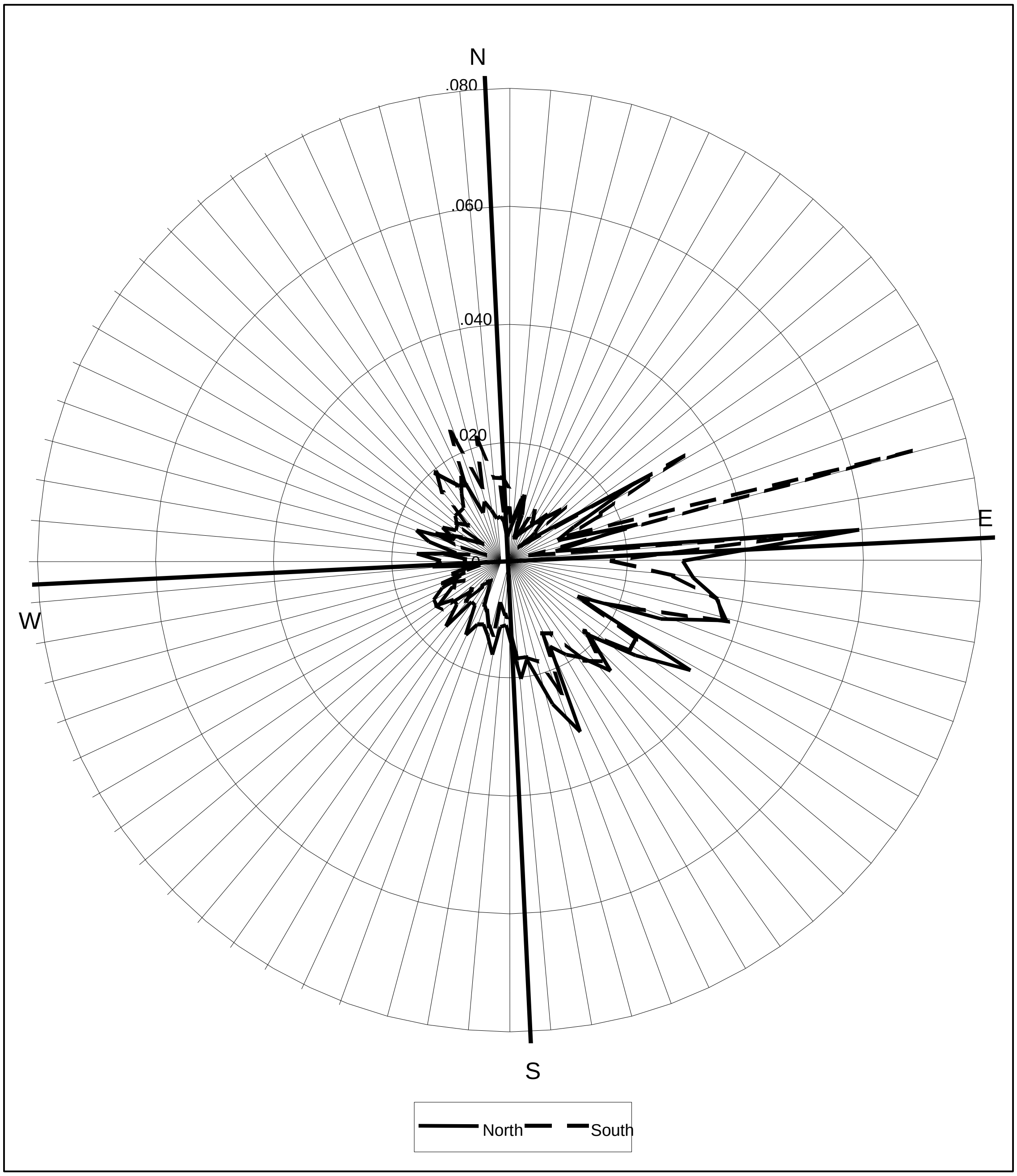


Figure 6. Average NO concentration (ppm) by wind direction. Hourly data (July – September 1998) from Sites 1 (North) and 16 (South)

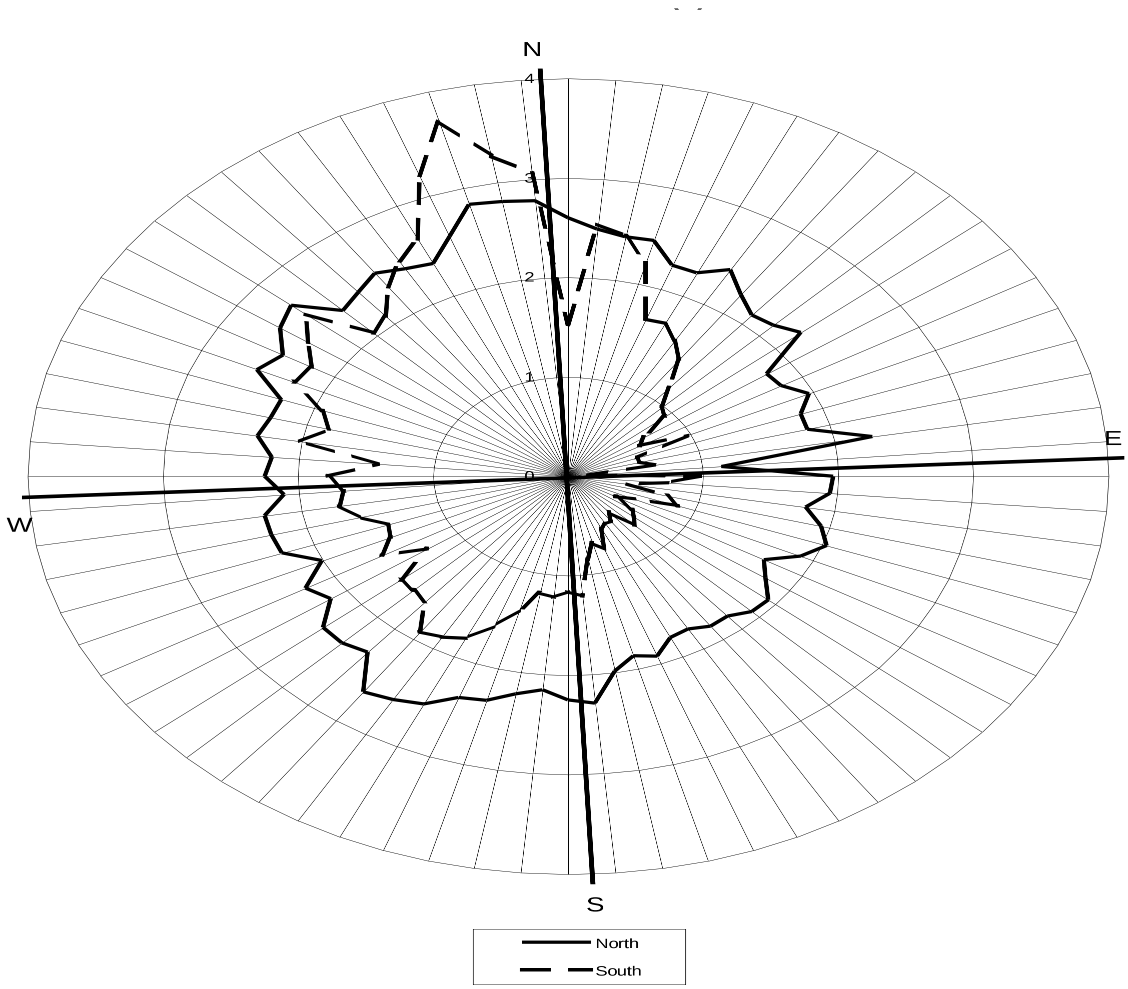


Figure 7. Average wind speed (m/s) by wind direction. Hourly data (July – September 1998) from Sites 1 (North) and 16 (South)

This study does not provide overwhelming evidence that the airport has a significant impact on SeaTac community NO_2 levels. Both spatial data and wind direction analyses do demonstrate that automobile traffic impacts local NO_2 concentrations. While it is not possible to quantify the additional NO_2 exposure directly resulting from aircraft, two firm conclusions can be made based on the results of this study:

- Airport operations do not cause local ground level NO_2 concentrations significantly greater than in surrounding urban areas, and
- Aircraft emissions are not a dominant NO_2 source affecting local concentrations.

Oxides of Nitrogen and Particulate Monitoring Study

Oxides of Nitrogen Conclusions

The continuous analyzer at SeaTac North and Tyee Valley Golf Course produced a data set with important differences from the SeaTac Airport Spatial Nitrogen Dioxide Study. Hourly averages of NO, NO_2, NO_X, wind speed, wind direction and Bscat were collected. One-hour averages provided the opportunity to analyze short-term differences in the data.

Monthly and annual NO and NO_2 averages were calculated using data collected during the study. Table 4 represents annual averages for each of the automated sites (SeaTac North, Tyee Valley Golf Course and Beacon Hill)
.

	SeaTac North	Tyee Valley Golf Course	Beacon Hill
Annual Average NO	.015 ppm	.012 ppm	.016 ppm
Annual Average NO_2	.021 ppm	.015 ppm	.019 ppm

Table 4
Annual Averages of NO and NO_2

Figure 8 and Figure 9 depict monthly averages of NO and NO_2 concentrations for each site. Both NO and NO_2 concentrations peak in September and October with minimum levels recorded in June. The Puget Sound area experienced unusually wet and windy weather during the winter of 1998-99, with relatively few periods of stable conditions that would promote higher average pollutant concentrations. Longer-term averages may yield somewhat different graphs but the general trend of higher average concentrations from September through March seems reasonable.

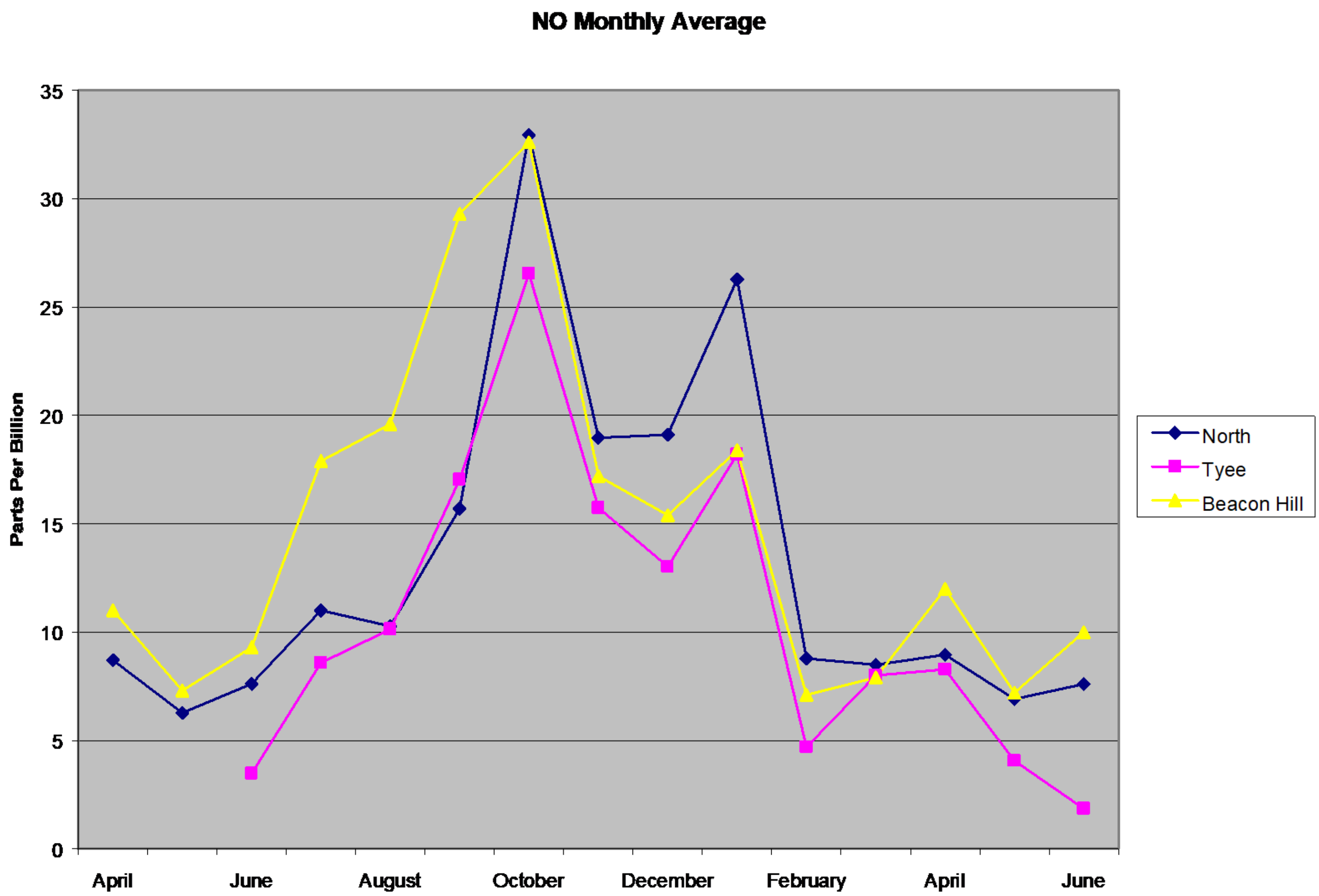


Figure 8. Monthly Average of NO at Beacon Hill, SeaTac North and Tyee Valley Golf Course

