Air Quality Issues in the Beverly Hills High School Area, Beverly Hills, CA

Expert Report
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Acronyms and Abbreviations

µg	Microgram (10^{-6} gram)
χ	Long-term average concentration
χ_e	Exposure concentration
AADD	Annual average daily dose
AF	Athletic field
ag	Attogram (10^{-18} gram)
BH/CC	Beverly Hills/Century City area
BHHS	Beverly Hills High School
BHOC	Beverly Hills Oil Company
CA	California
CalEPA	California Environmental Protection Agency
CARB ATN	California Air Resources Board Air Toxic Network
CARB	California Air Resources Board
CDC	Center for Disease Control
CDM	Camp Dresser and McKee, Inc.
CFD	Computational fluid dynamics
Cr^{+6}	Hexavalent Chromium (or Chromium VI)
D	Dispersion factor
d	Distance
DOT	Department of Transportation
DPM	Discrete particle model
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
H	Number of hours per year
h	Plaintiff hours
ISC	Industrial source complex
ISCST	Industrial source complex short term
LA	Los Angeles
LAX	Los Angeles International Airport
LST	Local standard time
LTC	Long-term concentration
MC	Main campus
mg	Milligram (10^{-3} gram)
MO	Missouri
NE	Nebraska
ng	Nanogram (10^{-9} gram)
NMOC	Non-methane organic compound
PAH	Polycyclic aromatic hydrocarbons
PCB	Poly-chlorinated bipheyls
PCDD	Poly-chlorinated dibenzodioxins
PCDF	Poly-chlorinated dibenzofurans

PDCH	Perfluoro-1,4-dimethylcyclohexane
pg	picogram (10^{-12} gram)
PIC	Pico Blvd. monitoring station
PM	Particulate matter
PMCH	Perfluoromethycyclohexane
PMCP	Perfluoromethylcyclopentane
ppb	Parts per billion
ppt	Parts per trillion
PTCH	Perfluoro-1,3,5-trimethylcyclohexane
Q	Average emission rate
SCAQMD	South Coast Air Quality Management District
SF_6	Sulfur hexafluoride
SMA	Santa Monica Airport monitoring station
SMC	Santa Monica CIMIS monitoring station
SS	Summer school
SY	School year
TEAM	Total exposure assessment methodology
TEQ	Toxic equivalents
TOG	Total organic gases
Tracer ES&T	Tracer Environmental Sciences and Technologies
UCL	Upper confidence level
UCLA	UCLA campus monitoring station
US EPA	US Environmental Protection Agency
WEST	West Los Angeles monitoring station
WSLA	West Los Angeles

1 Introduction and Overview

The law firm HAIGHT, BROWN & BONESTEEL, LLP, on behalf of defendants, retained the services of Dr. Paolo Zannetti and his company EnviroComp Consulting, Inc.[1] for this case. Under this retention, Dr. Zannetti and his scientific team were asked to read and review relevant documents and reports, collect available data and information, review the technical work performed by the experts designated by plaintiffs, and understand and model the local emissions of atmospheric chemicals that could impact the area surrounding Beverly Hills High School (BHHS) in Beverly Hills, CA.

Dr. Zannetti has performed studies and scientific research in environmental sciences for more than 30 years. His activities have covered pure research in the fields of atmospheric diffusion and numerical computation, written publications, seminars and courses, project management, environmental consulting, editorial productions, and expert testimony. His major field of investigation and competence is air pollution. He has written more than 250 publications, including the book "Air Pollution Modeling"[2], completed in 1990, which was the first comprehensive book in the field, and is still today a widely used textbook[3].

Dr. Zannetti has studied air quality problems all over the world, often using computer models to simulate the transport and fate of atmospheric chemicals. In most of these cases, he simulated the ambient concentrations caused by the emissions using his own computer models and/or those developed and recommended by government agencies, such as the US Environmental Protection Agency (US EPA).

1 http://www.envirocomp.com

2 Zannetti, P. (1990): Air Pollution Modeling – Theories, Computational Methods, and Available Software. Computational Mechanics Publications, Southampton, and Van Nostrand Reinhold, New York. 450pp. http://www.witpress.com/acatalog/1002.html

3 A multi-volume, multi-author, revised and expanded edition of this book is being published under Dr. Zannetti's direction and editorial management. The first volume was published in late-2003; the second volume in summer 2005 [http://www.envirocomp.org/aqm]. The third volume is expected in late-2006.

This report presents the current results of our scientific work in this case and our preliminary opinions. We reserve the right to supplement the report in the event new information is presented.

2 Review of Reports by Experts Designated by Plaintiffs

This section contains our review of the work performed by experts designated by plaintiffs.

2.1 Mr. Jay Rosenthal

Mr. Jay Rosenthal performed analyses that compared wind conditions at Los Angeles International Airport (LAX) with those in the Beverly Hills/Century City area[4]. Mr. Rosenthal abbreviates this area as BH/CC.

Mr. Rosenthal bases his analysis on wind streamline maps reported in the South Coast Air Quality Management District (SCAQMD) report entitled “California South Coast Air Basin Hourly Wind Flow Patterns”, published in 1977 (PLEXJR0000037 through 0000325). In this report, wind observations from 60 stations throughout the Los Angeles Basin during the years 1950-1973 are used to produce streamline maps of climatological wind patterns in the basin[5]. These maps are presented for each hour of each month.

An example of a streamline map is shown in Figure 2-1, which is for the month of April and the hour 1400 LST (2 PM). This map was presented as Exhibit 6009 during Mr. Rosenthal’s deposition. The annotations denote the location of the BH/CC area assumed by Mr. Rosenthal and the locations of the four nearest wind-measuring stations to the area.

The lines on the map are called “streamlines”, and are drawn parallel to the average wind direction[6]. The arrow at the end of the streamlines denotes the direction of the wind flow. The circles on the lines show the observational stations used to construct the map, the number next to a station denoting the average wind speed measured at that station for the month and hour corresponding to the map. Note that while the LAX area is represented by a corresponding observational station, no such station corresponds to the BH/CC area. The closest stations are

4 “Some Comparisons of Wind at Area of Interest with those Measured at Los Angeles International Airport” (PLEXJR-0000004 through 0000018).

5 By “climatological” we mean averages over a long period of time, e.g., a decade or longer.

6 Wind direction is defined as the direction from which the wind is blowing.

WEST (West Los Angeles) and UCLA (UCLA campus), which are roughly a couple miles to the west of BH/CC, and PIC (Pico Blvd.), which is close to downtown Los Angeles roughly five miles to the east of BH/CC.

From these maps, Mr. Rosenthal constructs tables for each month and hour of climatological winds at the LAX and BH/CC areas. The wind directions reported in the tables for the LAX area were obtained from the streamline passing through the LAX station, and the wind speeds were taken from the value directly reported for the corresponding LAX station. The wind directions reported for the BH/CC area were apparently obtained from the streamline passing through the BH/CC area, and the wind speeds were obtained from inspection of the speeds at the WEST, UCLA and PIC stations. He apparently did these wind speed and direction estimations for BH/CC by eye, using a magnifying glass at times[7].

From our inspection of these tables, Mr. Rosenthal finds an agreement between the LAX and BH/CC areas for wind direction generally within 45 degrees. Wind speeds are found to be reduced at the BH/CC area by roughly one half compared to the LAX area.

The observational period (1950-1973) on which the streamline maps are based is before the majority of the current-day towers associated with Century City existed. Mr. Rosenthal's wind analysis is therefore inappropriate to determine the current-day wind climatology of the Beverly Hills High School campus, which is immediately downwind of these buildings.

2.2 Dr. David Neff

Dr. David Neff performed wind tunnel experiments to replicate dispersion of gaseous emissions from facilities operated by certain defendants onto BHHS[8,9]. These experiments were conducted by building a small-scale replica (i.e., a "physical model") of BHHS, the facilities, and the surrounding Century City area, and placing this inside a wind tunnel to simulate the dispersion of

7 See Item (9) in PLEXJR-0000006.

8 "Beverly Hills High School Pollutant Concentration, Study I", May 2005 (PLEXDEN2-000377 through 000439).

9 "Beverly Hills High School Pollutant Concentration, Study II", May 2005 (PLEXDEN1-038904 through 038999).

emissions onto BHHS. Tracer was released during each experimental run from each facility replica to represent these emissions. The physical model includes replications of the major buildings comprising Century City.

Emissions from five facilities were studied: Old Drill Site (Beverly Hills Oil Company, BHOC), New Drill Site (BHOC, Wainoco, Venoco), Drill Site #1 (Chevron), Boilers (Central Plants), and Cooling Towers (Central Plants). These facilities are shown in Figure 2-2. Concentrations of tracer released from each source were measured at 47 receptors placed over the BHHS area of the physical model. These receptors are shown as "Neff Receptors" in Figure 2-2.

Dr. Neff conducted separate wind tunnel runs for the following: a) emissions from each source; b) each of 19 "approach" (i.e., inflow to the physical model) wind directions ranging in 10-degree increments from 100 to 280 degrees; and, c) each of three approach wind speeds (2.5, 5.0, and 7.5 m/s) for the Boilers and Cooling Towers and a single speed (7.5 m/s) for the drill sites (Old Drill Site, New Drill Site, Drill Site #1). These wind inputs are referred to by Dr. Neff as "reference" wind speeds and directions. These runs were conducted for building scenarios representative of the following periods: 1975-1982 and 1983-2000 (Cooling Towers); 1975-1982, 1983-1994, 1995, and 2000 (Boilers); 1975-1982 (Old Drill Site); 1983-2000 (New Drill Site), 1975-1982 and 1983-1989 (Drill Site #1).

The reference wind speeds correspond to those measured at LAX. The actual wind speeds applied by Dr. Neff as inflow to the wind tunnel, however, were smaller to conform to the smaller dimensions of the physical model relative to the field. Scaling theory is applied by Dr. Neff to transfer the wind speed from true field scale to the laboratory scale of the physical model. To generate a wind speed profile (variation of wind speed with height, also called wind shear) and turbulence level within the approach flow before entering the physical model table, the flow was sent over a series of roughness elements on the floor of the wind tunnel prior to striking the physical model table. These surface irregularities, which can be seen in Dr. Neff's Figure 16 in Study II (PLEXDEN1-038979), are regularly spaced over the floor, and act to slow the air speed near the floor of the wind tunnel. This creates wind shear and turbulence in the approach flow.

The concentrations at the 47 receptors from each wind tunnel run are tabulated in Dr. Neff's Study I in Tables 11 through 24 (PLEXDEN2-000400 through 000413) and in Dr. Neff's Study II in Tables 17 through 38 (PLEXDEN1-038938 through 038959). These can be interpreted as "short-term" averages, over a period in the field of typically one hour. The results in each table are for all reference wind directions for a particular combination of source and reference wind speed. Dr. Neff also presents the maximum of the short-term concentrations computed over all runs at each receptor in Table 25 of Study I (PLEXDEN2-000414) and Table 40 of Study II (PLEXDEN1-038961).

Dr. Neff then computes long-term average concentrations for each source by first multiplying the short-term concentrations at each receptor for each run by the percentage of hours over a chosen time period (as explained below) that the LAX 10-meter[10] wind was at the wind speed and wind direction corresponding to the run, and then summing the results of these multiplications for each receptor over all runs corresponding to each source. Dr. Neff uses the winds measured at LAX from 8 AM - 5 PM to construct these wind speed and wind direction percentages. In Study I, two time periods were chosen to construct these percentages, 1975-1982 and 1983-1994. In Study II, six years were chosen – 1975, 1980, 1985, 1990, 1995, and 2000 – to correspond to the time periods used by Mr. Tarr (Section 2.5) in his modeling work. For Study I, Dr. Neff only presents the maximum at each receptor of the long-term average concentrations calculated using each of the 1975-1982 and 1983-1994 percentages. These are listed in Table 25 of Study I (PLEXDEN2-000414). For Study II, he presents the long-term averages calculated for each of the above six years. These are listed in Table 39 of Study II (PLEXDEN1-038960). In both, the results are presented in units of $\mu g/m^3$ assuming a 1 g/s emission rate from each source. Dr. Neff's Table 39 of Study II is reproduced in Table 2-1 – we will refer to this in various points throughout the remainder of this report.

Wind tunnel experiments in past studies have proved useful in replicating air pollution dispersion in areas immediately downwind of tall buildings. This is because the buildings and wind flow over and between them (and, in turn, the dispersive character of the flow) are replicated by the

10 Above surface level.

physical model apparatus. This is an alternative, for example, to standard EPA modeling approaches to compute dispersion, in which the dispersive characteristics of the flow are characterized by equations that have been designed for and validated against situations without large buildings.

Wind tunnel experiments, however, are still idealizations, not able to represent several physical features important for actual dispersion in the field.

For example, the wind tunnel experiments conducted by Dr. Neff do not simulate vertical air motions induced by heating of the ground by the sun. These vertical motions increase dispersion of pollutants both in the vertical and horizontal directions.

Another feature not simulated is the slow horizontal back and forth change in wind direction around the average wind direction observed in real atmospheric flows. This is often called horizontal “meandering”, and causes increased dispersion primarily in the horizontal direction. By not including meandering, therefore, wind tunnel experiments often produce unrealistically narrow plumes.

The regularly spaced cubes on the floor of the wind tunnel used by Dr. Neff to generate his approach flow are also an idealization of the true conditions upwind of Century City. In particular, this setup does not include replications of the hills and several areas of large buildings that have been built in West Los Angeles over the last roughly 30 years. The presence of these buildings and hills enhances the turbulence in the approach flow, a feature that was not captured in Dr. Neff’s approach flow. The larger turbulence may lead to increased dispersion.

Dr. Neff’s wind tunnel simulations, therefore, do not account or have limitation in accounting for several real world processes that affect atmospheric dispersion. Since these features tend to increase turbulence and dispersion, his dispersion rates may be underestimated.

Finally, we note that although Dr. Neff applied different building configurations in many of his runs, the effect of this difference on dispersion is small. A comparison of the long-term average concentrations resulting from emissions from the Boilers, Cooling Towers, and Drill Site #1 for the 1975-1982 versus the 1983-2000 building configurations, each using the 1980 wind frequency distribution, for example, shows that the results are generally within a factor of two of one another. Furthermore, this comparative analysis shows that at most receptors the ratio of the long-term average concentration using the 1983-2000 configuration over that using the 1975-1982 configuration is greater than one, indicating that the 1983-2000 configuration yields higher concentrations of Boiler and Cooling Tower emissions over most of the BHHS area than does the 1975-1982 configuration. Based on this, our use of dispersion measurements from the Tracer ES&T Tracer Experiment, conducted on the BHHS campus during early 2005, to represent dispersion during previous years back to the mid-1970s (i.e., since Century City was built) would give a conservative estimate of dispersion for these sources[11],[12].

A scan across the columns of Dr. Neff's Study II Table 39 (Table 2-1) also shows similarly small year-to-year variations. This further supports the conclusion that the building variations applied by Dr. Neff from run-to-run lead to small variation in long-term average concentrations.

2.3 Dr. Robert Meroney

Dr. Robert Meroney conducted Computational Fluid Dynamics (CFD) computer simulations of droplet deposition from the Central Plants Cooling Towers onto BHHS[13]. The FLUENT[14] CFD model was used to compute the flow field, with the FLUENT "discrete particle model" (DPM) algorithm employed to calculate trajectories and surface deposition of liquid drops emitted from the towers.

Dr. Meroney first reviews past modeling approaches for calculating deposition, pointing out the advantages of his CFD approach over simpler models, two of which being ISCST3 (part of the

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11 This comparative analysis of Dr. Neff's long-term concentrations from boiler and cooling tower emissions using the 1975 – 1982 versus the 1983 – 2000 building configuration was carried out by Dr. Ron Peterson. The results are presented in the document, "Annual Average Concentration Summary using 1980 Wind Distribution and the C/Q Values for the New and Old Building Configurations", which was provided to us by Dr. Peterson.

12 The ES&T Tracer Experiment and its use in our estimation of long-term average concentrations at BHHS is discussed in Sections 4, 6, and 7 of this report.

13 "Prediction of the Impact of Cooling Tower Drift Near Beverly Hills High School", dated January 2005. The figures associated with this report were contained in a separate computer file entitled meroney_figures.pdf (Bates numbers PLEXRNM-002203 through 002228).

14 http://www.fluent.com/.

ISC3 models, as described in Section 2.5) and SACTI (Section 2.4). He then presents comparisons of his CFD predictions of the Chalk Point experiment (June 1977, Chesapeake Bay) to field observations taken during the experiment as an *a priori* model validation exercise. His runs for deposition of droplets emitted from the Cooling Towers onto BHHS were then presented. He conducted two runs. The first was for what Dr. Meroney terms an "isolated" Central Plant facility, i.e., without the presence of the Century City and BHHS campus buildings. The second encompasses of a set of runs that included the Century City and BHHS buildings. These runs were made for four approach wind directions (160, 180, 220, and 240 degrees) and a wind speed corresponding to 5 m/s at LAX.

For both the isolated Cooling Tower runs and those with the campus and Century City buildings, a normalized emission rate of 1 kg/s was applied, and a "Rosin-Rammler" droplet size distribution with a mass-weighted mean diameter of 0.1 mm (i.e., 100 μm) and a shape factor n = 1.0 was assumed. The initial droplet velocity exiting the stack was 8.35 m/s.

Results, as a series of color contour plots, were presented for flow cross-sections, near-ground level water vapor concentrations, and droplet deposition (deposited mass per unit area per unit time).

Dr. Meroney also performed a set of runs in which he derives a set of "multipliers" or "correction factors" to be used by Dr. Hanna for his SACTI runs (Section 2.4)[15]. The multipliers are computed as the ratio of Dr. Meroney's deposition calculated from his runs with the Century City and BHHS campus buildings divided by those from his isolated Cooling Tower runs, i.e., with just the Central Plant Cooling Tower facility and not the Century City and BHHS campus buildings. The wind, emission, and particle size distribution inputs for these runs are identical to those described above, except additional runs were made for wind speeds of 2.5 and 7.5 m/s. The manner of how these correction factors are determined from these runs is discussed in Section 2.4, where we review Dr. Hanna's modeling.

15 "Prediction of the Impact of Cooling Tower Drift Near Beverly Hills High School – Addendum", March 2005 (PLEXRNM-002135 through 002150).

CFD has many of the same advantages as Dr. Neff's wind tunnel in simulating flow affected by tall buildings. By numerically solving the basic equations of fluid flow, the droplet dispersion and deposition resulting from the wind flow between and over the buildings is better reproduced than what results from applying simpler modeling approaches such as ISCST3 and SACTI, which do not solve the basic equations of fluid flow.

CFD, however, is an idealization of the real world, not including several processes known to be important for actual dispersion in the field. For example, as with the wind tunnel, Dr. Meroney's simulations do not include thermal phenomena (heating and cooling by the sun) and wind meandering.

The method of generating the approach flow applied in Dr. Meroney's CFD runs is not stated in his main report. A power-law exponent of 0.25 for the approach wind profile, however, is reported in his "Addendum" (PLEXRNM-002138). This is identical to what Dr. Neff applied in his Draft II report (PLEXDEN1-038911), and nearly the same as the value of 0.28 applied by Dr. Neff in Draft I (PLEXDEN2-000382). We thus expect that Dr. Meroney's approach flow and the turbulence level within it are similar to that present in Dr. Neff's approach flow. As discussed in Section 2.2, this turbulence level is probably underestimated.

The Chalk Point experiment, which Dr. Meroney used for *a priori* validation of his CFD model, is very limited for this purpose. Dr. Meroney only evaluates his results against one night of the experiment, and droplet deposition during this night is measured only at two locations downwind of the two Chalk Point Cooling Towers: 500 and 1,000 meters. These distances are further downwind of the source than any point on the BHHS campus to the Central Plants Cooling Towers. Chalk Point was also an experiment performed over flat land with nearby wetlands and a bay, rather than over an urban area. The Chalk Point Cooling Towers, furthermore, were natural draft, while those of the Central Plants were mechanical draft[16]. The use of these data as an effective *a priori* validation tool for the BHHS simulations is thus highly questionable.

[16] http://www.cheresources.com/ctowerszz.shtml.

2.4 Dr. Steve Hanna

Dr. Steve Hanna applied the SACTI model to compute chromate[17] deposition from the Central Plants Cooling Towers onto BHHS[18].

SACTI[19] is a mathematical model for the prediction of the seasonal/annual air quality and meteorological impact of Cooling Tower plumes, drift, fogging, icing, and shadowing. The model is aimed at providing predictions to be used in the licensing of power plants with Cooling Towers. SACTI was originally developed for the Electric Power Research Institute (EPRI), but is no longer supported by EPRI[20]. Current information about the SACTI can be found at its home page[21].

Dr. Hanna applied SACTI to three years: 1975, 1980, and 1985. The runs were driven by winds measured at LAX over the entire 8,760 hours of each of these years. Chromate emission rates, supplied to Dr. Hanna by Matson and Associates, are given in Table 1 of Dr. Hanna's report (PLEXSRH–008418). These were 0.0814 (year 1975), 0.02812 (1980), and 0.02356 g/s (1985).

A Rammler-Rosin droplet size distribution with mass-weighted mean diameter of 0.1 mm and shape factor n = 1 was assumed. This is the same distribution used by Dr. Meroney in his CFD computations of droplet deposition onto BHHS.

The total chromate deposition (expressed as mass per unit area per unit time) for each of the three years was computed at distances ranging from 100-1,000 meters in 100 meter increments at all directions in 10-degree increments from the source. These results were interpolated to also obtain deposition values at each of the 47 receptors specified by Dr. Neff (Figure 2-2).

Dr. Hanna then multiplies these SACTI results by what he terms a "correction factor" or "multiplier", which was derived from the CFD results of Dr. Meroney. The correction factors

17 A salt of chromic acid. http://www.m-w.com/dictionary/chromate.
18 "Deposition of Chromate Released to the Atmosphere in Drift Water from Cooling Towers Adjacent to Beverly Hills High School", July 26, 2005 (PLEXSRH-008411 through 008455).
19 http://www.dis.anl.gov/SACTI/SactiManual.doc (user manual).
20 http://yosemite.epa.gov/oar/Forums.nsf/0/6c2dd37ec9aea38b85256bf2006857cd?OpenDocument.
21 http://www.dis.anl.gov/SACTI/.

were defined as the ratio of the deposition computed by Dr. Meroney's CFD runs that included the Century City and BHHS buildings divided by those from his CFD runs without these buildings, i.e., with only the Central Plant Cooling Tower structure. These CFD runs are described in Section 2.3. According to Dr. Hanna, the correction factors account for "the enhanced deposition … due to recirculating wakes and downdrafts associated with the buildings around the cooling towers."[22]

Factors were computed by Dr. Meroney for four directions relative to the source – 160, 180, 220, and 240 degrees – and distances from 0 to 1,250 feet in increments of 250 feet in each of these directions. Dr. Meroney then averaged the factors over distance, producing individual multipliers for each of the above four directions. They range in value over these directions from 1.27 to 4.45. Dr. Hanna then projected these multipliers over the six wind direction sectors (SSE, S, SSW, SW, WSW, and W) for which the most deposition was computed in his SACTI runs. The resulting correction factors are tabulated in Table 6 of his report (PLEXSRH-0008428). Dr. Hanna then multiplies the deposition predicted by SACTI at each distance and direction by the correction factor corresponding to the direction. The results of these multiplications are presented for each year in Table 7a through 7c (PLEXSRH-008431 through 008433) of Dr. Hanna's report and represent what we understand is his final opinion concerning chromate deposition onto BHHS.

The ensuing critique of Dr. Hanna's results focuses solely on dispersion. No critique of emission rates is given.

The enhanced downdrafts Dr. Hanna mentions in the above citation are known effects of tall buildings upwind of elevated stacks, and it is largely understood among pollution modelers that standard mathematical models such as SACTI and ISC3 for estimating pollution concentrations are not effective in the vicinity of tall buildings due to underestimation of the intensity of these downdrafts. The fact that the correction factors are greater than one is thus consistent with the effects of enhanced downdrafts, which more efficiently mix droplets to the surface. As such,

[22] See Dr. Hanna's report, Section 3.5 (PLEXSRH-008428).

Dr. Hanna's application of the above correction factor is expected to improve the deposition prediction relative to what would be achieved from SACTI alone.

Because the correction factors are derived from Dr. Meroney's CFD results; however, any inaccuracies in these CFD results will carry over into Dr. Hanna's results. Possible sources of error in Dr. Meroney's results were discussed in Section 2.3.

Finally, we note that the droplet size distribution used by Dr. Hanna is quite different from that provided by Sierra Research (Section 5.2). For example, the mean droplet diameter of 0.1 mm used by Dr. Hanna is approximately a factor of three smaller than that estimated by Sierra Research (0.317 mm). Also, the value of the 95-percentile diameter (i.e., that below which 95% of the droplet mass exists) used by Dr. Hanna is approximately 0.307 mm; whereas, that of Sierra Research is approximately 0.8 mm (Figure 5-6)[23].

2.5 Mr. Jim Tarr

The modeling work of Mr. Jim Tarr provides what appears to be the final opinion of the experts designated by plaintiffs concerning ambient concentrations of chemicals emitted from surrounding facilities operated by the defendants onto BHHS. Mr. Tarr's work consists of three reports - an original, "Supplement" and "Supplement 2"[24,25,26]. Additional information for this review was obtained from computer files supplied to us by Mr. Tarr.

Mr. Tarr used the EPA model ISC-PRIME[27] in his work. ISC-PRIME incorporates an advanced treatment of building downwash into the Industrial Source Complex Short Term Model (ISCST3, which is part of ISC3). ISC3[28] is a steady-state Gaussian plume model used to assess

23 Dr. Hanna's 95% cut diameter was estimated from the size distribution values given in his Table 2 (PLEXSRH 008418).

24 "An Evaluation of the Impact of Toxic Chemical Air Emissions from Industrial Facilities at Beverly Hills High School", May 16, 2005.

25 "An Evaluation of the Impact of Toxic Chemical Air Emissions from Industrial Facilities at Beverly Hills High School – Supplement", July 21, 2005.

26 "An Evaluation of the Impact of Toxic Chemical Air Emissions from Industrial Facilities at Beverly Hills High School – Supplement 2", January 9, 2006.

27 http://www.epa.gov/scram001/dispersion_alt.htm#iscprime.

28 http://www.epa.gov/scram001/dispersion_alt.htm#isc3.

pollutant concentrations from a wide variety of sources associated with an industrial complex. This model can account for the following: settling and dry deposition of particles; downwash; point, area, line, and volume sources; plume rise as a function of downwind distance; separation of point sources; and limited terrain adjustment. ISC3 operates in both long-term and short-term modes.

ISC-PRIME is run hour-by-hour driven by user-supplied meteorological inputs and emissions. When run in an annual mode, the resulting hourly concentrations at each user-specified receptor are averaged to give annual (long-term) average concentrations at each receptor. Shorter averaging times can also be specified to give averages over, for example, 8 hours. The model is also able to output the individual 1-hour concentrations at each receptor. These hourly and average concentrations can be output for individual sources as well as for the sum over all the simulated sources[29].

Until recently (October 2005), ISC3 and ISC-PRIME were "preferred/recommended" models of the EPA. The AERMOD and CALPUFF modeling systems, however, are now the preferred regulatory tools, with ISC-PRIME and ISC3 listed as "alternative" models[30].

Mr. Tarr ran ISC-PRIME to estimate concentrations resulting from emissions from the New Drill Site, Old Drill Site, Drill Site #1, and Central Plants Boilers and Cooling Towers for the years 1975, 1980, 1985, 1990, 1995, and 2000. The locations of these sources are shown in Figure 2-2. Concentrations were estimated for the following species: benzene (emitted from the Drill Sites and Boilers), Cr^{+6} (emitted from the Cooling Towers), formaldehyde (emitted from the Boilers), polycyclic aromatic hydrocarbons (PAH, emitted from the Boilers), chromium (emitted from the Boilers), nickel (emitted from the Boilers) and arsenic (emitted from the Boilers), poly-chlorinated biphenyls (PCBs, emitted from the Boilers) and poly-chlorinated dibenzofurans (PCDFs, emitted from the Boilers).

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29 See http://www.epa.gov/scram001/dispersion_alt.htm for further description of both ISC-PRIME and ISCST3.
30 http://www.epa.gov/scram001/dispersion_alt.htm.

Mr. Tarr makes model runs for what he defines as “average” and “maximum” emission rates for benzene, formaldehyde, chromium, nickel, arsenic and PAH. These emission rates were, with exceptions noted below, calculated by Mr. Tarr. Mr. Tarr also defines what he terms two “scenarios” of average and maximum emission rates. These were defined for 1985 benzene emissions from the New Drill Site. Two “scenarios” were also defined for benzene emission rates from Drill Site #1 for 1975, 1980, and 1985. The “Scenario 1” emission rates for Drill Site #1 were those used in the original report, and the “Scenario 2” rates were those used in the Supplement. Two runs for Cr^{+6} emissions, one based on PM_{10} droplet emissions and the other on PM_{30} droplet emissions from the Cooling Towers, were made. These emission rates were calculated by Matson and Associates.

PCBs and PCDFs were modeled by Mr. Tarr in the Supplement and Supplement 2 reports. The emission rates for PCBs and PCDFs were calculated by Dr. Barry Dellinger of Louisiana State University. Three “scenarios” (A, B, and C) were specified for PCBs and PCDFs in the Supplement, with average and maximum emission rates defined for each “scenario”. Two additional “scenarios” (D and E) were run in Supplement 2. Average and maximum emission rates were defined for “Scenario D” and average emission rates were defined for “Scenario E”. The emission rates for “Scenario E” are for four time periods: 1981-1989, 1990-1994, 1995-1999, and 2000-2003.

Concentrations were calculated at 55 receptors – the 47 specified by Dr. Neff (hereafter referred to as “Neff-receptors”) plus an additional eight receptors specified by Mr. Tarr (hereafter referred to as “Tarr-receptors”). These receptors are shown in Figure 2-2.

The ensuing description and critique of long- and short-term concentrations produced by Mr. Tarr focuses solely on dispersion. No discussion and critique of emission rates is given in this section.

2.5.1 Long-Term Concentrations

Mr. Tarr estimated long-term concentrations as follows. For each of the six years modeled (1975, 1980, 1985, 1990, 1995, and 2000) he ran ISC-PRIME with a unit emission rate (1 g/s) for each source. LAX surface meteorological inputs were used. Long-term average concentrations were computed as the average of the hourly concentrations computed by ISC-PRIME between the hours 8 AM - 5 PM for all days of the year excluding summer. These were the same hours and days used by Dr. Neff in computing his long-term average concentrations. We define this first run by Mr. Tarr as “ISC-PRIME1”.