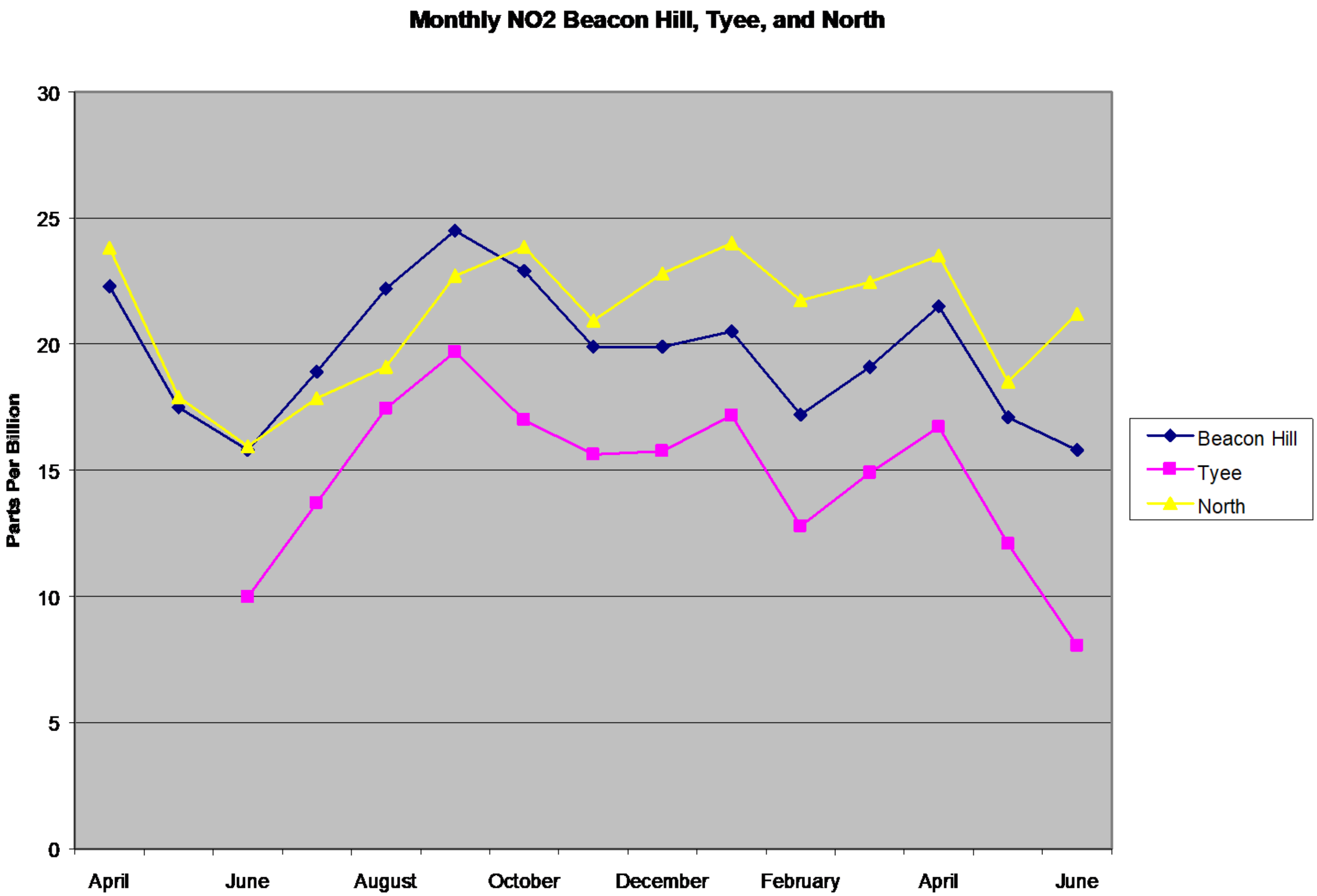


Figure 9. Monthly Average of NO2 at Beacon Hill, SeaTac North and Tyee Valley Golf Course

The graphs represent the average of all of the valid data for each site, beginning in April 1998 and ending in June 1999. The annual averages were calculated by averaging all of the valid data from June 1, 1998 to May 31, 1999.

The automated sites were used to evaluate diurnal NO and NO_2 concentrations. Figure 10 depicts NO concentrations in parts per million and Figure 11 depicts NO_2 concentrations in parts per million. For each hour of the day, an average concentration was calculated, using the entire data set, to create these graphs. There is no data for the fourth hour of the day as this period is used for calibration.

The three sites track closely together. SeaTac North and Beacon Hill resulted in slightly higher concentrations than Tyee Valley Golf Course. Both NO and NO_2 show sharp rises in concentrations in the sixth and seventh hours, roughly corresponding to rush hour activity, and a second peak in the evening following the rush hour. The highest concentrations of NO are reached in the morning with a secondary peak in the evening, while NO_2 shows peak concentrations at hours twenty and twenty-one with a secondary peak late in the morning.

These charts appear to depict a normal diurnal cycle of both NO and NO_2 concentrations. As expected, higher concentrations accompany increased transportation related activity. The increases in NO_2 concentrations are delayed a couple of hours, which is expected since it takes a period of time to convert NO into NO_2. The data from the SeaTac sites depict a pattern similar to that from Beacon Hill, suggesting that the daily cycle of NO and NO_2 concentrations correlate with daily traffic patterns. However, aircraft activity follows a similar pattern. Figure 12 represents the average hourly flight departures from SeaTac International Airport. Departures reach a peak in the morning about the same time as NO and NO_2 concentrations, then decline slowly until midnight.

Further analysis was performed to determine the contribution of the airport to the NO and NO_2 levels measured at the automated sites. Figures 13 and 14 depict the results of this analysis. In Figure 13 the first group represents the annual NO levels measured at each site. In order to determine if concentrations of NO rose when air from the runways flowed toward the analyzer at SeaTac North, an average concentration of NO was calculated for only those hours when the wind blew from 180 to 240 degrees. This is depicted in the second group. The result was lower concentrations at all three sites.

Since the direction from the runways to SeaTac North is the direction from which the wind tends to blow at high speeds, the data was sorted again. An average NO level was calculated for only those hours when the wind speed was less than 4 miles per hour and when the wind blew from 180 to 240 degrees. Four miles per hour was selected subjectively as a cutoff for light wind. The result, depicted in the third group, was dramatic. Both SeaTac North and Beacon Hill concentrations rose to over .040 ppm, while the concentrations at Tyee only rose to about .012 ppm. This would suggest that during those low wind hours when the air flowed past Tyee Valley Golf Course, over the runways and then past the SeaTac North site, somewhere in between a significant volume of NO was added to the air.