At each Neff-receptor and for each source, Mr. Tarr then derived what he terms a “correction factor” by dividing the long-term concentration computed by Dr. Neff’s wind tunnel with unit emission rate (Table 2-1) by those computed by ISC-PRIME. Mr. Tarr linearly interpolates the resulting correction factors to produce additional correction factors at the Tarr-receptors.

Mr. Tarr then reran ISC-PRIME for each of the six years and for each species employing his, Dr. Dellinger’s, and Matson and Associates’ estimated emission rates. He again used LAX meteorology for these runs. In these “second” ISC-PRIME runs (which we define as “ISC-PRIME2”), Mr. Tarr computes long-term averages over hours 8 AM - 5 PM over a “school-day” schedule, which excludes weekends, holidays and winter break days in addition to summer days. The long-term average concentrations resulting from each source and at each of the 55 receptors from these second ISC-PRIME runs were then multiplied by the corresponding correction factor for each source-receptor combination. For each species, the products of these multiplications at each receptor were then added for each source. These sums are Mr. Tarr’s final results for long-term concentrations at BHHS. They are tabulated for each run in the “Concentration Tables” sections of Mr. Tarr’s reports for the total long-term concentration and their source-by-source contributions.

Mr. Tarr does not give any physical explanation or detailed justification for applying his correction factors in calculating long-term average concentrations. As with the SACTI model used by Dr. Hanna (Section 2.4), however, ISC-PRIME (as well as the ISC3 family as a whole) is inappropriate for areas downwind of very tall buildings and, as such, application of Mr. Tarr’s correction factor is expected to improve his long-term concentration predictions compared to what would be calculated by ISC-PRIME alone. Because the correction factors are derived from Dr. Neff’s wind tunnel results, however, any inaccuracies in the wind tunnel results will carry over into Mr. Tarr's final long-term concentrations. Possible sources of error in Dr. Neff's wind tunnel results were discussed in Section 2.2.

Mr. Tarr's correction factor, however, is unlike Dr. Hanna's in that it is defined as the ratio of the long-term averaged concentration from the "correct" model (in this case, Dr. Neff's wind tunnel) over that from the "incorrect" model (ISC-PRIME). Multiplication of the long-term averaged concentrations resulting from Mr. Tarr's second ISC-PRIME run by the correction factors therefore leads essentially to Dr. Neff's long-term averaged concentrations multiplied by Mr. Tarr's emission rates, i.e.,

$$\text{LTC} = (\text{ISC - PRIME2}) \times \left(\frac{\text{Wind Tunnel}}{\text{ISC - PRIME1}} \right) \approx \text{Emission Rate} \times \text{Wind Tunnel}$$

where 'LTC' denotes long-term concentration and 'ISC-PRIME1' and 'ISC-PRIME2' denote Mr. Tarr's first and second ISC-PRIME runs, respectively. ISC-PRIME, as a result, has very little influence on the value of Mr. Tarr's long-term averaged concentrations[31].

The values of the correction factors at each receptor for each of Mr. Tarr's long-term concentration runs are listed alongside his final long-term concentrations at each receptor in his "Concentration Tables" sections of his reports. They are greater than one at most receptors, particularly those within the main part of the BHHS campus, away from the athletic area. Receptors where correction factors are less than one are on the athletic field part of campus for Old Drill Site and Drill Site #1 emissions, and on the far northwest part of campus for Cooling Tower emissions. Contours of Mr. Tarr's correction factors for selected years for the five sites, shown in Figure 2-3 through Figure 2-7, illustrate these patterns.

[31] The only differences between the long-term concentrations that result from multiplying Dr. Neff's long-term concentrations by Mr. Tarr's and Dr. Dellinger's emission rates and those computed by Mr. Tarr are due to the different choice of days applied by Dr. Neff and Mr. Tarr in performing their long-term averaging. Tarr applied a school-year schedule to perform his averaging in his second ISC-PRIME run. Dr. Neff, on the other hand, excluded only summer days in performing his averaging. Checks performed by us for the case of 1985 maximum benzene emissions show that the differences in the long-term concentrations resulting from these two methodologies are very minor. We expect that this holds for other years and species as well.

The fact that the correction factors are generally greater than one can reflect a number of differences in the dispersion as approximated by the wind tunnel versus ISC-PRIME. The increased downwash associated with the surrounding Century City buildings (Section 2.4), which the wind tunnel better replicates than does ISC-PRIME, probably explains a major part of the fact that correction factors are greater than one over most of the campus area for the Cooling Tower (Figure 2-3) and Boiler (Figure 2-4) emissions. Differences in wind speed may also play a role.

A likely explanation for the fact that areas of correction factors less than one are found on the athletic field for Old Drill Site and Drill Site #1 emissions (Figure 2-6 and Figure 2-7) has to do with the increased lateral dispersion in the wind tunnel flow compared to the dispersion rates assumed in ISC-PRIME, which do not directly include building effects for area source emissions. One of the effects of this large lateral dispersion is to more effectively disperse pollutants onto the main part of the campus than would be achieved without the enhanced lateral dispersion due to the buildings. Because Mr. Tarr's uncorrected runs are from ISC-PRIME with LAX winds, plumes do not account for this enhanced dispersion, and are therefore very narrow and head eastward towards the athletic field, down the prevailing direction of LAX winds. Taking the ratio of Dr. Neff's over Mr. Tarr's long-term average concentrations therefore leads to correction factors less than one on the athletic field since the increased dispersion in the wind tunnel moves a greater portion of concentrations away from the athletic field and onto the main campus than is captured by ISC-PRIME, thereby reducing the concentration on the athletic field relative to that predicted by ISC-PRIME[32].

2.5.2 Short-Term Concentrations

Mr. Tarr also presents short-term concentrations in his reports. These short-term concentrations are presented in two ways. The first is as the daily 8-hour (8 AM - 4 PM) average concentrations for each considered day in a given year at selected receptors, and the second as the maximum 1-hour concentrations computed over all considered hours in a given year at all receptors. These

[32] Although not shown in Figure 2-5, a single receptor – Receptor 45 – located immediately east of the New Drill Site, also has a correction factor less than one. Its value for Mr. Tarr's 1985 run is 0.45. This can be checked in PLEXJT-044438 through 044439. This value is similar to the values for his 1990, 1995, and 2000 runs.

are presented for benzene and Cr^{+6}. The 8-hour concentrations are plotted in the "Concentration Graphs" section of his reports. The maximum 1-hour concentrations are tabulated in the "Concentration Tables" portion of his reports (PLEXJT-042777 through 042780 in the original report, PLEXJT-044452 in the Supplement).

Short-term benzene concentrations are presented for his 1985 maximum emission rate runs, assuming "Scenario 2" emission rates for the New Drill Site. The Cr^{+6} concentrations were presented for his 1975, 1980, and 1985 PM_{10}-based emissions.

The short-term results are obtained directly from the hour-by-hour results from Mr. Tarr's second ISC-PRIME run, without any correction factor applied. As stated above, ISC-PRIME is not an appropriate tool to compute concentrations downwind of tall buildings. Mr. Tarr's short-term results are therefore inaccurate.

2.6 Dr. William Sawyer

Dr. William Sawyer produced environmental and occupational exposure history summaries for each of the 12 plaintiffs (Mr. Davidson, Mr. Gordon, Ms. Lee, Ms. Shapiro, Ms. Shore, Mr. Tackaberry, Mr. Frankel, Ms. Gross, Ms. Day, Mr. Laurie, Ms. Busch, and Ms. Revel). This material was received by us in the form of Excel spreadsheets and accompanying summary reports[33].

Dr. Sawyer provides background information such as date of birth and past and present residences for each of the 12 plaintiffs. He summarizes their residential and occupational chemical exposure, as well as their educational and occupational history.

For each plaintiff, he summarizes their BHHS exposure and provides a table for each except Ms. Busch (who did not claim exposure on BHHS, but rather at the nearby hospital). Based upon each plaintiff's exposure duration, activity, and location, Dr. Sawyer created tables of exposures

[33] The Excel spreadsheets were constructed by Dr. Clark (Section 2.7).

by inhalation for the 11 plaintiffs. He used the guidance report[34] by CalEPA, CDC stature-for-age and weight-for-age percentile based upon height and weight noted within specific medical records, and exposure information he gathered to create the tables. These exposure assessments were then used by Dr. Clark, as described next.

2.7 Dr. James Clark

Dr. James Clark performed analyses of the estimated exposure to species emitted from defendant facilities for each of the twelve plaintiffs, who are listed in Section 2.6. He based his analyses on the estimated ambient concentrations at BHHS produced from the modeling work of Mr. Tarr (Section 2.5) and the exposure assessments for each plaintiff produced by Dr. Sawyer (Section 2.6). Dr. Clark's exposure analyses are contained in a series of Excel spreadsheets. These sheets are accompanied by a report[35].

Dr. Clark performs exposure analysis for the following chemicals: benzene, arsenic, formaldehyde, polycyclic aromatic hydrocarbons (PAHs), nickel, hexavalent chromium, poly-chlorinated biphenyls (PCBs) and poly-chlorinated dibenzofurans (PCDFs). The output of his analysis is the annual average daily dose (AADD) of each of these species experienced by each plaintiff due to claimed exposure from defendant facilities. The units of AADD are grams of chemical per kilogram body weight per day. Dr. Clark also multiplies this number by the plaintiff body weight to give the grams per day of annual averaged exposure. A post-processing analysis is then performed by Dr. Clark for benzene, hexavalent chromium and PCDFs to calculate what he terms the "Percentage Differential", which is the ratio of AADD to which the plaintiffs were exposed due to facility emissions plus background concentrations over the AADD for a hypothetical case of exposure to just background levels.

Dr. Clark uses the long-term average concentrations generated by Mr. Tarr's maximum emission rate runs to base his AADD calculations. For certain species and years, however, Mr. Tarr

[34] "Guidance for School Site Risk Assessment Pursuant to Health and Safety Code Section 901(f): Guidance for Assessing Exposures and Health Risks at Existing and Proposed School Sites", Feb. 2004, CalEPA.

[35] "Exposure Quantification Assessment for Plaintiffs from Emissions of Arsenic, Benzene, Hexavalent Chromium, PCBs, Formaldehyde, Dioxin Like Compounds, & Nickel from Facilities Adjacent to the Beverly Hills High School 241 Moreno Drive, Beverly Hills, California", SWAPE, January 6, 2006.

defines different emission "scenarios" for his average and maximum rates. Dr. Clark's choice of maximum emission rate runs among these "scenarios" is as follows: for Drill Site #1 during the period 1980-1984, Dr. Clark uses Mr. Tarr's "Scenario 1" 1980 maximum emission rates, for the New Drill Site during 1985-1989 Dr. Clark uses Mr. Tarr's "Scenario 2" 1985 maximum emission rates, and for PCBs and PCDFs he uses Mr. Tarr's Scenario D emissions (calculated by Dr. Dellinger, see Section 2.5)[36]. In each case, Dr. Clark's choice represents the run for the highest of Mr. Tarr's maximum emission rates. Dr. Clark uses Mr. Tarr's long-term concentration estimates for a given year to represent exposure for that year and the following four years, for example he uses Mr. Tarr's concentrations for 1980 to represent exposure during the period 1980-1984[37].

Dr. Clark divides the BHHS campus into four zones[38]: the athletic field area (Zone 1), the gym area (Zone 2), the front lawn area (Zone 3) and the classrooms and cafeteria area (Zone 4). He then determines the subsets of Mr. Tarr's 55 receptors that are within each of these zones and computes statistics (mean, median, standard deviation, and others) over the long-term concentrations comprising these subsets. The mean values ("sample mean") comprise the average long-term concentrations for each considered species in each zone. Dr. Clark then determines the 95% upper confidence limit (UCL) for the mean of each species in each zone using these statistics. Conceptually, the 95% UCL represents that for which it is 95% certain the "true mean" value does not exceed. The 95% UCL is therefore larger than the sample mean computed from a finite number of samples[39]. Dr. Clark then adds to the 95% UCL for each

[36] There appears to be some errors in Dr. Clark's application of Mr. Tarr's long-term averaged concentrations. First, it appears that Dr. Clark applies Mr. Tarr's long-term concentrations from the maximum emission rate chromium (emitted from the boilers) run as input to his hexavalent chromium (emitted from the cooling towers) AADD calculations. Second, for Ms. Melissa Gross, Clark applies the hexavalent chromium concentrations entered into his spreadsheets for PCBs and PCDFs.

[37] An inconsistency with this general approach is noted for Ms. Monica Revel, however, where Dr. Clark used concentrations resulting from Mr. Tarr's 1990 maximum benzene emission rates to represent Ms. Revel's exposure during 2001-2002.

[38] Dr. Clark refers to these as "sections", however we use the word "zone" here to not confuse the reader with sections in our report.

[39] See "Experimental Statistics – Handbook 91", U.S. Department of Commerce, National Bureau of Standards, Issued August 1, 1963 for further details. The 95% UCL would approach the sample mean as the number of samples increases.

species the background level he estimates for that species. He uses these sums to start his exposure analyses for each species and each plaintiff.

A series of multiplications is then performed to compute the AADDs from the 95% UCL concentrations in each zone. These multiplications involve: the minutes spent per day by each plaintiff in each zone (calculated primarily by Dr. Sawyer and varying depending on zone and plaintiff); the number of days the plaintiffs were at BHHS (assumed to be 90 per semester for students – different assumptions were made for Ms. Busch and Mr. Laurie since they were not students at BHHS); and the plaintiffs' activity levels in each zone. The calculations of AADD were made semester by semester for student plaintiffs, and therefore did not include summer school periods. They were calculated in five-year intervals for weekdays and weekends for Mr. Laurie, and for the period January – August 1994 for Ms. Busch.

Dr. Clark then computed the "Percentage Differential" for selected periods for the 10 student plaintiffs[40] as

$$\text{Percentage Differential} = \frac{(\text{On campus AADD}) + (\text{Off campus AADD})}{(\text{Hypothetical AADD})} \times 100$$

The "On Campus AADD" is that due to their on-campus activity and includes exposure to both defendant emissions and background concentrations. The "Off Campus AADD" is that due to their exposure off-campus and assumes background concentrations and a reduced activity level relative to that assumed by Dr. Clark for on campus exposure. The "Hypothetical AADD" is that due to 24 hours per day exposure to background concentrations at the reduced activity level. All three of these assume exposure for 90 days per semester, and therefore only 180 days per year. Dr. Clark therefore does not consider exposure to background concentrations during the other roughly half year when plaintiffs were not on campus. It is also emphasized that numerator of the "Percentage Differential" ratio, through the "On Campus AADD" term, includes Dr. Clark's assumed increased activity level of plaintiffs while they are on campus, while the denominator of the ratio, i.e. the "hypothetical AADD" term, does not include the increased activity level.

[40] Dr. Clark did not calculate percentage differentials for Ms. Busch and Mr. Laurie.

Dr. Clark also computes an "hourly concentration" AADD by performing the above calculations assuming a maximum hourly concentration in each zone. He computes this maximum hourly concentration by multiplying the 95% UCL for each species and each zone by 12.5. This value is the reciprocal of 0.08 (12.5 = 1/0.08), a value suggested[41] by the EPA to transform measured maximum hourly-averaged concentration over a year to an annual average. No "Percentage Differential" is computed by Dr. Clark from the "hourly concentration" AADD.

Our points of critique of Dr. Clark's analysis are as follows:

- The application of a 95% UCL is inappropriate for this analysis. As stated above, the reason for the application of a 95% UCL is to provide an upper bound to the estimates of statistics of sampled data (for example, the mean value of a sample) due to uncertainty associated with having a finite number of samples. With observational data, it is generally impossible to redo an experiment exactly to obtain more samples, and therefore a statistical analysis is necessary if one wishes to estimate an upper bound to the mean due to this uncertainty. With Mr. Tarr's modeling work, however, it is possible to redo the modeling runs (or only a required subset of them) exactly with additional receptors specified to obtain more "samples" in each of Dr. Clark's zones, and this is what *should* be done if there is concern about a limited number of receptors in Mr. Tarr's model output. We have recently performed this analysis (test runs) of adding extra receptors to the 1980 maximum benzene emission rate, "Scenario 1" ISC-PRIME run performed by Mr. Tarr. In these test runs (3 runs) we increased the number of receptors in Zone 4 from the original value of 31 to 95, 374, and 1,492, and verified that the average concentration is practically unaffected by the number of receptors. We therefore believe that the application of the 95% UCL by Dr. Clark is

41 EPA/454/R-92-019, 1992, as reported by Dr. Neff (PLEXDEN1-038914).

scientifically unsound in this context and leads to an incorrect increase in average concentrations in each zone[42].

- Dr. Clark determines his background concentrations for benzene by multiplying his estimates of the benzene concentrations observed in Downtown Los Angeles (based on a historical database that he compiled) by 0.5[43]. This "reduction factor" of 0.5 was derived from the ratio of the average benzene concentration of 1.37 μg/m^3, which was computed from seven samples of benzene taken by the South Coast Air Quality Management District in the BHHS area in early 2003 over the average of daily averaged benzene measurements that occurred over six days during early 2003 taken by the California Air Resources Board (CARB) at their Downtown Los Angeles measurement[44,45].

  The methodology Dr. Clark applied to obtain this "reduction factor" is not valid because it relies only on a very limited number of measurements. To determine such a factor for use in the AADD calculations, which require *long-term averaged* concentrations as input, one should compare measured *annual or long-term averaged* benzene concentrations. Since such measurements for benzene do not exist to our knowledge in the western side of the Los Angeles Basin, a firm scientific basis to determine the value of Dr. Clark's reduction factor is not available.

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42 Also, the 95% UCL as used by Dr. Clark has been proposed (e.g.,www.hanford.gov/dqo/training/289cmb02.pdf and http://www.epa.gov/esd/tsc/images/proucl3apr04.pdf) for cases of soil and groundwater contamination and remediation (Superfund cases) rather than air quality applications.

43 Pages 144-145 of Dr. Clark's deposition testimony, Volume One.

44 See PLEXJJC-004188 through 004189 in Dr. Clark's report for a listing of the seven measurements over four days for which the SCAQMD measurements were taken.

45 From Pages 463-469 of Dr. Clark's deposition testimony, Volume Two, the specific days for which benzene measurements were examined at the CARB Downtown LA measurement station were February 2, February 14, February 26, March 22, April 15, and April 27. The average of the CARB measurements for these days (computed from data entered in Dr. Clark's spreadsheet "City Benzene") was 2.0 μg/m^3. The ratio of the average SCAQMD measurements to the CARB measurements is therefore 1.37/2.0 ≈ 0.7, rather than the value 0.5 that Dr. Clark applies.

- Dr. Clark does not state how he obtained the background concentrations he applied in his AADD calculations for the other species besides benzene. Furthermore, there appears to be several inconsistencies in his entries of these values in his spreadsheets. For example, the background concentrations entered for Ms. Shore for arsenic, formaldehyde and PAH are each different that what was entered for Ms. Shapiro, although both plaintiffs attended BHHS during the same general time period (mid- to late-1970s). Furthermore, the values for formaldehyde for Ms. Shore vary with zone, which does not make sense for a background value. Several other instances of similar inconsistencies are present in Dr. Clark's spreadsheets.

- The activity level for the plaintiffs was specified in Dr. Clark's spreadsheets through breathing rates. Dr. Clark assumes, for student plaintiffs, a 0.3 L/kg-min breathing rate in his calculations for "Off Campus" and "Hypothetical" AADD, whereas the breathing rates applied in his "On Campus" AADD calculations are 0.9, 0.9, 0.6 and 0.3 L/kg-min in each of the four zones, respectively[46]. Part of the portion of "Percentage Differential" greater than 100 that Dr. Clark reports, therefore, is due to differences in breathing rates between the numerator and denominator entries in the "Percentage Differential" (see equation above). This leads to ambiguity in interpreting the physical meaning of the "Percentage Differential", in particular in discerning what part of the portion greater than 100 is due to the presence of defendant emissions and which part is due to the higher breathing rate applied in the "On Campus AADD".

- Dr. Clark does not consider exposure to background concentrations during days when plaintiffs were not on campus. This biases the "Percentage Differential" to high values since exposure to background air, which strongly affects the value of the denominator of the above equation, is underestimated.

[46] We do not offer an opinion on whether the values of the breathing rates used by Dr. Clark are appropriate.

- The "Percentage Differential" is a misleading indicator of the effects of facility emissions on plaintiff exposure since its value does not indicate the true percent increase of exposure due to the facility emissions. Rather, a value of 100 must be subtracted from the values of "Percentage Differential" that Dr. Clark reports to arrive at this percent increase.

To examine the effects of these inaccuracies on Dr. Clark's "Percentage Differential", we have recomputed the value of Percentage Differential for benzene for a single plaintiff - Ms. Day - assuming the following changes to what Dr. Clark assumed:

- No 95% UCL is applied. The annual-averaged concentrations in each of the four zones are therefore those arriving directly from Mr. Tarr's maximum emission rate modeling runs.

- A reduction factor of 0.7 is applied, rather than 0.5, to specify the local background concentration value. This is to correct the error in Dr. Clark's calculation of his "reduction factor" discussed in Footnote 45.

- The breathing rates in the "Hypothetical AADD" calculation for the hours in which plaintiffs are at BHHS are set equal to the breathing rates Dr. Clark used in his "On Campus AADD" calculation (see above for these values).

- Exposure is assessed over an entire year (365 days) rather than only over the days in which Ms. Day was on campus.

- A value of 100 is subtracted from the "Percentage Differential".

Dr. Clark reports a "Percentage Differential" of 218% for each semester for Ms. Day. After making the above modifications and redoing the calculations, we obtain a value of 21%. Therefore, a very large fraction of the value of 218% that Dr. Clark reports as an indicator of the effects of facility emissions on Ms. Day's exposure therefore has nothing to do with facility emissions, but is rather a result of inaccurate assumptions and errors in Dr. Clark's analysis. A similar large fraction is obtained when this analysis is applied to Ms. Gross' exposure.

The remaining value, 21%, represents the percent increase of Ms. Day's AADD assuming the long-term average benzene concentrations resulting from Mr. Tarr's maximum emission rates are present at BHHS and assuming the breathing rates applied by Dr. Clark are valid. In addition, and unlike Dr. Clark's analysis, this value also accounts for exposure to background concentrations during days when plaintiffs were off-campus. As will be discussed in Section 5.3, however, Mr. Tarr's maximum emission rates are unrealistically high. Applying the ambient long-term concentrations at BHHS resulting from our calculations, which lead to the results presented in Table 6-2 and are based on the emission rates computed by Ms. Wilson, yields instead a value for Ms. Day's percentage increase in benzene exposure due to the facilities of approximately 0.025%.

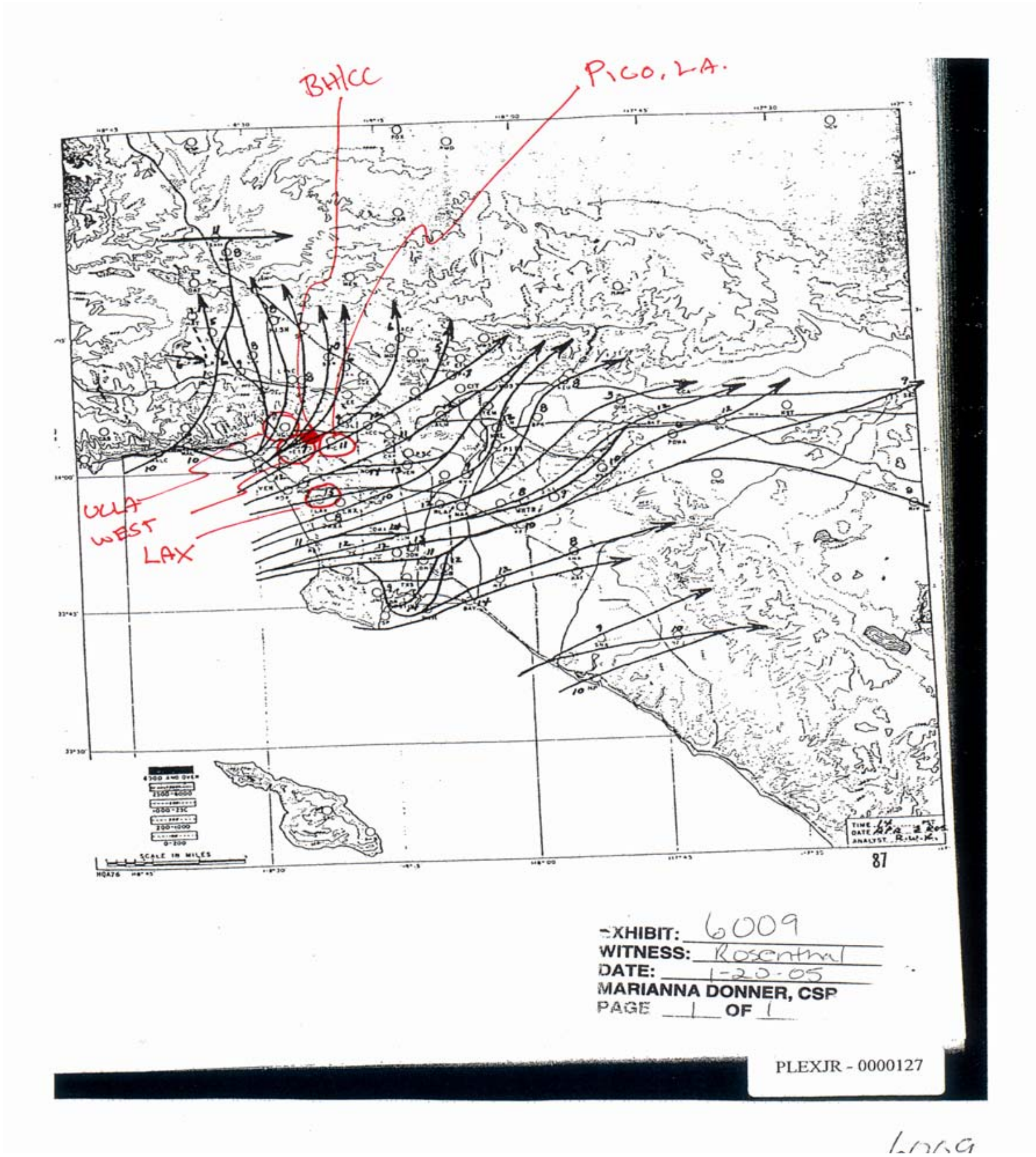

Figure 2-1: Mr. Rosenthal's streamline map for April 1400 LST. Original picture extracted from the deposition files.

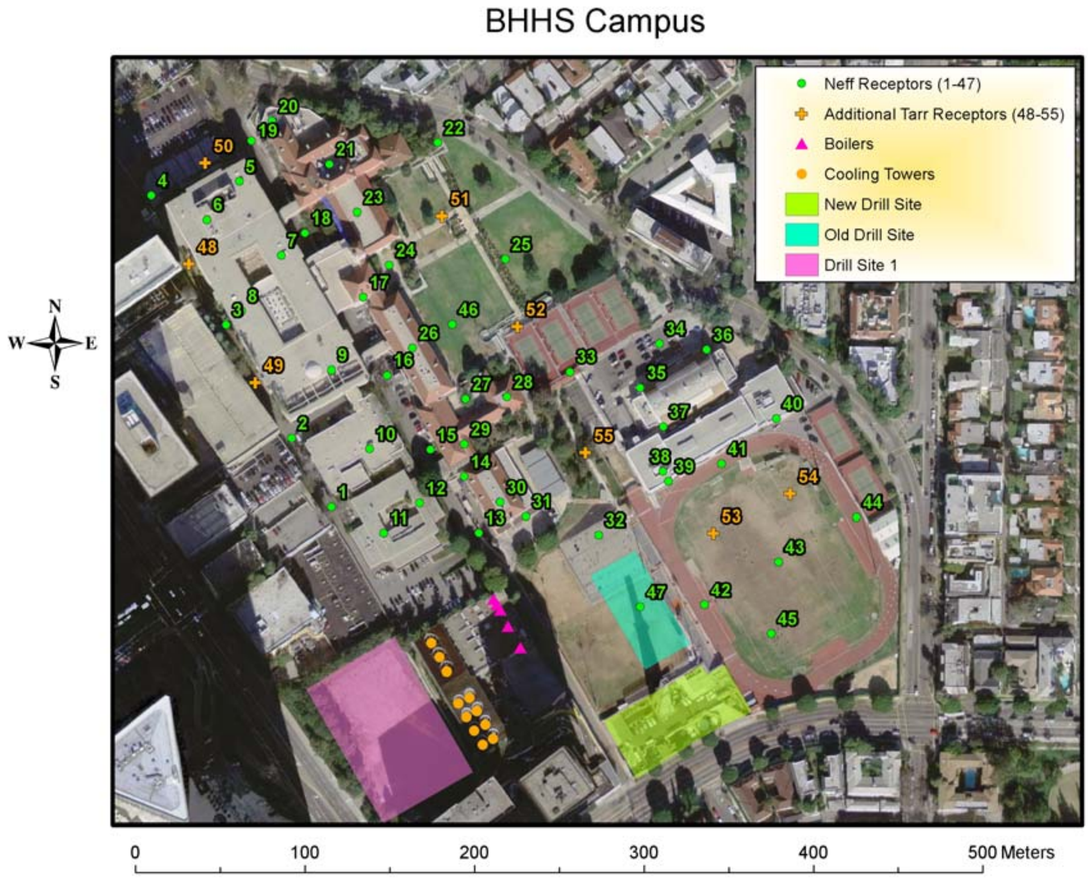

Figure 2-2: Map of Beverly Hills High School (BHHS) showing location of facilities along with 47 receptors used by Dr. Neff to calculate concentrations in his wind tunnel simulations.