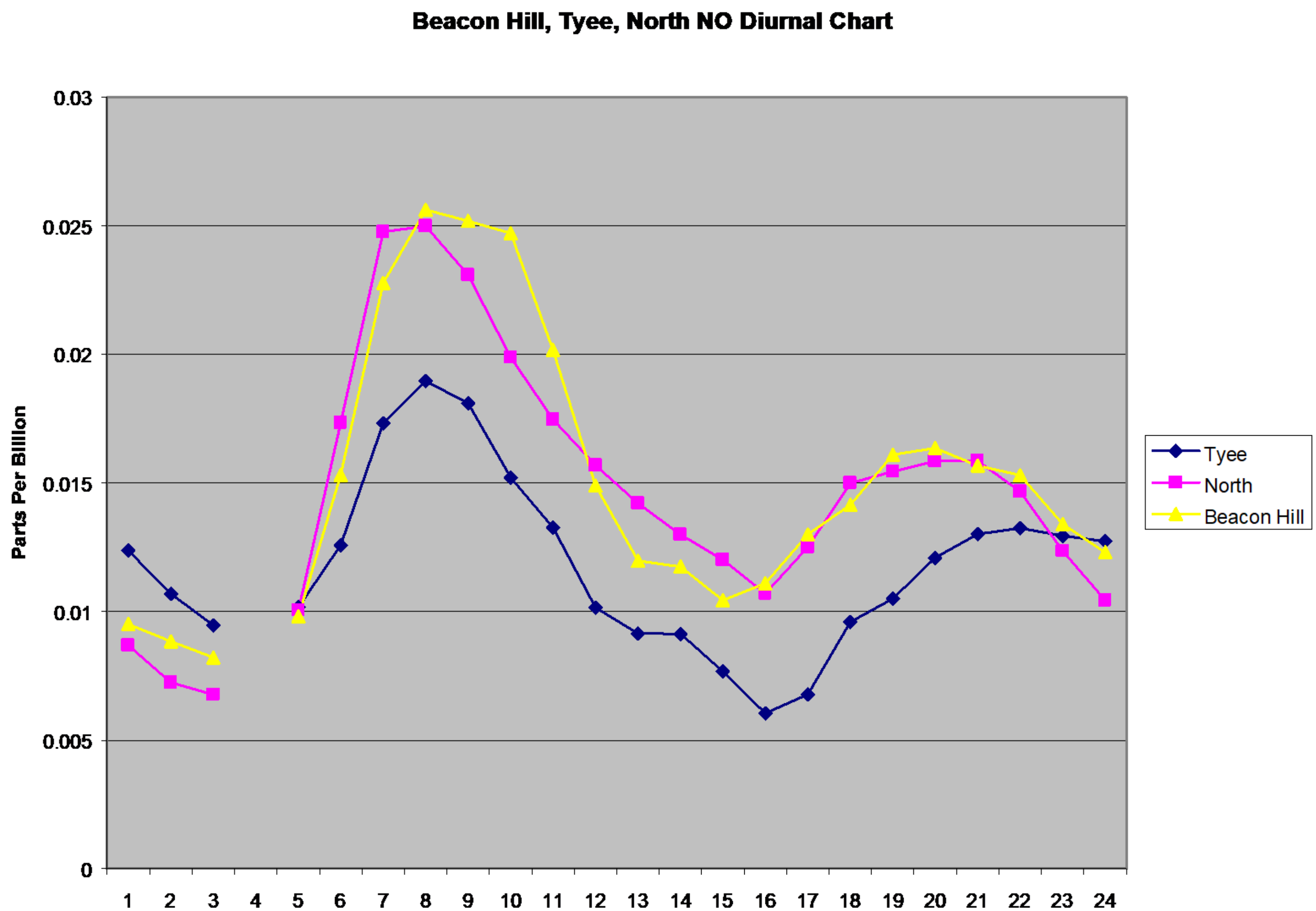
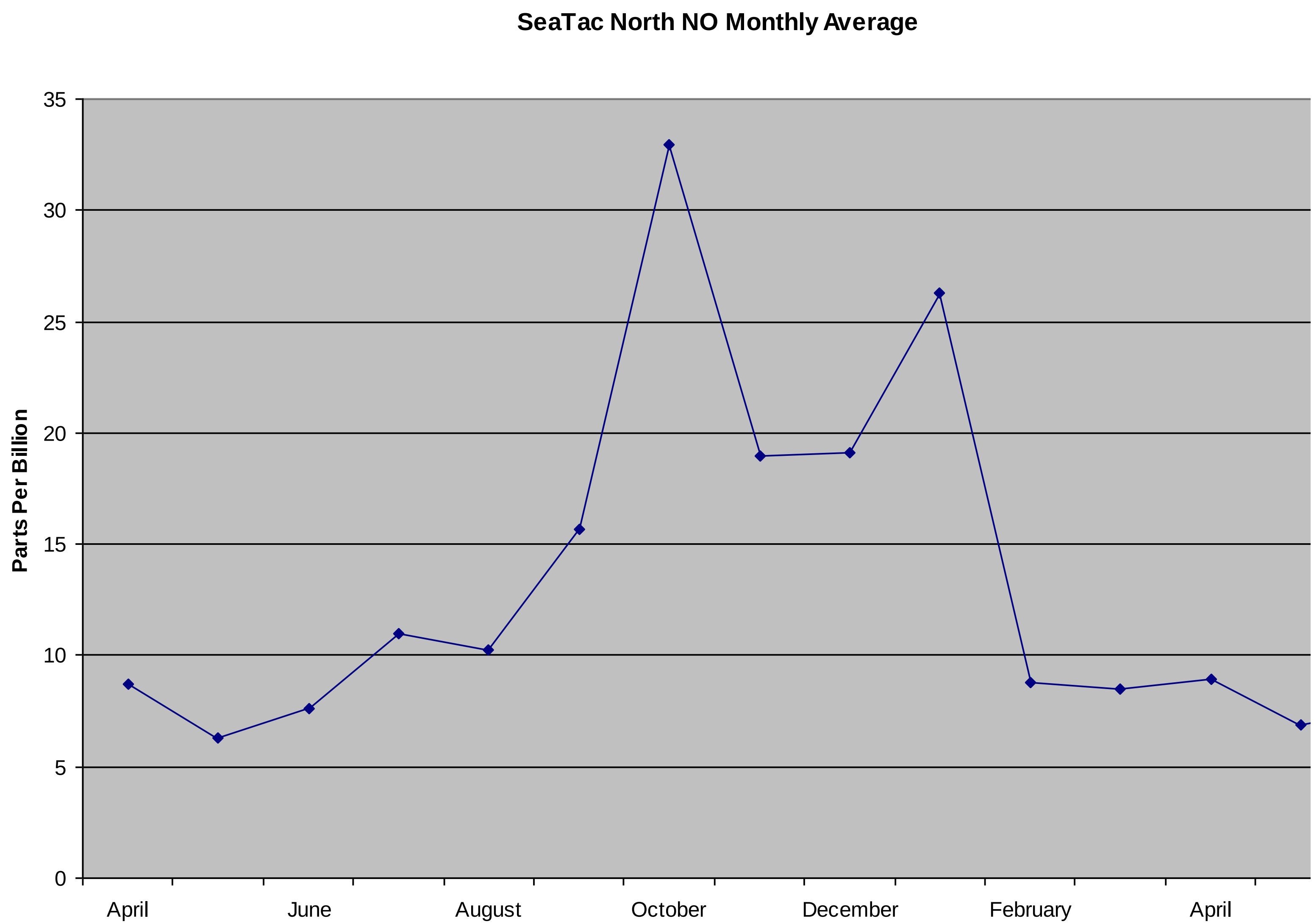
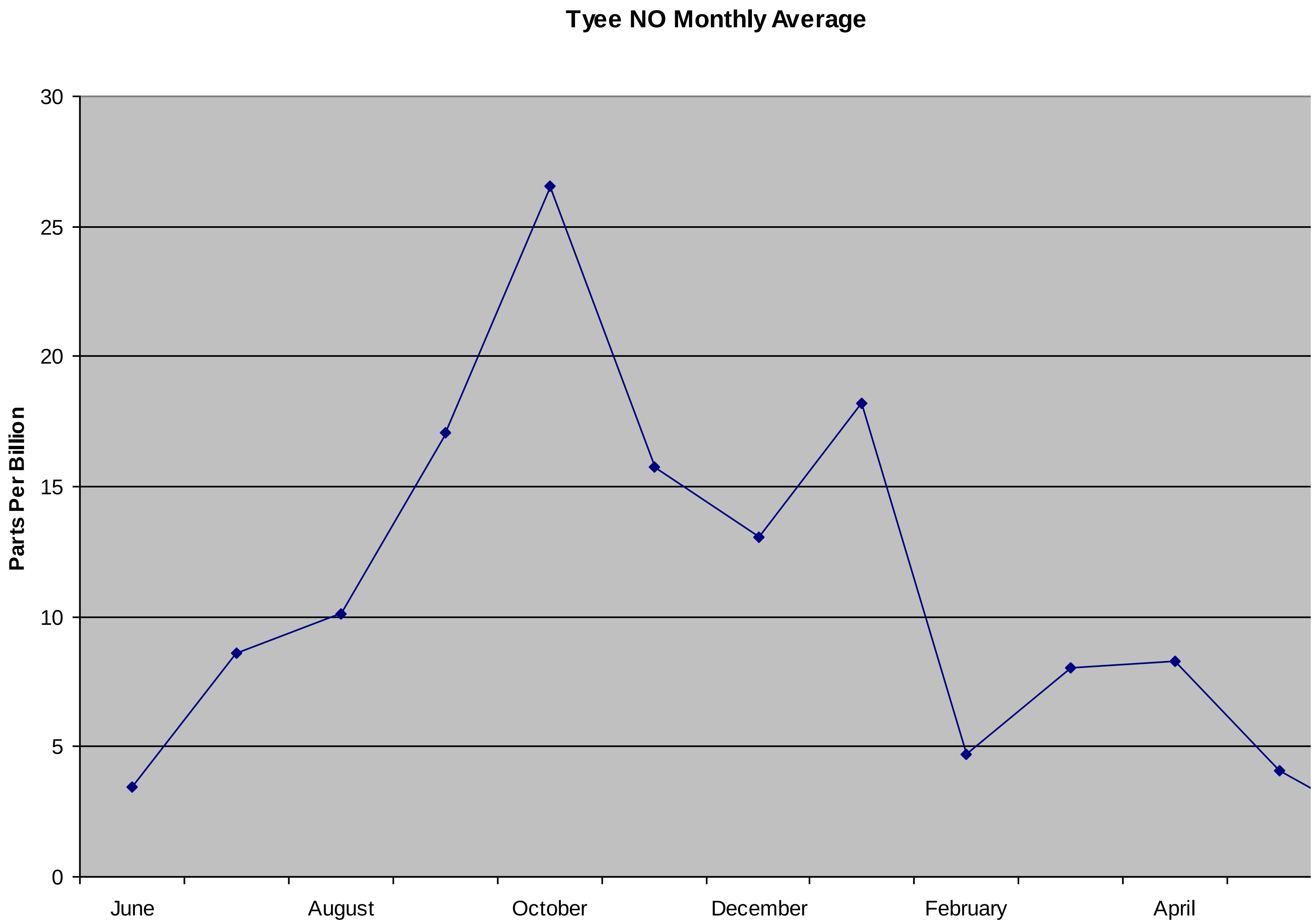
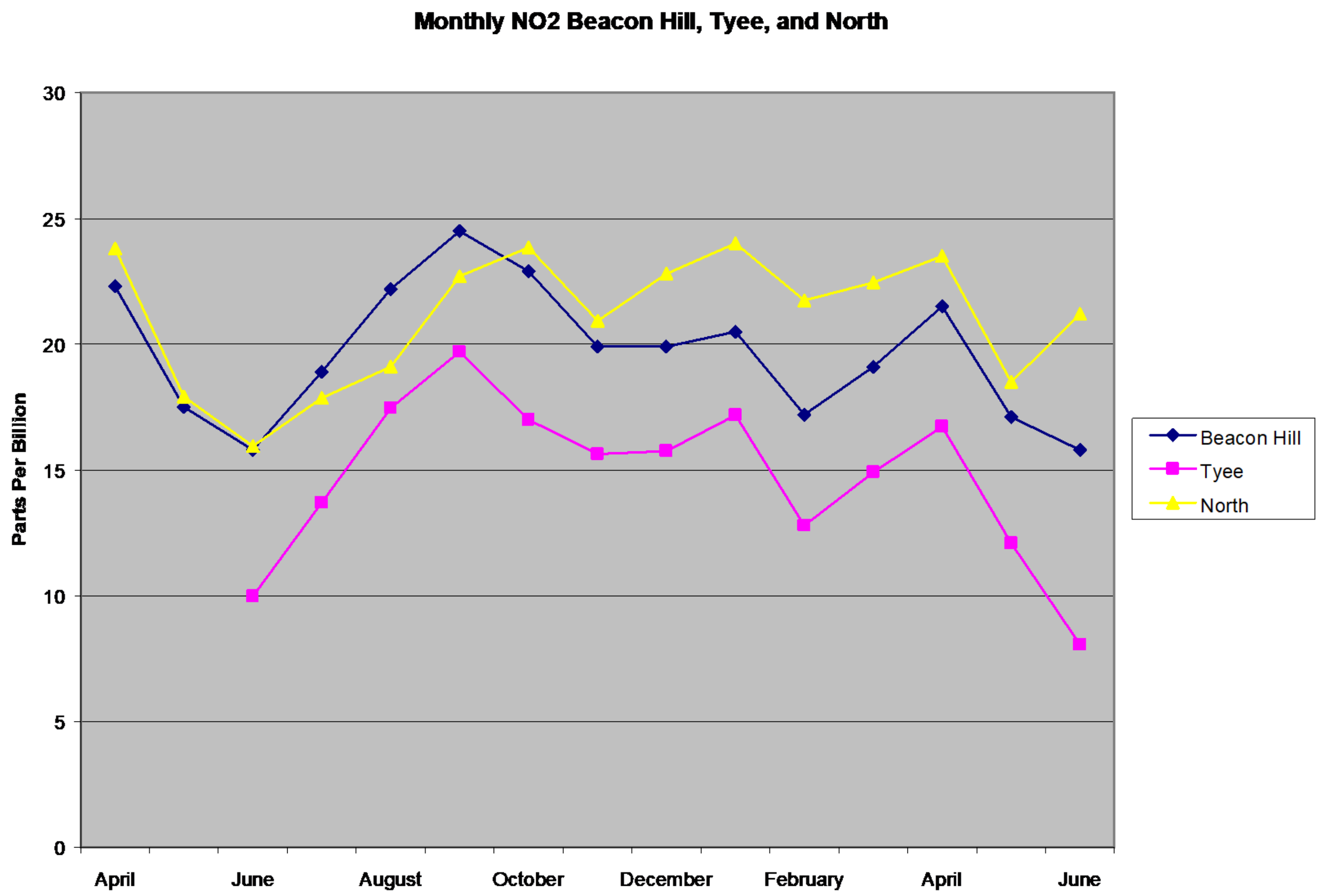
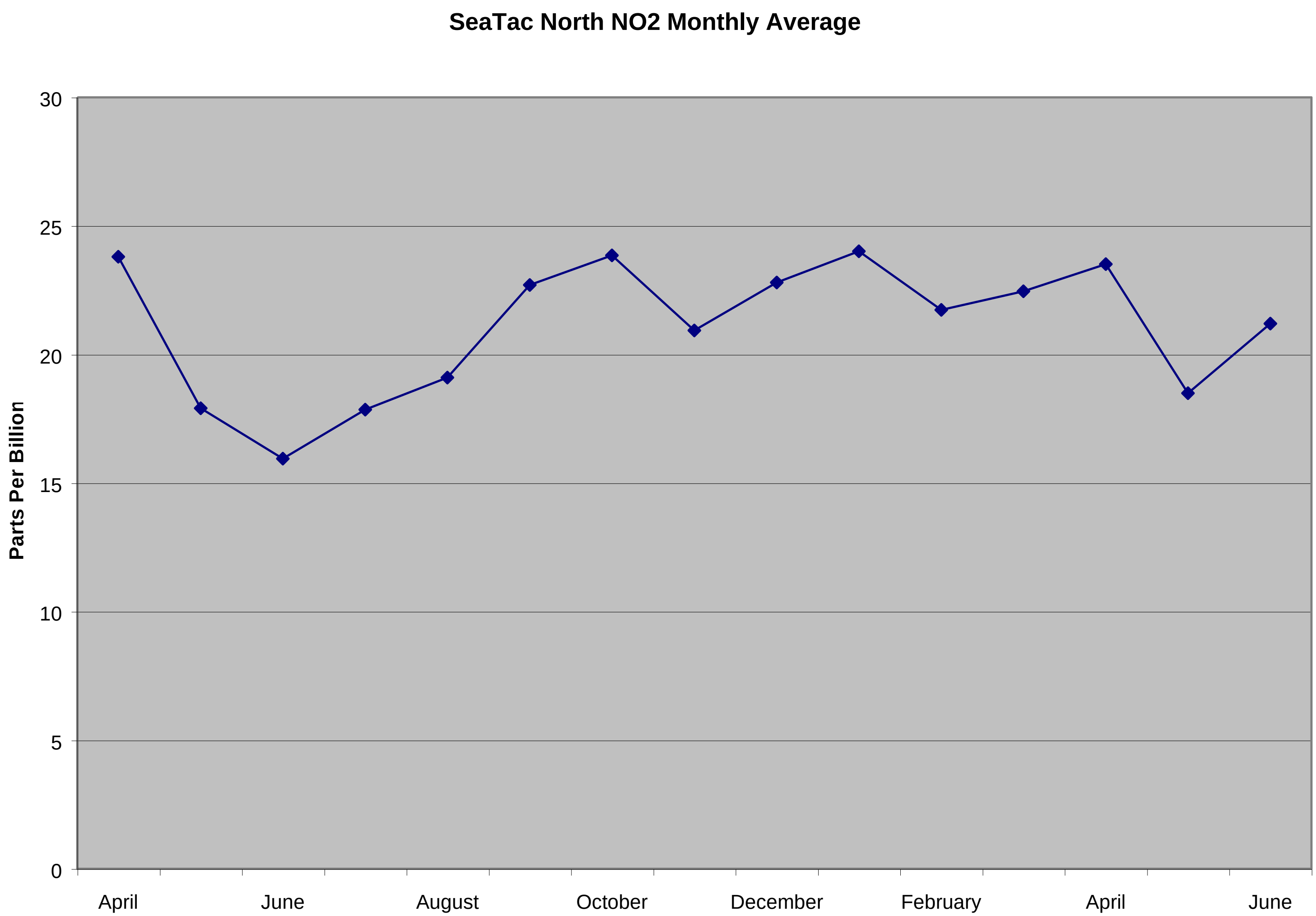