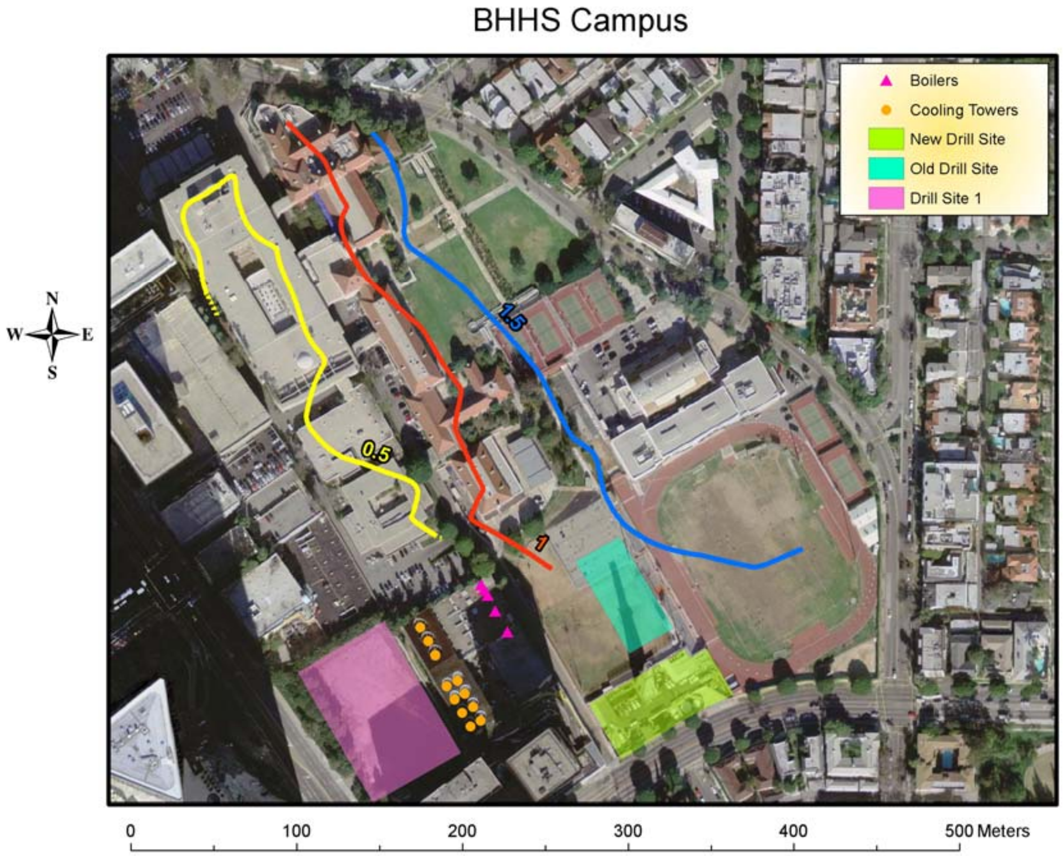

Figure 2-3: Contours of the correction factors applied by Mr. Tarr for emissions from the Cooling Towers for 1985.

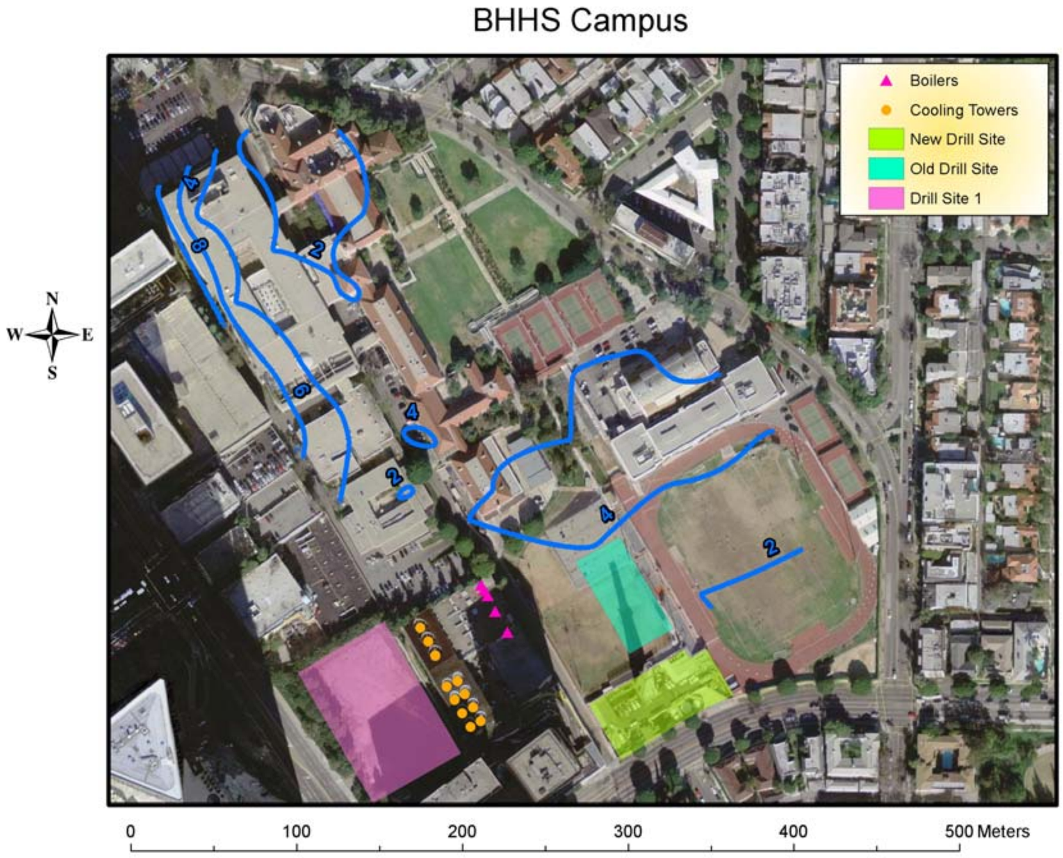

Figure 2-4: Contours of the correction factors applied by Mr. Tarr for emissions from the Boilers for 1985.

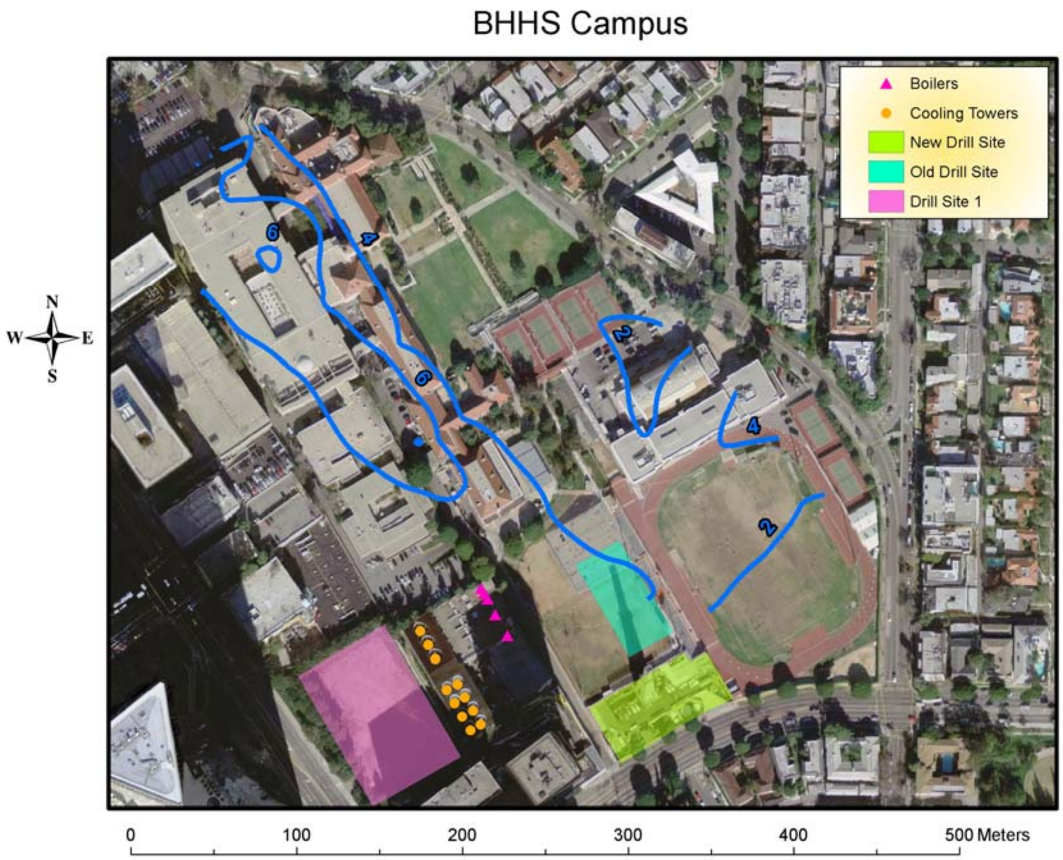

Figure 2-5: Contours of the correction factors applied by Mr. Tarr for emissions from the New Drill Site for 1985.

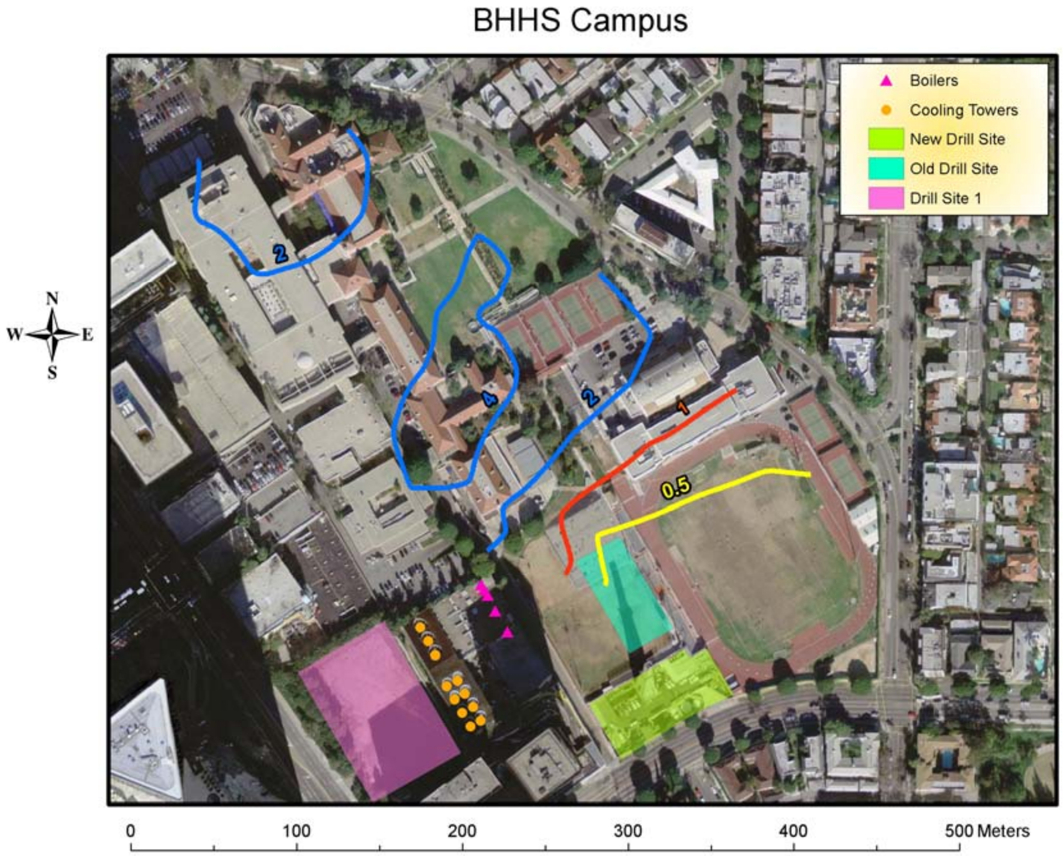

Figure 2-6: Contours of the correction factors applied by Mr. Tarr for emissions from Drill Site #1 for 1985.

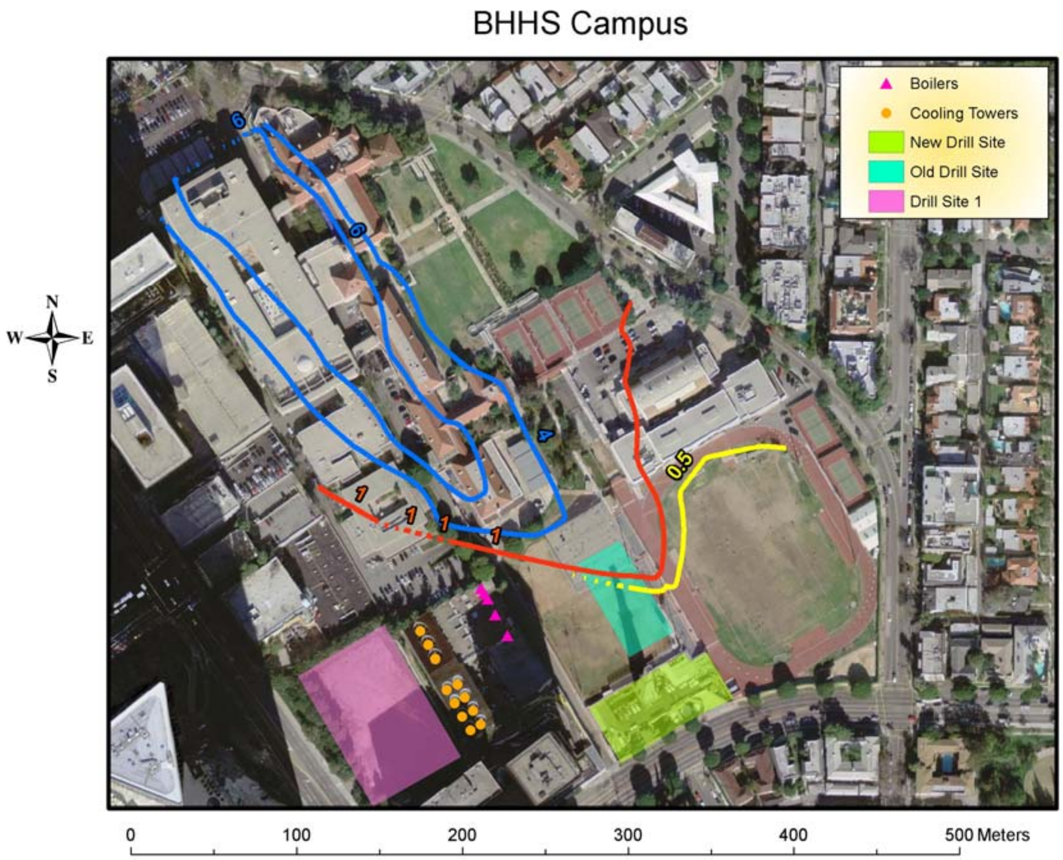

Figure 2-7: Contours of the correction factors applied by Mr. Tarr for emissions from the Old Drill Site for 1975.

Table 2-1: Long-term average concentrations computed by Dr. Neff from data resulting from his wind tunnel experiment. Concentrations are shown for emissions from each defendant facility and at each of the 47 measurement receptors Dr. Neff specified on the Beverly Hills High School portion of Dr. Neff's physical model table. See Figure 2-1 for locations of these receptors. This table was taken from Table 39 of Dr. Neff's Study II, referenced in Footnote 9 (Section 2.2) of this report.