Figure 10. Diurnal Averages of NO at Beacon Hill, SeaTac North and Tyee Valley Golf Course

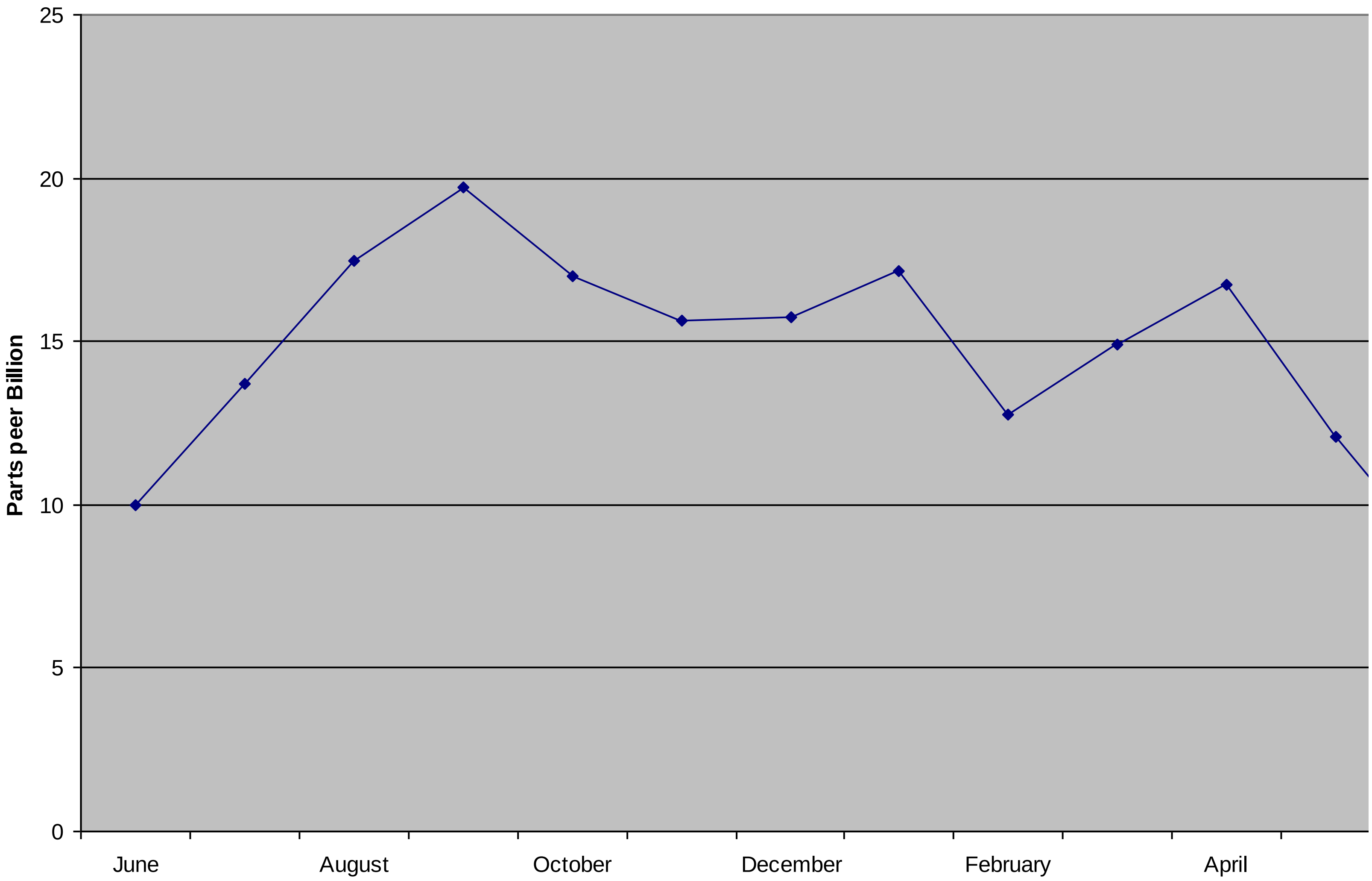

SeaTac North NO Monthly Average
Parts Per Billion
0
5
10
15
20
25
30
35
April
June
August
October
December
February
April

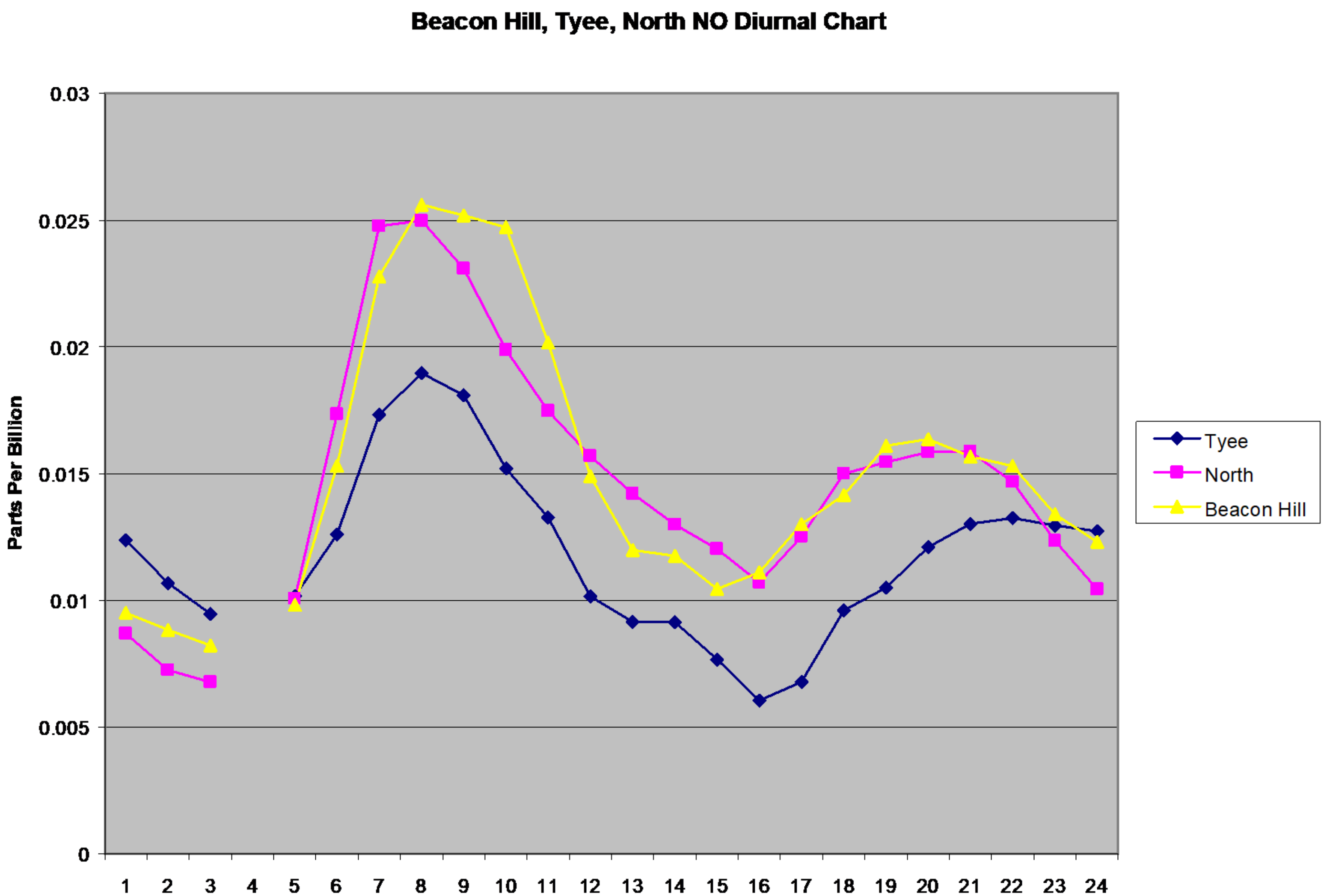

Tyee NO Monthly Average
Parts Per Billion
30
25
20
15
10
5
0
June
August
October
December
February
April


Monthly NO2 Beacon Hill, Tyee, and North
Parts Per Billion
30
25
20
15
10
5
0
April
June
August
October
December
February
April
June
Beacon Hill
Tyee
North

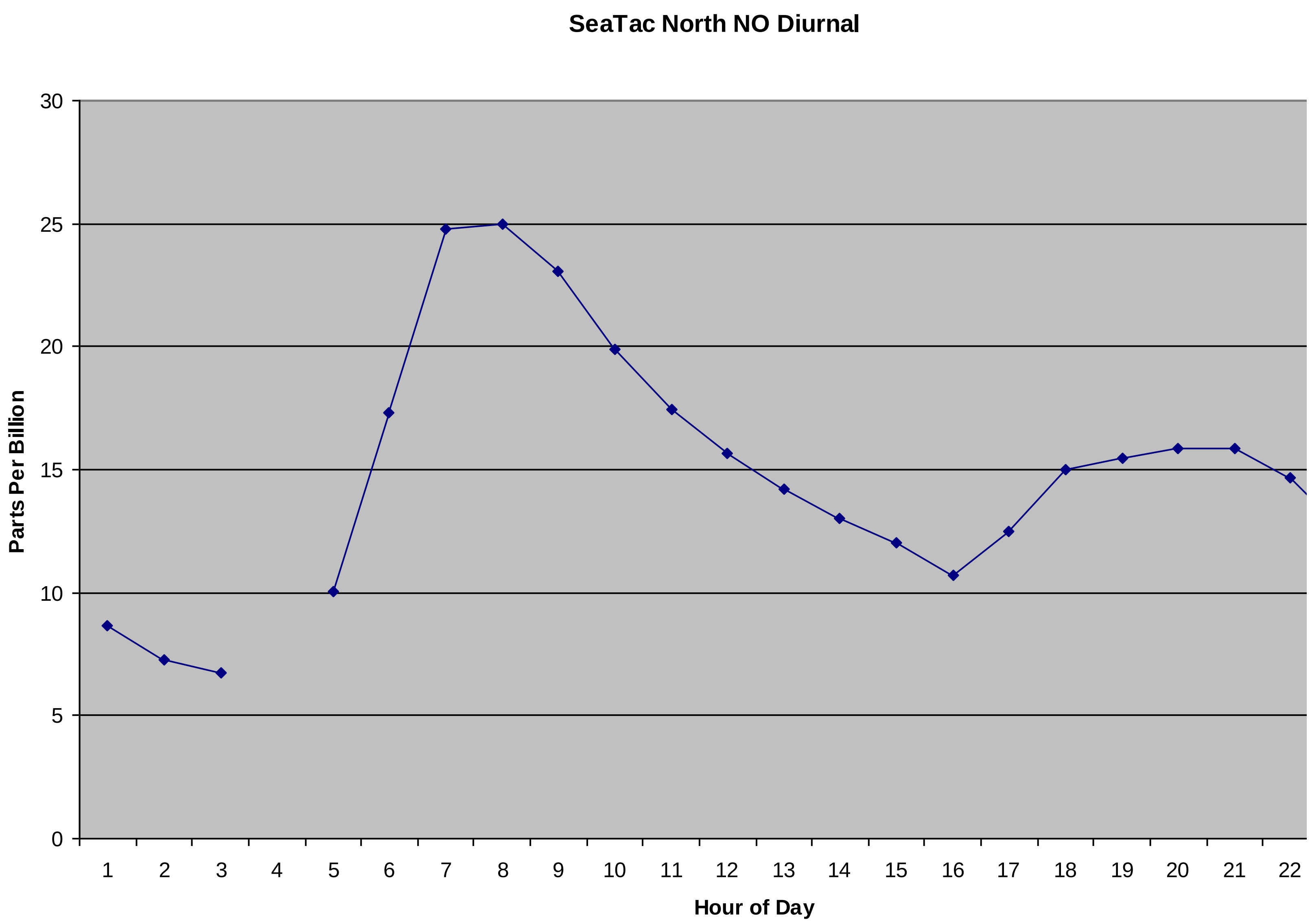

SeaTac North NO2 Monthly Average
Parts Per Billion
30
25
20
15
10
5
0
April
June
August
October
December
February
April
June

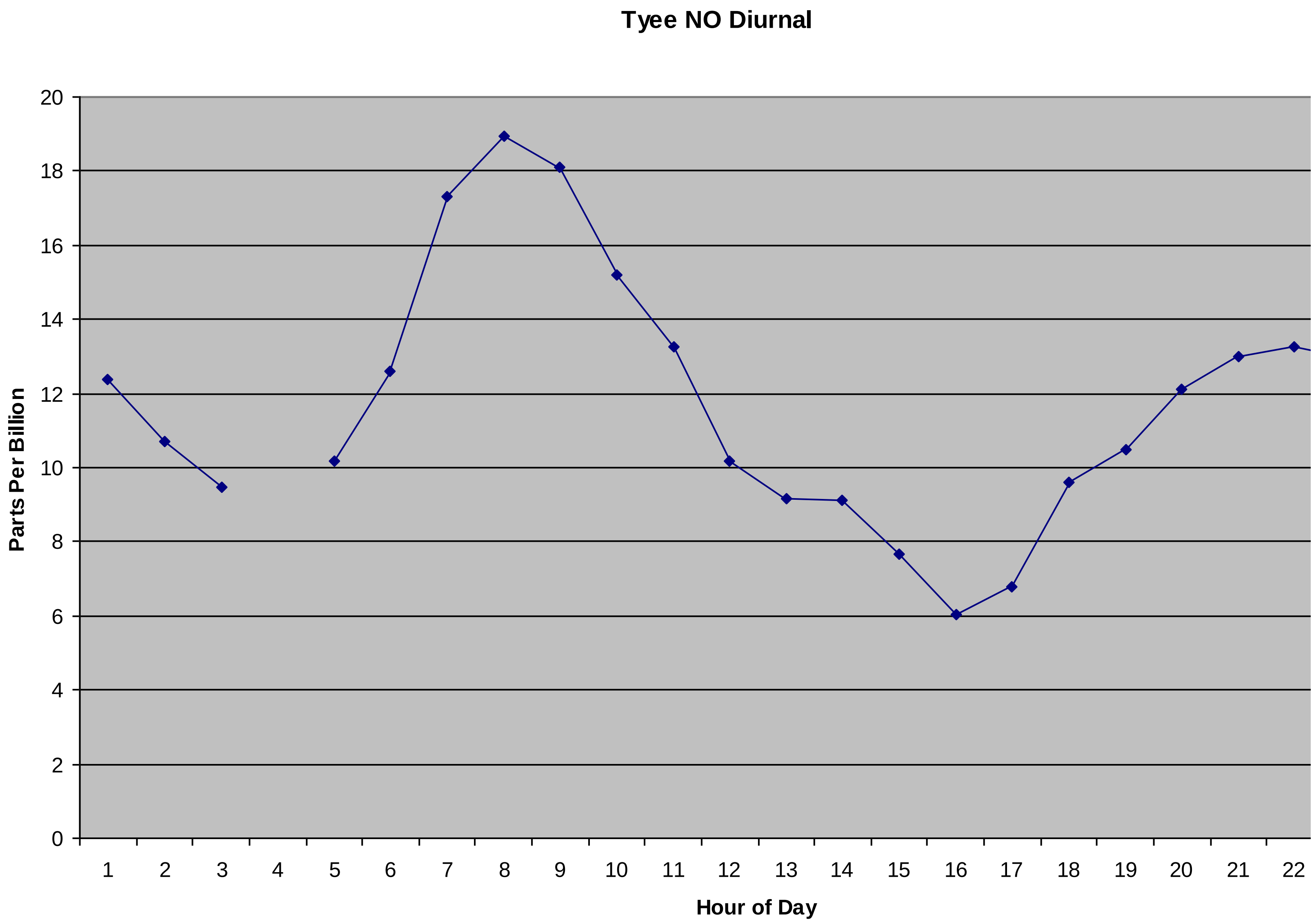
Tyee NO2 Monthly Average

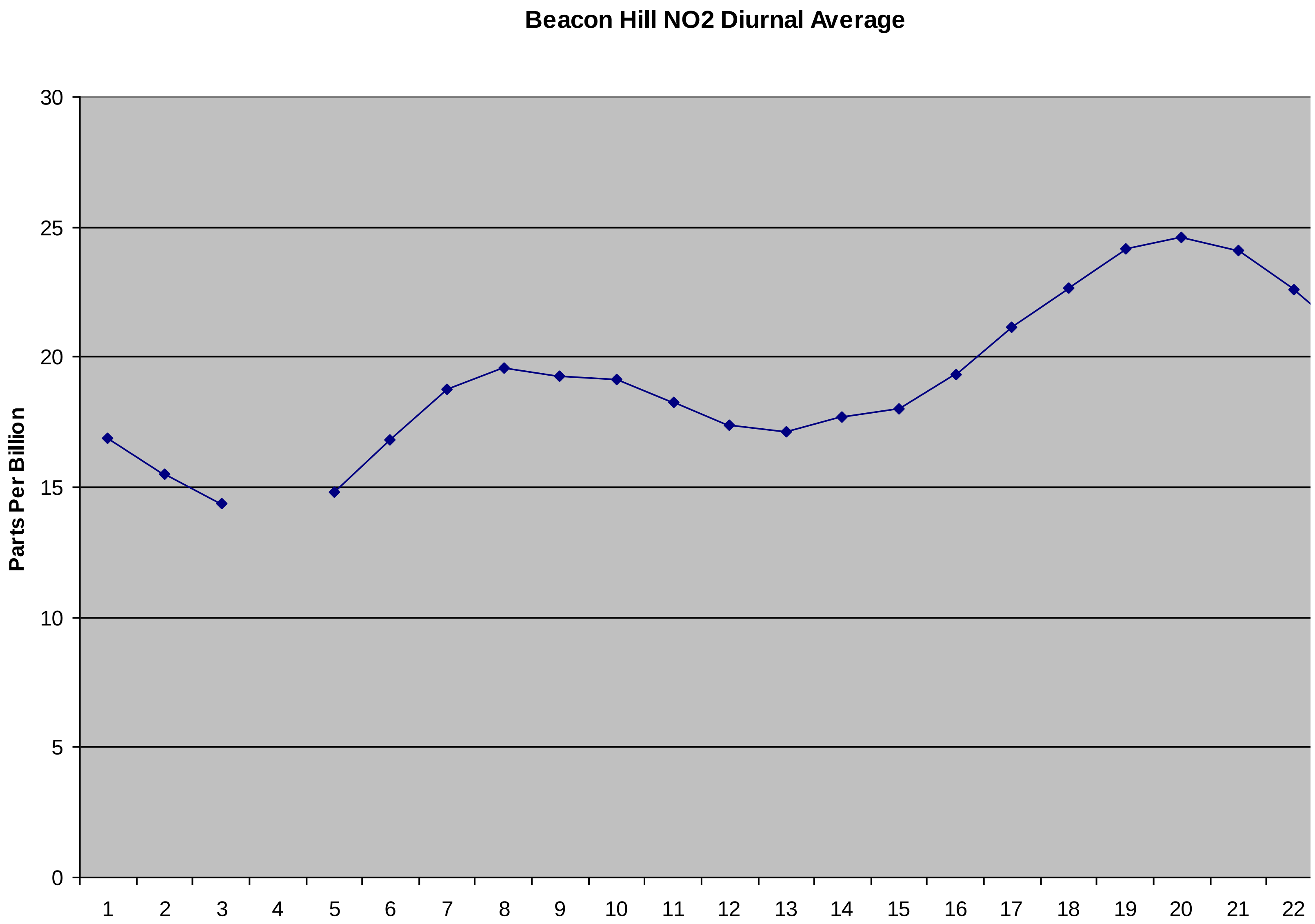


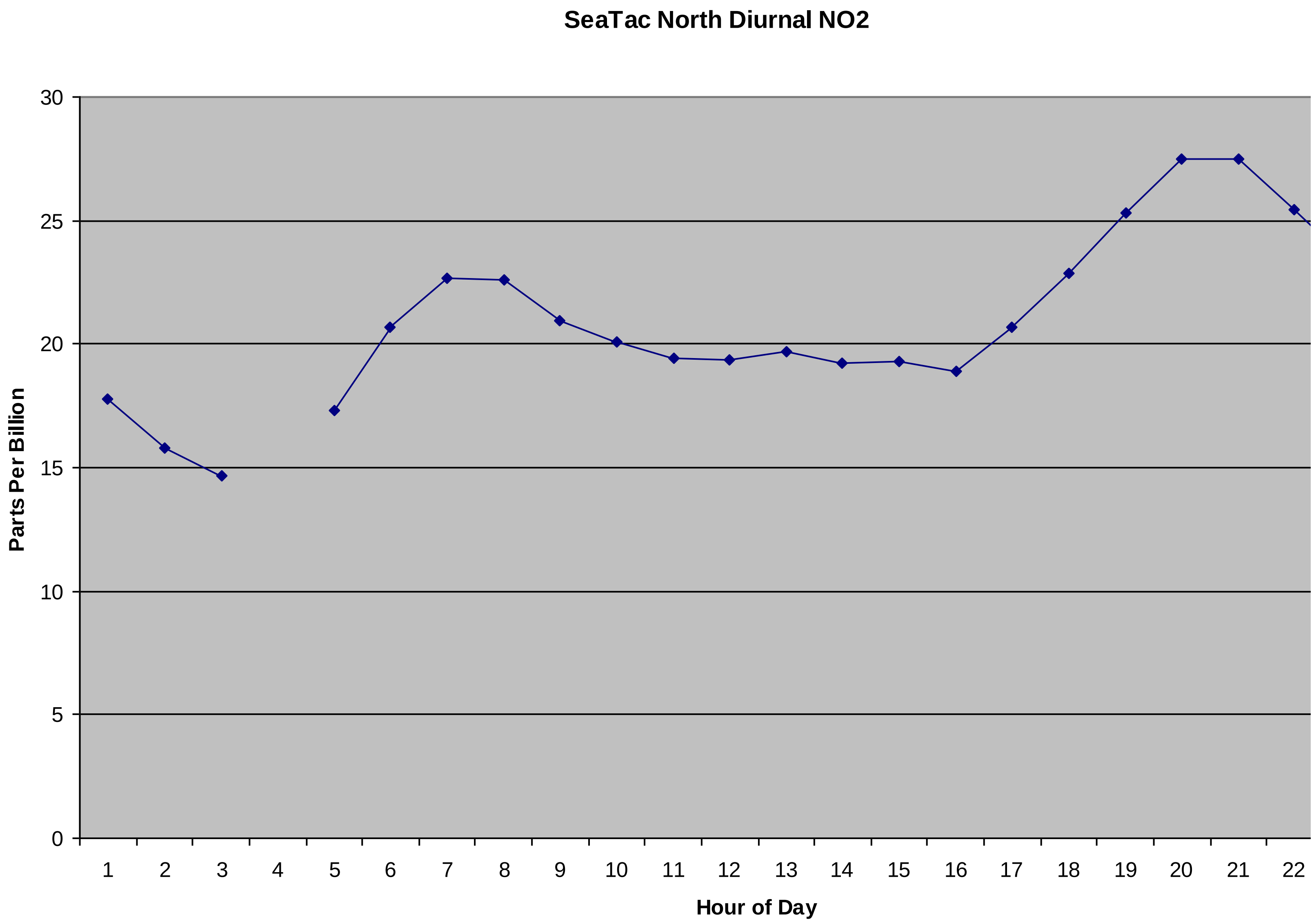


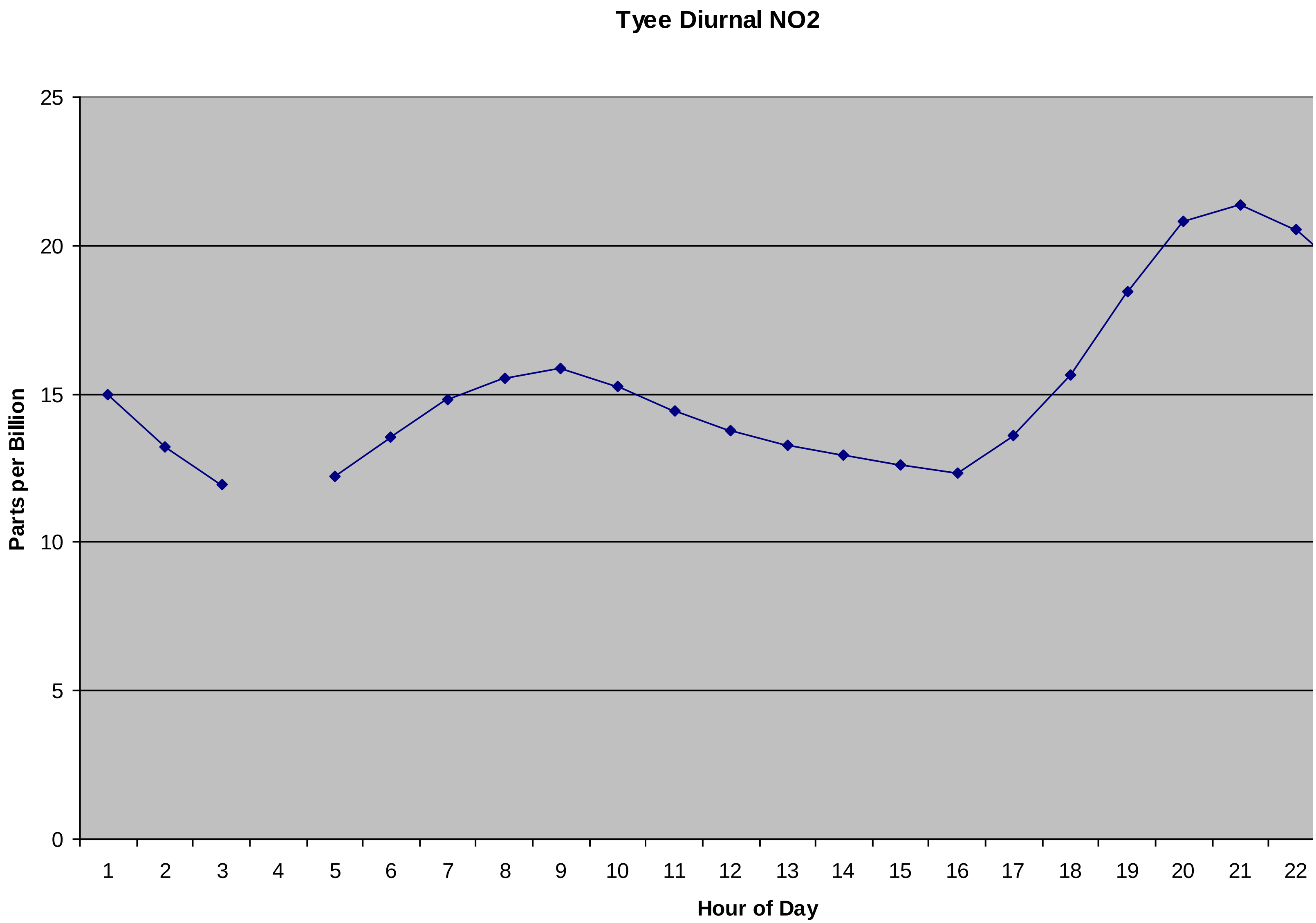
Beacon Hill, Tyee, North NO Diurnal Chart
Parts Per Billion
0.03
0.025
0.02
0.015
0.01
0.005
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Tyee
North