Parsed Annual Averaged Concentration Summary

Receptor	Cooling Towers						Boilers						Old Drill Site		New Drill Site				Drill Site #1		
Number	1975	1980	1985	1990	1995	2000	1975	1980	1985	1990	1995	2000	1975	1980	1985	1990	1995	2000	1975	1980	1985
1	0.53	0.59	0.32	0.35	0.37	0.41	8.72	9.08	4.47	4.33	6.20	3.25	4.0	3.7	13.6	13.5	13.3	8.1	9.2	9.0	17.3
2	0.34	0.38	0.26	0.29	0.27	0.36	3.54	3.79	2.71	2.81	1.81	1.69	10.1	10.1	10.8	10.7	11.1	6.6	4.0	3.8	4.7
3	0.34	0.37	0.21	0.21	0.25	0.23	4.84	4.98	2.92	2.89	2.30	1.91	5.1	5.0	7.3	7.2	7.1	4.2	3.3	3.4	3.2
4	0.20	0.22	0.18	0.18	0.22	0.20	1.72	1.97	2.27	2.32	1.80	1.50	5.8	6.8	5.4	5.4	5.5	3.3	1.2	1.2	1.8
5	0.22	0.24	0.15	0.16	0.16	0.20	0.62	0.68	0.73	0.75	0.39	0.46	8.8	10.3	3.9	4.0	4.6	2.7	0.9	0.8	1.0
6	0.22	0.25	0.15	0.15	0.16	0.19	1.20	1.32	1.30	1.32	0.68	0.72	9.7	10.9	5.5	5.5	6.0	3.5	1.3	1.2	1.3
7	0.27	0.30	0.20	0.20	0.20	0.26	0.66	0.72	0.76	0.78	0.39	0.51	13.3	15.4	5.5	5.6	6.4	3.8	1.4	1.2	1.5
8	0.29	0.32	0.17	0.18	0.19	0.24	2.41	2.62	2.09	2.13	1.24	1.31	10.5	11.0	7.8	7.9	8.3	4.9	2.3	2.1	2.2
9	0.33	0.38	0.32	0.35	0.29	0.45	1.30	1.45	1.68	1.80	0.83	1.22	20.9	22.5	10.8	10.9	11.7	7.1	3.0	2.7	4.9
10	0.37	0.43	0.51	0.58	0.42	0.67	2.36	2.56	2.54	2.83	1.32	1.92	28.1	28.2	17.3	17.4	18.3	11.1	4.6	4.3	8.9
11	0.49	0.55	0.37	0.43	0.38	0.55	7.43	7.69	4.53	4.43	3.43	2.46	7.1	6.6	20.0	19.9	19.9	12.2	10.9	10.5	19.5
12	0.49	0.53	0.70	0.78	0.54	0.93	3.31	3.48	2.89	3.20	1.53	2.39	29.6	28.8	23.5	23.5	24.6	15.2	9.0	8.7	15.6
13	1.14	1.30	2.68	2.86	1.95	3.37	3.04	3.46	9.92	11.05	3.96	6.86	110.3	113.9	32.8	32.8	35.0	22.2	13.8	13.5	18.7
14	0.79	0.86	1.66	1.77	1.23	2.07	1.87	2.04	5.67	6.35	2.43	4.10	90.1	94.4	24.8	24.9	26.7	16.7	10.0	9.7	15.0
15	0.58	0.64	1.09	1.17	0.81	1.36	1.69	1.82	3.62	4.06	1.67	2.74	63.4	65.7	23.8	23.8	25.4	15.7	7.6	7.3	11.9
16	0.39	0.43	0.49	0.52	0.41	0.65	0.99	1.06	1.39	1.53	0.71	1.21	32.7	35.0	13.4	13.6	14.7	9.0	3.7	3.4	6.2
17	0.39	0.42	0.36	0.36	0.30	0.46	0.69	0.73	0.63	0.66	0.41	0.71	21.1	23.0	6.5	6.6	7.5	4.8	2.4	2.2	3.1
18	0.31	0.33	0.27	0.26	0.25	0.32	0.62	0.66	0.41	0.40	0.25	0.37	20.4	23.1	6.9	7.1	8.0	5.0	1.1	1.0	1.3
19	0.22	0.24	0.20	0.20	0.19	0.23	0.39	0.42	0.28	0.28	0.19	0.26	12.7	14.5	4.3	4.4	5.2	3.3	0.5	0.5	0.6
20	0.23	0.25	0.22	0.21	0.20	0.24	0.28	0.29	0.23	0.22	0.16	0.21	3.6	3.8	1.8	1.9	2.3	1.7	0.5	0.5	0.6
21	0.29	0.30	0.30	0.27	0.25	0.31	0.33	0.34	0.30	0.28	0.19	0.27	4.2	4.5	1.9	2.0	2.5	1.9	0.9	0.8	0.9
22	0.39	0.41	0.54	0.45	0.40	0.55	0.38	0.41	0.60	0.50	0.35	0.57	2.8	2.9	1.6	1.6	1.8	1.7	1.3	1.1	1.7
23	0.35	0.37	0.38	0.34	0.31	0.39	0.39	0.41	0.40	0.37	0.25	0.38	5.6	6.1	2.2	2.3	2.8	2.2	1.4	1.3	1.4
24	0.46	0.49	0.58	0.51	0.45	0.64	0.53	0.57	0.79	0.76	0.49	0.89	8.9	9.9	3.1	3.2	3.9	3.0	2.2	2.0	3.0
25	0.58	0.63	0.77	0.67	0.57	0.94	0.70	0.75	1.13	1.02	0.72	1.42	3.9	4.1	2.3	2.3	2.5	2.5	2.5	2.3	3.3
26	0.45	0.48	0.54	0.54	0.45	0.67	0.62	0.65	1.02	1.07	0.70	1.20	17.4	20.2	5.5	5.7	6.8	4.5	3.3	3.1	4.7
27	0.59	0.63	0.91	0.88	0.70	1.08	0.83	0.89	1.97	2.10	1.14	2.02	27.9	32.7	7.7	7.9	9.4	6.3	5.0	4.7	7.5
28	0.76	0.83	1.24	1.17	0.94	1.49	1.15	1.26	2.69	2.81	1.65	3.02	25.4	28.9	6.5	6.8	7.9	5.9	5.2	5.0	7.2
29	0.66	0.73	1.33	1.31	0.97	1.57	1.12	1.25	3.63	3.92	1.87	3.33	60.6	68.4	11.8	12.0	13.7	9.2	7.1	6.8	10.3
30	1.23	1.36	2.46	2.53	1.81	3.06	2.84	3.09	8.77	9.57	4.02	7.47	85.2	91.2	19.3	19.4	21.6	14.1	10.9	10.7	14.0
31	1.84	1.98	3.63	3.77	2.80	4.64	5.26	5.64	14.10	15.23	6.29	12.24	166.1	178.8	25.0	25.2	28.1	19.4	11.7	11.5	13.7
32	2.63	2.67	4.33	4.44	3.59	5.73	6.34	6.50	14.35	15.05	7.98	14.86	300.8	322.0	21.0	21.4	24.7	20.0	7.7	7.6	8.4
33	1.08	1.14	1.44	1.34	1.12	1.99	1.80	1.92	3.08	3.05	2.15	4.35	12.2	13.0	4.3	4.4	4.9	4.6	4.4	4.3	5.4
34	1.10	1.13	1.30	1.22	1.06	1.89	1.79	1.86	2.72	2.68	2.13	4.00	3.6	3.5	2.6	2.5	2.6	2.9	3.4	3.4	4.0
35	1.44	1.48	2.00	1.94	1.61	2.78	2.83	2.93	5.30	5.42	3.51	6.68	6.5	6.4	4.0	3.8	4.2	4.3	4.8	4.8	5.8
36	1.27	1.26	1.55	1.47	1.32	2.36	1.96	2.04	3.18	3.15	2.42	4.39	3.1	3.0	2.9	2.7	3.0	3.5	3.0	3.0	3.7
37	1.63	1.66	2.29	2.24	1.85	3.16	3.46	3.57	6.26	6.44	4.17	7.72	7.3	7.1	4.5	4.3	4.8	4.9	5.0	5.0	5.9
38	2.09	2.11	3.14	3.13	2.62	4.29	4.47	4.63	8.93	9.26	5.59	10.00	11.6	11.1	7.5	7.3	8.4	8.5	5.4	5.4	6.4
39	2.76	2.75	4.09	4.14	3.56	5.48	5.23	5.29	10.06	10.49	6.70	10.94	16.0	15.3	12.1	11.7	14.0	14.0	5.0	5.1	6.1
40	2.34	2.35	3.43	3.49	3.07	4.65	4.10	4.20	6.99	7.31	5.21	7.98	8.0	7.8	9.4	9.2	11.1	11.9	3.7	3.8	4.6
41	2.60	2.59	3.86	3.92	3.39	5.18	4.88	4.95	8.91	9.29	6.20	9.80	10.5	10.1	11.7	11.2	13.3	13.9	4.5	4.5	5.4
42	3.98	3.68	5.02	5.15	4.40	6.43	8.78	7.66	9.55	9.93	7.57	10.94	63.0	57.8	54.0	53.0	64.0	63.4	5.1	5.0	5.8
43	2.89	2.78	4.07	4.19	3.68	5.21	5.41	5.09	7.13	7.43	6.15	8.43	13.0	12.2	23.9	23.8	29.3	31.0	4.0	4.0	4.6
44	2.30	2.25	3.38	3.49	3.13	4.29	3.95	3.83	5.67	5.92	4.95	6.56	8.0	7.7	14.6	14.5	18.4	19.3	3.1	3.1	3.9
45	3.28	2.92	3.72	3.83	3.36	4.51	6.75	5.59	6.02	6.19	5.59	7.05	20.6	19.0	39.6	39.2	49.4	51.9	3.8	3.6	3.9
46	0.56	0.60	0.73	0.66	0.55	0.86	0.73	0.78	1.23	1.21	0.83	1.54	11.8	13.1	3.6	3.8	4.6	3.6	3.2	3.0	4.7
47	5.07	4.72	6.01	6.17	5.23	7.80	15.64	13.45	15.55	16.09	10.29	16.46			89.4	89.5	101.5	79.7			7.6
max=	**5.1**	**4.7**	**6.0**	**6.2**	**5.2**	**7.8**	**15.6**	**13.4**	**15.5**	**16.1**	**10.3**	**16.5**	**300.8**	**322.0**	**89.4**	**89.5**	**101.5**	**79.7**	**13.8**	**13.5**	**19.5**

Annual averaged (school hours only)

all values are micrograms/m^3 given a source strength of 1.0 gm/s

3 Winds in the Western Los Angeles Basin

The Los Angeles Basin covers an area of Los Angeles County from coastal metropolitan Los Angeles to the San Gabriel Mountains in the northeastern interior of the county. BHHS is located in the western part of the Los Angeles Basin. The Pacific Ocean is the primary moderating weather influence in this area due to the prevalence of sea breezes, which blow roughly southwest to northeast across the western LA Basin and give rise to mild temperatures in the area. This ocean-moderated air, often called a “marine-layer”, can extend several miles inland from the coast. In the eastern and northeastern portions of the LA Basin, where the influence of the marine layer is much smaller, temperatures are often considerably warmer during day and colder at night than closer to the coast. Storms off the Pacific Ocean affect the LA Basin predominantly during winter months. These storms are responsible for most of the annual precipitation in the area[47].

The Los Angeles metropolitan area is one of the most heavily air polluted regions of the United States. This is due to its large population, and hence large mobile-source and industrial emissions, and relatively mild weather conditions, which inhibit dilution of the emitted pollutants with cleaner air aloft. The presence of a temperature inversion, usually at roughly half a kilometer above the surface, also acts as a “lid” inhibiting dilution of pollution with cleaner air above the inversion[48]. Furthermore, the large amount of sunlight in the area promotes the development of photochemical smog[49]. Automobile emissions are the predominant source of most of the major air pollutants (or their precursors) found in the Los Angeles area[50].

The following discusses specific aspects of the wind in the area important to the study of emissions onto BHHS from facilities operated by the defendants.

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47 See http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?WWDI~StnSrch~CallSign~LAX#ABOUT for further details.

48 A temperature inversion is a portion of the atmosphere where temperature increases with height.

49 Photochemical smog is a generic name for several pollution species that only form in the presence of sunlight. The most well known of these species is ozone.

50 See http://www.arb.ca.gov/aqd/almanac/almanac05/almanac05.htm.

BHHS is located in the Los Angeles Basin roughly seven miles inland from the closest point along the Pacific Ocean (Figure 3-1). Immediately to the west of BHHS are the large towers associated with Century City[51], most of which built in the early to mid-1970s. Because of the regularity of daytime sea breezes during most of the year in the Los Angeles Basin, the wind most frequently blows, in a general sense, from southwest to northeast across the basin during the day. Therefore, before the airflow hits BHHS it must first travel across the roughly seven-mile section comprising Santa Monica and West Los Angeles, and then over and between the large buildings associated with Century City.

The passage of the wind over and between these buildings causes increased turbulence (or gustiness) in the airflow. It also causes increased variability from hour-to-hour in the wind direction such that its southwest-to-northeast tendency upwind of the buildings is less exhibited at BHHS. This increased turbulence and wind direction variability causes strong lateral dispersion of emitted species across the campus. In Section 4, we illustrate this through inspection of wind measurements taken on the campus.

The purpose of this section, on the other hand, is to investigate the wind before it hits the buildings, i.e., in the area upwind of Century City. We will call this the "approach flow". To study this, we will look at winds measured regularly over several years at four stations: Los Angeles International Airport (LAX), Santa Monica Airport (SMA), Santa Monica CIMIS (SMC) and West Los Angeles (WSLA). These stations are plotted in Figure 3-1. Particularly, we will investigate the extent to which winds at LAX represent those at the other three stations, which are all closer to BHHS. This will give an indication of the extent to which winds at LAX, which is the station for which the longest history of meteorological measurements exists in the Los Angeles area, represent those in the area around BHHS.

51 www.centurycitycc.org/community/history.htm

Wind roses for the four stations are shown in Figure 3-2 through Figure 3-5[52]. The LAX wind rose is for hourly measurements over roughly the last 20 years, while those for SMA, SMC and WSLA are for hourly measurements over roughly the last five years. In each, only measurements during the hours 8 AM – 4 PM are plotted.

For LAX, the winds are predominantly out of the west-southwest, which is an indication of the prevailing sea breeze. The average speed is approximately 9 knots.

The winds at SMA and SMC also exhibit the sea breeze in that they both show roughly a southwest direction. The wind, however, is more frequently from the southwest rather than west-southwest, the latter being the case at LAX. In addition, the average speed of the two stations is around 6 knots, which is smaller than at LAX.

The WSLA winds exhibit notable differences from those at the three stations just discussed. The average speed is smaller, around 4 knots. The average wind direction is from the south-southwest rather than southwest (SMA and SMC) or west-southwest (LAX), and furthermore exhibits much stronger variability around the prevailing direction than what was exhibited at the other three stations.

Based on this, the winds in portions of the western Los Angeles Basin closer to BHHS are slower than at LAX. Depending on the measurement location within this West Los Angeles area, the prevailing wind direction can be anywhere in the SSW to W sector and exhibit much more variability around the prevailing direction than exhibited at near-coastal locations.

[52] A wind rose is a graphical depiction of how frequently the wind blows at a certain speed and from a certain direction. The length of each "petal" of the "rose" is proportional to the frequency of occurrence of the wind blowing from the direction to which the petal points. An individual petal is broken into sub-segments depicting the frequency of occurrence of the wind blowing within certain ranges of speeds.