Beacon Hill

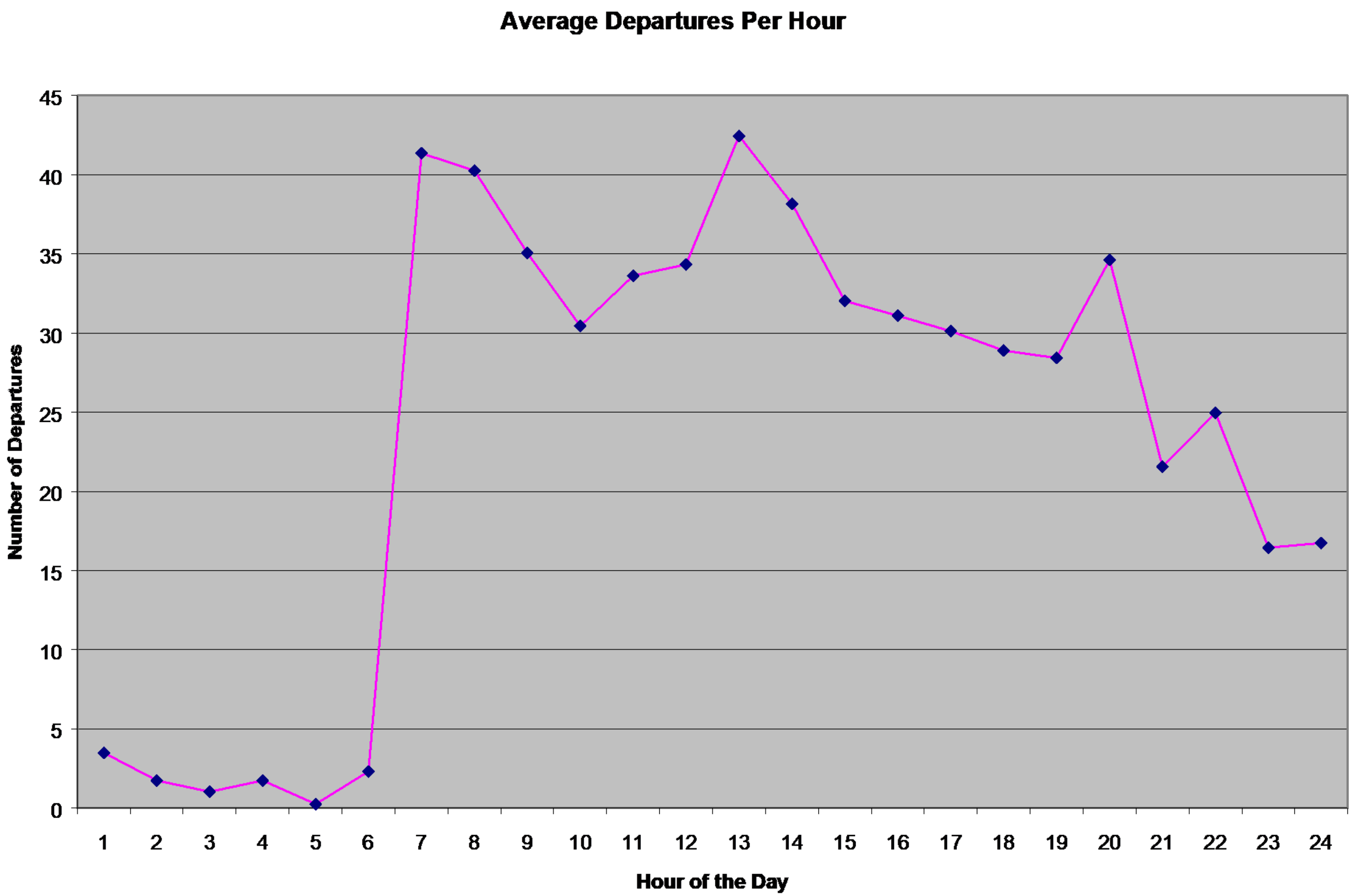

SeaTac North NO Diurnal
Parts Per Billion
0
5
10
15
20
25
30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Hour of Day

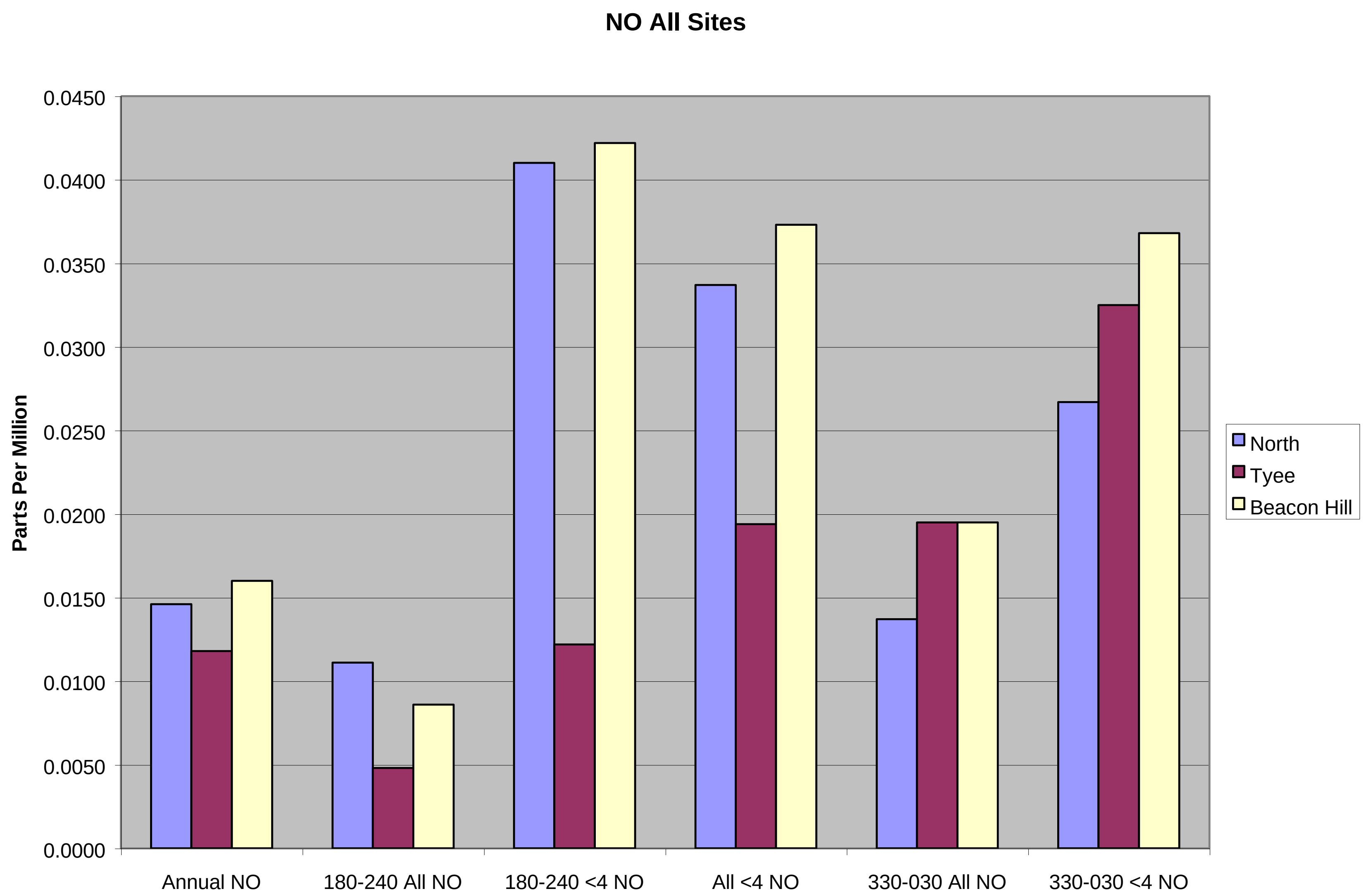

Tyee NO Diurnal
Parts Per Billion
0
2
4
6
8
10
12
14
16
18
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Hour of Day

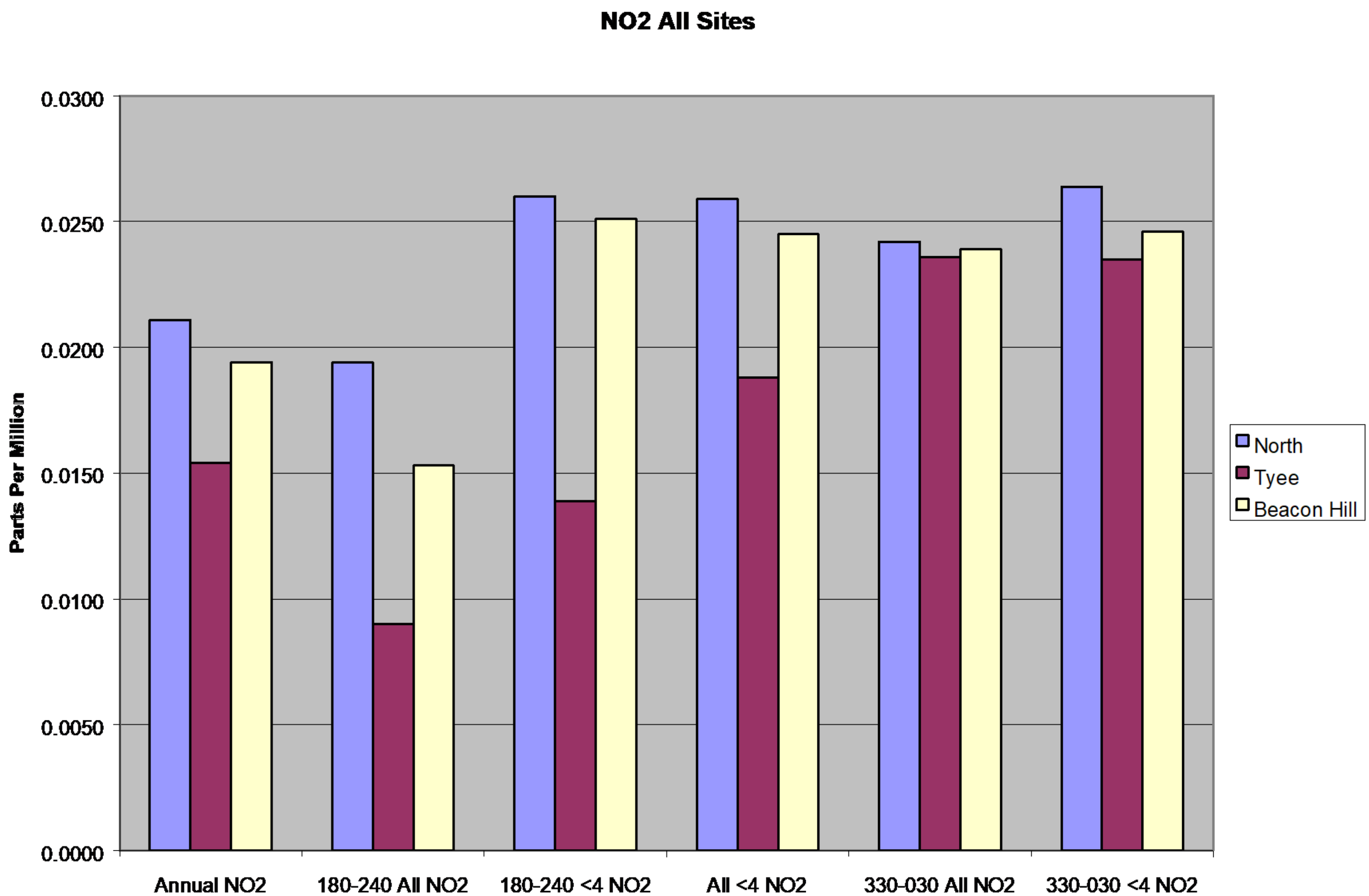

Beacon Hill NO2 Diurnal Average
Parts Per Billion
0
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22


SeaTac North Diurnal NO2
Parts Per Billion
0
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
Hour of Day


Tyee Diurnal NO2
Parts per Billion
0
5
10
15
20
25
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
Hour of Day


Average Departures Per Hour
Number of Departures
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Hour of the Day


NO All Sites
Parts Per Million
0.0450
0.0400
0.0350
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
Annual NO
180-240 All NO
180-240 <4 NO
All <4 NO
330-030 All NO
330-030 <4 NO
North
Tyee
Beacon Hill


NO2 All Sites
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
Parts Per Million
Annual NO2
180-240 All NO2
180-240 <4 NO2
All <4 NO2
330-030 All NO2
330-030 <4 NO2
North
Tyee
Beacon Hill

This result was then compared to the average concentrations of NO for all hours when the wind blew at less than 4 miles per hour, regardless of direction. This is depicted in the fourth group in Figure 13. Again, there is the suggestion that there is a contribution from a source between the two sites. In light wind conditions, SeaTac North has higher concentrations when the wind blows from 180 to 240 degrees than it does on average in light wind conditions. Conversely, Tyee Valley Golf Course has lower concentrations in light wind conditions when the wind is blowing from between 180 to 240 degrees.

Then the data was analyzed for the reverse conditions when the air flows over the SeaTac North site, past the runways and toward the analyzer at Tyee Valley Golf Course. Average NO concentrations were calculated for wind blowing from between 330 and 030 degrees. As expected SeaTac North yielded the lowest concentrations. In order to compare these results to the analysis of NO in light southwest winds, the data was sorted again using only those hours when the wind speed was less than 4 miles per hour and when the wind blew from 330 to 030 degrees. The result is depicted in the last group. Once again, all sites yielded higher average concentrations in light wind than in all wind from 330 to 030 degrees regardless of speed. Tyee Valley Golf Course resulted in the highest concentrations indicating that during those low wind hours when the air that flowed past SeaTac North, over the runways and then past Tyee Valley Golf Course, somewhere in between a significant volume of NO was added to the air. However, the difference between the two sites was much smaller than when the wind was light from the southwest.

Identical analyses were performed using NO_2 data. The results are presented in Figure 14. Although the results were similar, particularly when the wind was from 180 to 240 degrees, the magnitude of the differences was much smaller and less conclusive. When the concentrations from Beacon Hill are considered, the NO_2 data suggests a somewhat homogenous airshed. In fact NO_2 shows less variation than NO, not only from site to site regardless of wind speed or direction, but also less variation diurnally and from season to season. This makes sense in that there is some lag time between the creation of NO during combustion, and the formation of NO_2 as the NO oxidizes. During cool weather this lag time increases, and there is no shortage of cool weather in the Puget Sound region. It appears that NO_2 is relatively homogenous regionally. There is no point in monitoring near a suspected source for NO_2 since by the time NO has converted to NO_2 the air has had time to mix.

On the other hand the results from the analysis of the NO concentrations shows a correlation between the wind direction and NO, wind speed and NO, season of the year and NO, and a clear diurnal variation in NO concentrations. Monitoring in the neighborhood could potentially disclose a source.

Although the data suggests that a source of NO exists between SeaTac North and Tyee Valley Golf Course, it is inconclusive as to the identity of the source, or the magnitude of the source. The evidence suggesting a source is clearest during relatively light wind conditions. One possible source is idling and accelerating aircraft; another is Highway 518, which is situated between the airport and the SeaTac North site.

Since there is no standard for NO, all that can be concluded from the data is that from time to time, under light wind conditions, short periods of high concentrations of NO can occur in the vicinity of SeaTac. The NO inevitably mixes in the air shed with some unknown contribution to regional NO_2 concentrations.

The annual standard for NO_2 is .053 ppm. Average NO_2 concentrations for both SeaTac sites were less than half the standard regardless of the wind speed or direction, the season of the year, or the time of day. Furthermore, even if all the NO measured was converted on the spot into NO_2, it would have fallen far short of the annual standard. Consequently, there is no need for a SLAMS in the SeaTac area.

Finally, the modeling, which predicted the high NO_2 levels, drastically overestimated the expected concentrations of NO_2.

Particulate Monitoring Conclusions

Particulate monitoring was conducted at both SeaTac North and Tyee Valley Golf Course using Federal Reference Method PM_{10} samplers and integrating nephelometers. The PM_{10} samplers were programmed to sample every sixth day. The nephelometers operated continuously, and automatically downloaded real-time light scattering data to a central computer for hourly and daily averaging. By collocating the instruments, and later employing linear regression analysis to compare the data sets, a relationship between the nephelometers' relative response and actual ambient PM_{10} concentrations was established for both ends of the runway. Combining these methodologies effectively filled the data gaps inherent to the one day in six PM_{10} monitoring schedule. Neither the 24-hr (150 $\mu g/m^3$) nor annual (50 $\mu g/m^3$) National Ambient Air Quality Standard for PM_{10} was exceeded at either end of the runway during the monitoring period.

The PM_{10} sampler located at the north end of the runway (SeaTac North) operated from June 4, 1998, to May 31, 1999. Fifty-eight of sixty-one scheduled sampling opportunities resulted in valid data (95% data completeness). The maximum 24-hr PM_{10} concentration measured at SeaTac North was 34 $\mu g/m^3$, occurring on July 28, 1998. The computed annual arithmatic mean PM_{10} concentration was 14 $\mu g /m^3$. The nephelometer collocated at this site operated from April 9, 1998, through June 9, 1999, resulting in ninety-nine percent complete and valid data. The maximum equivalent 24-hr PM_{10} concentration predicted by the nephelometer was 89 $\mu g/m^3$ and occurred on January 4, 1999. SeaTac North PM_{10} data are summarized in Table 5. Daily nephelometer data for the period September 1, 1998, through June 7, 1999, are graphically summarized in Figure 15.

The PM_{10} sampler located at the south end of the runway (Tyee Valley Golf Course) operated from June 4, 1998 to June 5, 1999. Fifty-nine of sixty-two scheduled sampling opportunities resulted in valid data (95% data completeness). The maximum 24-hr PM_{10} concentration measured at Tyee Valley Golf Course was 36 $\mu g /m^3$ and occurred on July 28, 1998. The computed annual arithmetic mean PM_{10} concentration was 13 $\mu g /m^3$. The nephelometer collocated at this site operated from September 1, 1998, through June 7, 1999, resulting in ninety-nine percent complete and valid data. The maximum equivalent 24-hr PM_{10} concentration predicted by the nephelometer was 87 μg/m^3 and occurred on January 4, 1999. Tyee Valley Golf Course PM_{10} data are summarized in Table 6. Daily nephelometer data for the period September 1, 1998, through June 7, 1999, are graphically summarized in Figure 16.

The particulate monitoring resulted in remarkable similar data from both the SeaTac North and Tyee Valley Golf Course sites. None of the scheduled PM_{10} samples resulted in concentrations of more than 25% of the standard for a 24-hour average. The data from the nephelometers predicted maximum concentrations of about 60% of the standard for a 24-hour average.

The data indicates that PM_{10} concentrations in the SeaTac area are well under the standard for both the 24-hour and annual averages. It does not answer citizen concerns about deposition of fine mists that they suspect to be jet fuel. These events may not have occurred during the study or are of short duration and not heavy enough to significantly affect the 24 hour average of PM_{10}. Another possibility is that the particles that have been observed are volatile and evaporate before the filters are weighed.

Particulate Monitoring

Particulate monitoring was conducted at both ends of SeaTac International's runway using Federal Reference Method PM_{10} samplers and integrating nephelometers. The PM_{10} samplers were manually programmed and prepared to operate every sixth day in accordance with Federally and State prescribed protocols. The nephelometers operated continuously and automatically downloaded real-time light scattering data to a central computer for hourly and daily averaging. By collocating the instruments, and later employing linear regression analysis to compare their data sets, a relationship describing the nephelometers' relative response to actual, ambient PM_{10} concentrations was established for both ends of the runway. Combining these methodologies effectively filled the data gaps inherent to the one in six PM_{10} monitoring schedule. Neither the 24-hr (150 ug/m3) nor annual (50 ug/m3) National Ambient Air Quality Standard for PM_{10} was exceeded at either end of the runway during the monitoring period.

The PM_{10} sampler located at the north end of the runway (SeaTac North) operated from June 4, 1998, to May 31, 1999. Fifty-eight of sixty-one scheduled sampling opportunities resulted in valid data (95% data completeness). The maximum 24-hr PM_{10} concentration measured at SeaTac North was 34 ug/m3 and occurred on July 28, 1998. The computed annual arithmatic mean PM_{10} concentration was 14 ug/m3. The nephelometer collocated at this site operated from April 9, 1998, through June 9, 1999, resulting in ninety-nine percent complete and valid data. The maximum, equivalent 24-hr PM_{10} concentration predicted by the nephelometer was 89 ug/m3 and occurred on January 4, 1999. SeaTac North PM_{10} data are summarized in Table XX. Daily nephelometer data for the period September 1, 1998, through June 7, 1999, are graphically summarized in Figure XX.

The PM_{10} sampler located at the south end of the runway (Tyee Valley Golf Course) operated from June 4, 1998 to June 5, 1999. Fifty-nine of sixty-two scheduled sampling opportunities resulted in valid data (95% data completeness). The maximum 24-hr PM_{10} concentration measured at Tyee Valley Golf Course was 36 ug/m3 and occurred on July 28, 1998. The computed annual arithmatic mean PM_{10} concentration was 13 ug/m3.). The nephelometer collocated at this site operated from September 1, 1998, through June 7, 1999, resulting in ninety-nine percent complete and valid data. The maximum, equivalent 24-hr PM_{10} concentration predicted by the nephelometer was 87 ug/m3 and occurred on January 4, 1999. Tyee Valley Golf Course PM_{10} data are summarized in Table XX. Daily nephelometer data for the period September 1, 1998, through June 7, 1999, are graphically summarized in Figure XX.