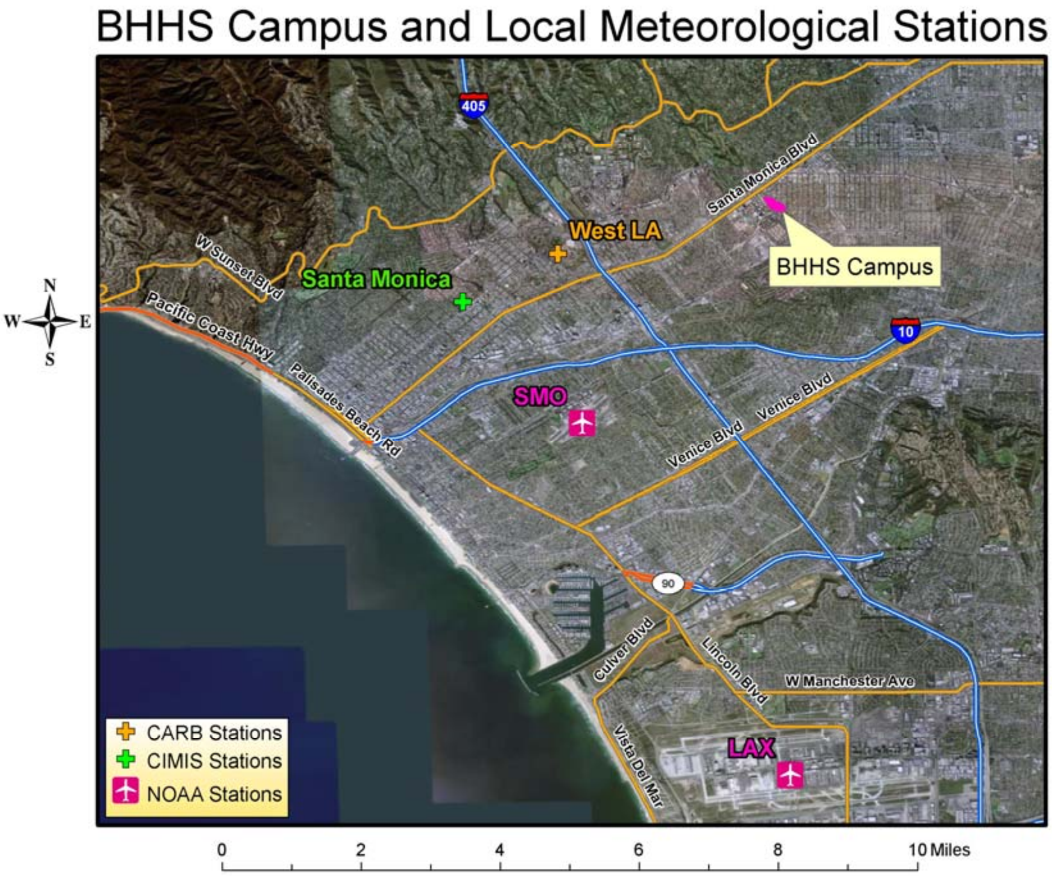

Figure 3-1: Location of meteorological stations in the western Los Angeles Basin relative to Beverly Hills High School campus.

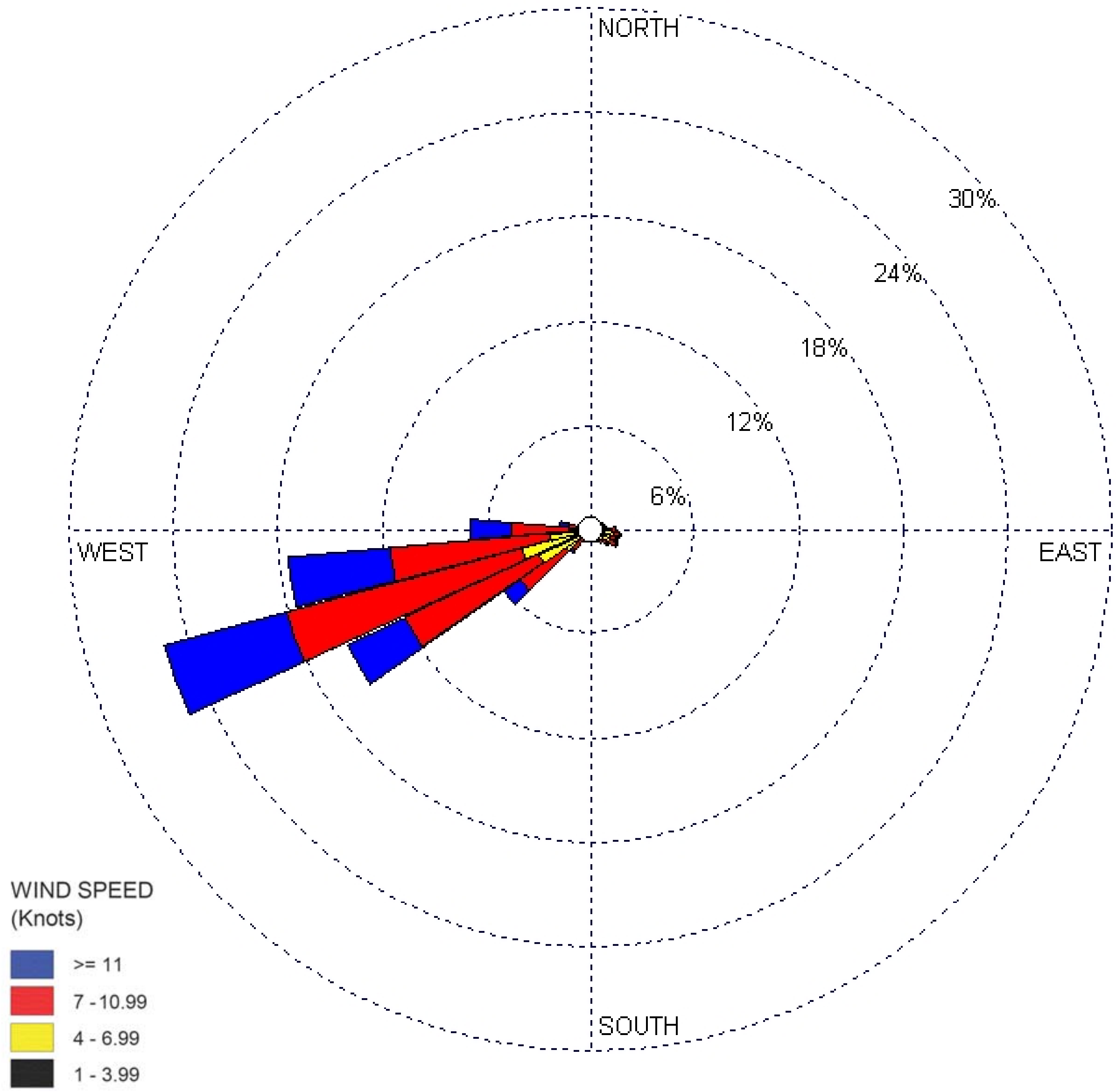

Figure 3-2: Wind rose for Los Angeles International Airport for 20 years of hourly wind data. Data are for hours 8 AM – 4 PM during the period Dec. 1, 1985 – Nov. 30, 2005. Average speed = 9.08 knots, % calms = 2.64%.

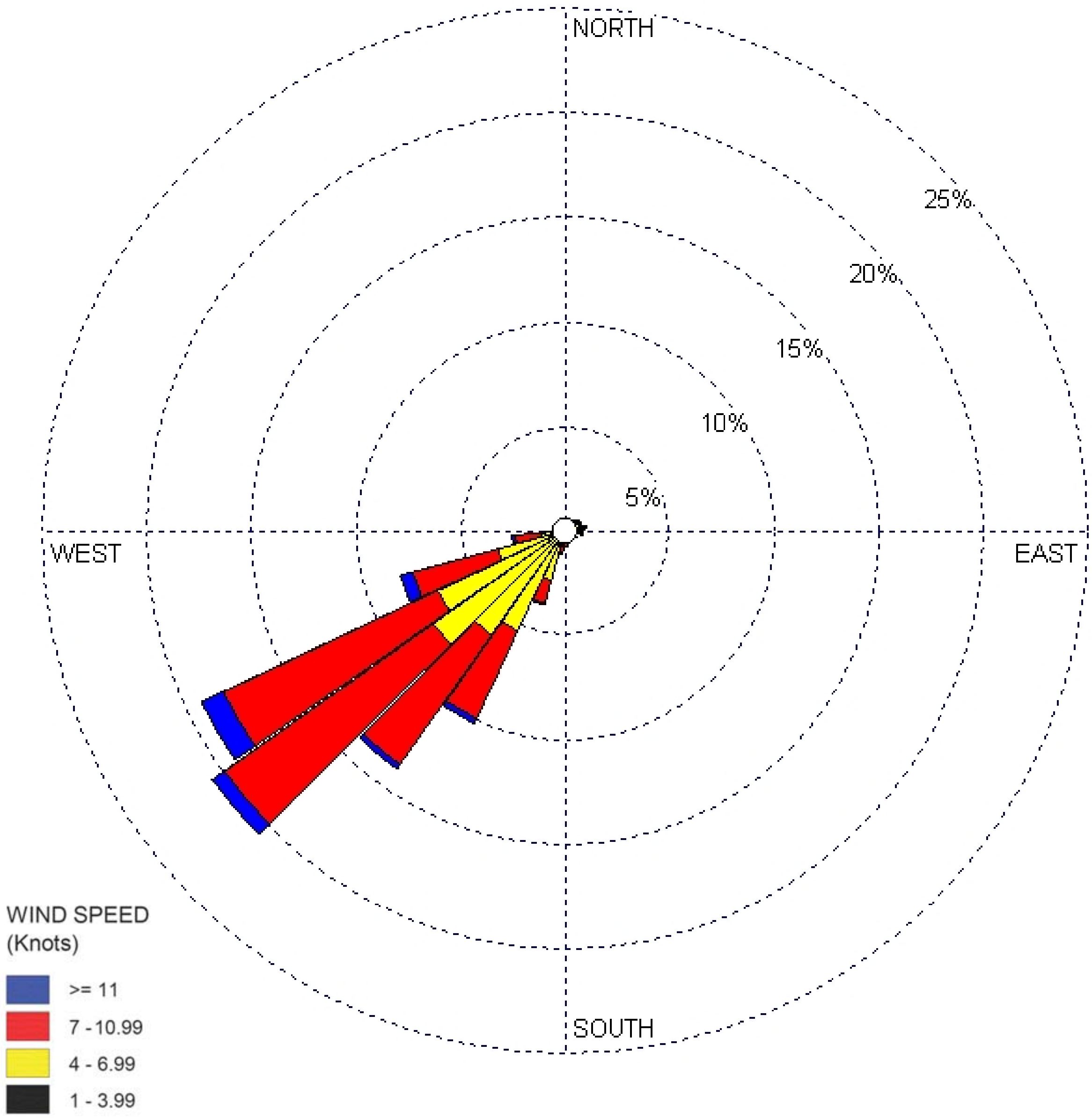

Figure 3-3: Wind rose for Santa Monica Airport for 5 years of hourly wind data. Data are for hours 8 AM – 4 PM during the period Dec. 1, 2000 – Nov. 30, 2005. Average speed = 7.16 knots, % calms = 6.19%.

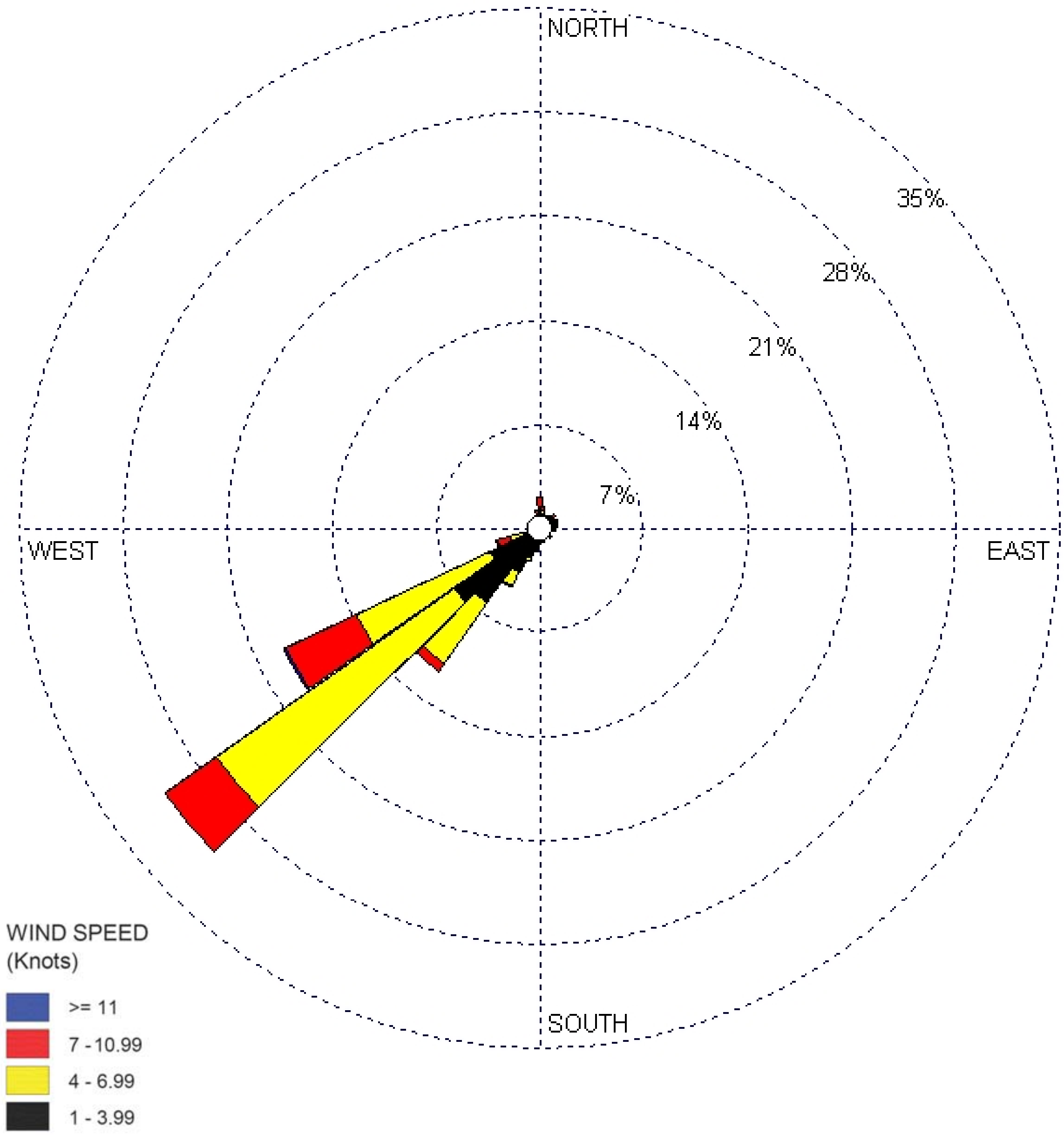

Figure 3-4: Wind rose for Santa Monica CIMIS for approximately 5 years of hourly wind data. Data are for hours 8 AM – 4 PM during the period Sept. 1, 2000 – Sept. 30, 2005. Average speed = 5.02 knots, % calms = 0.35%.