Table 6: Tyee Valley Golf Course-PM_{10} Data

Day	Jun-98	Jul-98	Aug-98	Sep-98	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99
1		-	-	-	-	17	4	-	-	3	-	-	-
2		-	-	19	5	-	-	-	-	-	-	-	-
3	Start	-	32	-	-	-	-	-	-	-	-	-	-
4	12	13	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	x	-	-	-	9
6	-	-	-	-	-	-	-	15	-	-	12	17	End
7	-	-	-	-	-	19	4	-	-	16	-	-	
8	-	-	-	21	10	-	-	-	-	-	-	-	
9	-	-	16	-	-	-	-	-	-	-	-	-	
10	8	22	-	-	-	-	-	-	-	-	-	-	
11	-	-	-	-	-	-	-	-	3	-	-	-	
12	-	-	-	-	-	-	-	3	-	-	7	6	
13	-	-	-	-	-	6	2	-	-	5	-	-	
14	-	-	-	18	9	-	-	-	-	-	-	-	
15	-	-	12	-	-	-	-	-	-	-	-	-	
16	14	19	-	-	-	-	-	-	-	-	-	-	
17	-	-	-	-	-	-	-	-	7	-	-	-	
18	-	-	-	-	-	-	-	2	-	-	17	x	
19	-	-	-	-	-	13	13	-	-	20	-	-	
20	-	-	-	15	25	-	-	-	-	-	-	-	
21	-	-	15	-	-	-	-	-	-	-	-	-	
22	15	29	-	-	-	-	-	-	-	-	-	-	
23	-	-	-	-	-	-	-	-	6	-	-	-	
24	-	-	-	-	-	-	-	16	-	-	21	x	
25	-	-	-	-	-	6	6	-	-	5	-	-	
26	-	-	-	21	18	-	-	-	-	-	-	-	
27	-	-	21	-	-	-	-	-	-	-	-	-	
28	19	36	-	-	-	-	-	-	-	-	-	-	
29	-	-	-	-	-	-	-	-		-	-	-	
30	-	-	-	-	-	-	-	10		-	16	20	
31		-	-		-		12	-		8		-	

Explanation

All Values are 24-hr Averages (ug/m3)

X = Invalid Sample Attempt

NAAQS 24-hr PM_{10} Standard = 150 ug/m3

Table 5: SeaTac North PM_{10} Data

Day	Jun-98	Jul-98	Aug-98	Sep-98	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99
1		-	-	-	-	16	6	-	-	3	-	-	-
2		-	-	X	10	-	-	-	-	-	-	-	-
3	Start	-	25	-	-	-	-	-	-	-	-	-	-
4	X	10	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	3	-	-	-	X
6	-	-	-	-	-	-	-	18	-	-	15	15	End
7	-	-	-	-	-	16	8	-	-	22	-	-	
8	-	-	-	16	14	-	-	-	-	-	-	-	
9	-	-	12	-	-	-	-	-	-	-	-	-	
10	11	15	-	-	-	-	-	-	-	-	-	-	
11	-	-	-	-	-	-	-	-	4	-	-	-	
12	-	-	-	-	-	-	-	11	-	-	X	8	
13	-	-	-	-	-	11	8	-	-	2	-	-	
14	-	-	-	17	14	-	-	-	-	-	-	-	
15	-	-	12	-	-	-	-	-	-	-	-	-	
16	20	22	-	-	-	-	-	-	-	-	-	-	
17	-	-	-	-	-	-	-	-	5	-	-	-	
18	-	-	-	-	-	-	-	4	-	-	18	8	
19	-	-	-	-	-	14	15	-	-	19	-	-	
20	-	-	-	16	24	-	-	-	-	-	-	-	
21	-	-	15	-	-	-	-	-	-	-	-	-	
22	25	23	-	-	-	-	-	-	-	-	-	-	
23	-	-	-	-	-	-	-	-	5	-	-	-	
24	-	-	-	-	-	-	-	18	-	-	18	19	
25	-	-	-	-	-	7	11	-	-	6	-	-	
26	-	-	-	16	19	-	-	-	-	-	-	-	
27	-	-	17	-	-	-	-	-	-	-	-	-	
28	17	34	-	-	-	-	-	-	-	-	-	-	
29	-	-	-	-	-	-	-	-		-	-	-	
30	-	-	-	-	-	-	-	9		-	14	15	
31		-	-		-		17	-		13		-	

Explanation

All Values are 24-hr Averages (ug/m3)

X = Invalid Sample Attempt

NAAQS 24-hr PM_{10} Standard = 150 ug/m3

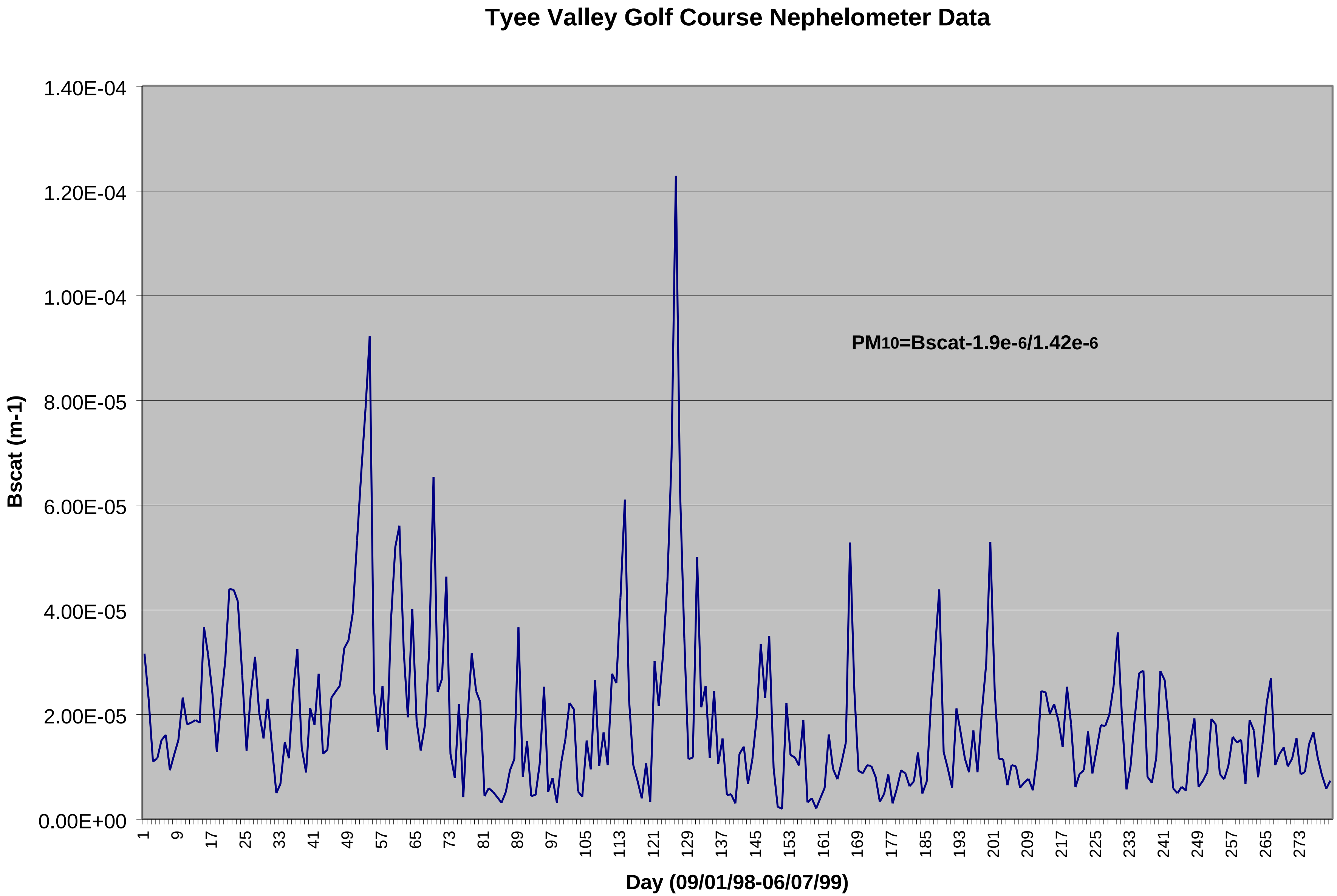


Figure 16: Tyee Valley Golf Course Nephelometer Data – Daily Trend

Table 5: SeaTac North PM_{10} Data

Day	Jun-98	Jul-98	Aug-98	Sep-98	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99
1		-	-	-	-	16	6	-	-	3	-	-	-
2		-	-	X	10	-	-	-	-	-	-	-	-
3	Start	-	25	-	-	-	-	-	-	-	-	-	-
4	X	10	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	3	-	-	-	X
6	-	-	-	-	-	-	-	18	-	-	15	15	End
7	-	-	-	-	-	16	8	-	-	22	-	-	
8	-	-	-	16	14	-	-	-	-	-	-	-	
9	-	-	12	-	-	-	-	-	-	-	-	-	
10	11	15	-	-	-	-	-	-	-	-	-	-	
11	-	-	-	-	-	-	-	-	4	-	-	-	
12	-	-	-	-	-	-	-	11	-	-	X	8	
13	-	-	-	-	-	11	8	-	-	2	-	-	
14	-	-	-	17	14	-	-	-	-	-	-	-	
15	-	-	12	-	-	-	-	-	-	-	-	-	
16	20	22	-	-	-	-	-	-	-	-	-	-	
17	-	-	-	-	-	-	-	-	5	-	-	-	
18	-	-	-	-	-	-	-	4	-	-	18	8	
19	-	-	-	-	-	14	15	-	-	19	-	-	
20	-	-	-	16	24	-	-	-	-	-	-	-	
21	-	-	15	-	-	-	-	-	-	-	-	-	
22	25	23	-	-	-	-	-	-	-	-	-	-	
23	-	-	-	-	-	-	-	-	5	-	-	-	
24	-	-	-	-	-	-	-	18	-	-	18	19	
25	-	-	-	-	-	7	11	-	-	6	-	-	
26	-	-	-	16	19	-	-	-	-	-	-	-	
27	-	-	17	-	-	-	-	-	-	-	-	-	
28	17	34	-	-	-	-	-	-	-	-	-	-	
29	-	-	-	-	-	-	-	-		-	-	-	
30	-	-	-	-	-	-	-	9		-	14	15	
31		-	-		-		17	-		13		-	

Explanation

All Values are 24-hr Averages ($\mu g/m^3$)

X = Invalid Sample Attempt

NAAQS 24-hr PM_{10} Standard = 150 $\mu g/m^3$

Table 6: Tyee Valley Golf Course PM_{10} Data

Day	Jun-98	Jul-98	Aug-98	Sep-98	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99
1		-	-	-	-	17	4	-	-	3	-	-	-
2		-	-	19	5	-	-	-	-	-	-	-	-
3	Start	-	32	-	-	-	-	-	-	-	-	-	-
4	12	13	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	x	-	-	-	9
6	-	-	-	-	-	-	-	15	-	-	12	17	End
7	-	-	-	-	-	19	4	-	-	16	-	-	
8	-	-	-	21	10	-	-	-	-	-	-	-	
9	-	-	16	-	-	-	-	-	-	-	-	-	
10	8	22	-	-	-	-	-	-	-	-	-	-	
11	-	-	-	-	-	-	-	-	3	-	-	-	
12	-	-	-	-	-	-	-	3	-	-	7	6	
13	-	-	-	-	-	6	2	-	-	5	-	-	
14	-	-	-	18	9	-	-	-	-	-	-	-	
15	-	-	12	-	-	-	-	-	-	-	-	-	
16	14	19	-	-	-	-	-	-	-	-	-	-	
17	-	-	-	-	-	-	-	-	7	-	-	-	
18	-	-	-	-	-	-	-	2	-	-	17	x	
19	-	-	-	-	-	13	13	-	-	20	-	-	
20	-	-	-	15	25	-	-	-	-	-	-	-	
21	-	-	15	-	-	-	-	-	-	-	-	-	
22	15	29	-	-	-	-	-	-	-	-	-	-	
23	-	-	-	-	-	-	-	-	6	-	-	-	
24	-	-	-	-	-	-	-	16	-	-	21	x	
25	-	-	-	-	-	6	6	-	-	5	-	-	
26	-	-	-	21	18	-	-	-	-	-	-	-	
27	-	-	21	-	-	-	-	-	-	-	-	-	
28	19	36	-	-	-	-	-	-	-	-	-	-	
29	-	-	-	-	-	-	-	-		-	-	-	
30	-	-	-	-	-	-	-	10		-	16	20	
31		-	-		-		12	-		8		-	

Explanation

All Values are 24-hr Averages ($\mu g/m^3$)

X = Invalid Sample Attempt

NAAQS 24-hr PM_{10} Standard = 150 $\mu g/m^3$

References

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Appendix A
Memorandum of Understanding

Appendix B
Monitoring and Quality Assurance Plan

Appendix C
SeaTac Airport Spatial Nitrogen Dioxide Study

Appendix D
Site Maps

Appendix E
Field and Laboratory Data

Appendix F
Meteorological Data

Appendix G
Audit Results

Appendix H
Correspondence