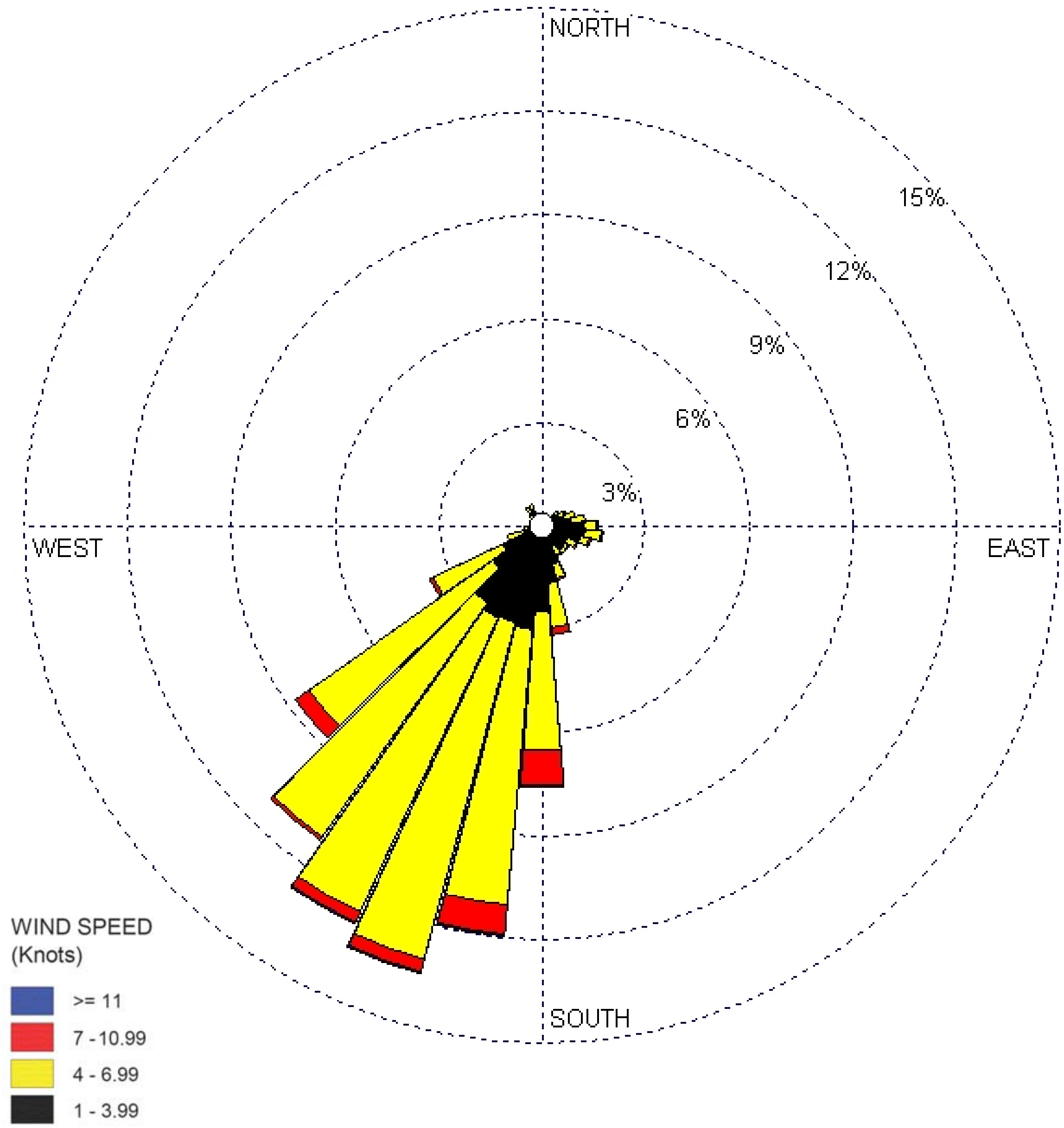

Figure 3-5: Wind rose for West Los Angeles for approximately 5 years of hourly wind data. Data are for hours 8 AM – 4 PM during the period Jan. 1, 2001 – Nov. 30, 2005. Average speed = 4.17 knots, % calms = 7.31%.

4 Examination of the Tracer Experiment

This section provides a review of the Tracer ES&T field experiment conducted from February 25 to April 30, 2005 at BHHS in Beverly Hills, CA[53]. The study was performed to quantitatively determine the transport and dispersion characteristics of air originating from the alleged source facilities adjoining the BHHS campus at various receptors within the school buildings and on the school grounds. This was carried out by releasing passive tracer material from release sites corresponding to these sources and measuring the tracer concentration at these receptors. We used these experimental data (over 13,000 valid data points for atmospheric dispersion and over 53,000 valid data points of meteorological parameters) to develop our modeling approach to estimate ambient pollution exposure resulting from these facilities. In the remainder of this report, we will simply refer to this field experiment as the “tracer experiment”.

The tracer release sites, concentration measurement receptors and meteorological measurement towers employed for the experiment are shown in Figure 4-1. Also shown are the locations of the defendant source facilities. The tracer releases associated with the New Drill Site and Drill Site #1 were line sources located close to the actual drill sites, while the releases associated with the Boilers and Cooling Towers were at the true sources, with tracer injected into one of the Boiler stacks and within the Cooling Tower air flow. No tracer release site was included to estimate concentrations resulting from emissions from the Old Drill Site.

4.1 Background

When a pollutant is released into the atmosphere it undergoes dispersion before it is detected at a receptor as a concentration, which is expressed as mass per unit volume (e.g., micrograms per meter cube, $\mu g/m^3$). This dispersion is caused by complicated atmospheric flows that distort and stretch the air mass carrying the pollutant. These “turbulent “flows are so complicated that they can often only be described in terms of their statistics: mean and standard deviations of the velocities.

[53] “Beverly Hills High School Atmospheric Dispersion Study”, Tracer Environmental Sciences and Technologies, Inc., Project No. TS-1702, 2005.

Starting conceivably from the pioneering work by Taylor (1921)[54], the laws of atmospheric diffusion have been well studied by the scientific community in the last 80 years. It was quickly recognized that the dispersion rates of chemicals in the atmosphere were quite different from the well-known molecular dispersion rates of gases. In fact, it was clear that atmospheric dispersion rates of gases were orders of magnitude higher than the molecular ones, since atmospheric diffusion was dominated by turbulence.

It was also clear that scientists did not possess a theory or a methodology to calculate turbulent diffusion rates and field studies were needed to estimate – empirically – the actual values of diffusion rates in the atmosphere. These field studies are called tracer studies. They typically involve a release of a known quantity of a gas not present in the atmosphere (e.g., SF_6) and the measurement of the concentrations of the released gas at different downwind distances under different meteorological conditions. From these measurements, actual average dispersion rates can be derived for each set of meteorological conditions. A classical tracer dispersion study of particular historical significance is the Prairie Grass Project conducted during July-August 1956 in a wheat field near O'Neil, NE[55,56]. This study provided a first set of dispersion rates, which are still used today. Since Prarie Grass, several other tracer studies have taken place in the US and throughout the world.

The dispersion rates resulting from tracer experiments are one of the most important parameters in today's air pollution models. Air pollution models are computational techniques that are routinely used today to assess the ambient concentration impact of virtually any type of atmospheric source (past, current, and future emissions). Since the 1970s, air pollution modeling techniques have been recognized and approved by the US EPA as reliable tools for emission

54 Taylor, G.I. (1921) Diffusion by continuous movements. Proceedings, London Math. Soc., 20: 196-211. Theories of dispersion in the atmosphere (Taylor, 1921) depict dispersion of pollutants released from a point source in terms of a plume with an elliptical cross-section. The growth of the horizontal and vertical dimensions of the plume as a function of the distance from the point source can be related to the statistics of the turbulent flow in which it is embedded. Knowledge of plume dimensions and the associated transport velocity allows one to estimate ground-level concentrations.

55 Project Prairie Grass. A Field Program in Diffusion. AFCRC-TR-58-235. Vol I and II.

56 Project Prairie Grass. A Field Program in Diffusion. AFCRC-TR-58-235. Vol III.

permit applications, regulatory compliance, environmental assessments, and emergency preparedness and response[57].

The reason models are needed to calculate air pollution dispersion rates is because it would be too expensive to perform a tracer experiment for each source of interest for a duration long enough to cover all the relevant meteorological scenarios. Therefore, tracer experiments are used to extract generic, semi-empirical dispersion rates (e.g., called "sigma" functions for Gaussian models) to be used later by the models in any arbitrary application. However, it must be emphasized that a tracer experiment is a precise characterization of atmospheric diffusion at a particular location – it depicts the "real world" – while models always give computational and approximate representations that are simplifications of reality. In other words, the problem with using empirical dispersion rates derived from a tracer experiment is that – in theory – they are strictly applicable only to situations similar to the experiment that was used to derive them. For example, the Pasquill-Gifford (named after the people who derived them) sigma functions[58] apply primarily to the relatively smooth flat terrain conditions of O'Neill, NE, and then only for surface releases that mimic those of the O'Neill tracer experiment. These functions have been modified and applied to other conditions, but the estimated concentrations can be uncertain. That is why a new set of tracer experiments were conducted in St. Louis, MO (McElroy and Pooler, 1968[59]) to derive sigma functions applicable to near surface releases in urban areas with tall buildings[60].

These considerations are important in the context of this project because a comprehensive tracer experiment *was* performed for the site of interest (BHHS), covering all the major sources of interest, for a duration of about two months around BHHS. This tracer study therefore gives us a unique data set of dispersion rates that describe the "real world" of atmospheric diffusion in the

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57 U.S. EPA (1986) Guideline on Air Quality Models. EPA-450/4/-80-023R.

58 Gifford, F. A., 1976, "Consequences of effluent release", Nuclear Safety, 17(1).

59 McElroy, J. L, and J. Pooler, 1968, "St. Louis dispersion study. Volume II". Publication AP-53, 51. U.S. Department of Health, Education, Welfare.

60 It should be noted, however, that the turbulence intensity measurements (sigma-theta) performed at BHHS during the tracer experiment are about four times the maximum value measured over the top of buildings under highly turbulent conditions in St. Louis (see Venkatram, 2005, Atmospheric Environment, Vol 39, No.21 pp. 3813-3822, July).

area of interest. Therefore, these tracer data represent the most accurate and scientifically reliable set of information that we can use to calculate the long-term concentration impact (annual averages) due to the sources in the area.

In mathematical notation, an air pollution model is a computer program that calculates – typically for each hour, each source, and each receptor – the ambient air pollution (concentration χ – mass over volume) caused by a specific source (emission Q – mass over time) as

$$\chi = Q \bullet D$$

Here, D is the dispersion factor, which is a function of the meteorology and is calculated by the model according to its internal sigma functions based upon previous tracer experiments in other locations. But if we have the actual measured dispersion factors

$$D = \chi / Q$$

directly provided by a tracer experiment in the region of interest, we already possess valid site-specific information, which is clearly scientific superior to the generic values D that a model internally calculates.

In this study, therefore, we have the unique luxury of having directly the local, site-specific dispersion factors to calculate the concentration impact due to the local sources. Therefore, we do not need to use generic modeling approaches.

The methodology by which we use the tracer measurements to estimate annual average concentrations from the defendant facilities is explained in Section 6.

4.2 Meteorological Analysis

Wind roses over the hours 8 AM – 4 PM of wind measurements taken at the three meteorological stations operating during the tracer experiment are shown in Figure 4-2 through Figure 4-4. These figures show that the flow at BHHS is strongly affected by the tall buildings. Strong variability in wind direction is seen at each of the three stations. Wind roses for measurements taken at Los Angeles International Airport (LAX), Santa Monica Airport (SMA) and the Santa Monica CIMIS station (SMC) for the same period (Figure 4-5 through

Figure 4-7) comparatively show less wind direction variability. Furthermore, even though the three tracer-experiment meteorological sites are very close to each other (within a few hundred yards), their measurements are quite different. We conclude that the typical wind in the BHHS area does not have an organized, steady pattern. We have instead a very complex flow.

The strong lateral turbulence induced by the buildings is exhibited in plots of turbulence parameter sigma-theta in Figure 4-8. Sigma-theta is a statistical parameter measuring the standard deviation[61] of the wind direction from its average value. It is an important parameter for air pollution dispersion because it is a measure of the ability of the flow to laterally disperse pollutants. It is seen that 5-minute sigma-theta is typically around 50 degrees for the sites at BHHS, and often higher in the case of measurements at the Girls Athletic Field. By comparison, 1-hour sigma-theta values at SMC, about 5 miles further west (Figure 3-1) and in an area without adjacent tall buildings, are typically much lower – around 20 degrees – which is consistent with the typical range of variation from 5 to 30 degrees found in the literature[62]. The higher sigma-theta at BHHS is clearly a result of the adjacent tall buildings associated with Century City, and suggests that the BHHS campus is characterized by very high lateral dispersion rates.

Since we will use the dispersion data measured during the tracer experiment as the basis for determining dispersion rates in the past onto BHHS, it is necessary to check how representative the meteorological conditions that existed during the experiment are of what is typical of the Los Angeles area. The LAX wind rose for the approximate two months of the tracer experiment versus that at LAX for the twenty year period December 1985 – November 2005 are shown in Figure 4-5 and Figure 4-9, respectively. In both wind roses, only hours between 8 AM – 4 PM are considered. The similarity indicates that the wind conditions during the two-month tracer

61 The standard deviation is about ¼ of the total range of variation. For example, an average wind from East (i.e., 90 degrees) with a sigma theta of 10 degrees means, approximately, that the instantaneous winds fluctuate from 70 to 110 degrees.

62 Zannetti, P. (1990) Air Pollution Modeling. Van Nostrand Reinhold, Page 148.

experiment represent well those typical of the Los Angeles area. The same correspondence is exhibited in comparing wind roses at SMA for two months versus five years of measurements (

Figure 4-6 and Figure 4-10).

A comparison of "stability class" as computed from LAX meteorology for the two months of the tracer experiment versus five years is shown in

Figure 4-11. Stability class is an input to many pollution models (for example, ISC3) that is used to determine which empirical "sigma" function, and hence how much dispersion, to apply to their hourly concentration calculations. The value of stability class ranges from 'A' ("very unstable", i.e., high dispersion) to 'E' ("very stable", i.e., low dispersion) based on the wind speed, cloud coverage and intensity of solar radiation measured at the site used to compute its value. Similar stability classes therefore indicate similar combinations of above three meteorological variables. Strong similarity between the two months of tracer experiment to those over a longer time period is again exhibited[63].

The meteorological conditions during the time period of the tracer experiment are thus very representative of those typical of the Los Angeles area.

4.3 Tracer Concentration Analysis

Pollution roses of the tracer released from the each of the four release sites are shown in Figure 4-12 through Figure 4-15. These were constructed from pairing meteorological Site M1 with tracer measurement S12, both of which were atop the Administration building and very close to one another. The purpose of the plot is to inspect the expected correlation of measured concentration and wind direction. One can then verify which direction is responsible for the highest concentrations. As seen, the highest concentration is correlated with the direction from source to receptor (Figure 4-1). This provides strong evidence that main source of tracer is the release site rather than from an unknown, unintended location.

[63] See Zannetti, P. (1990) Air Pollution Modeling. Van Nostrand Reinhold, Chapter 3, for further explanation of stability class.

Plots of logarithm of dispersion factor, χ/Q, versus the logarithm of distance (d) from each tracer release site are shown in Figure 4-16 through Figure 4-19**.** One can see good fit to linear regression lines, indicating that variation with distance from the source is the main contributor to the total variation. Lateral variation is less important, on the other hand, due to the large lateral dispersion caused by the buildings. Typical variation of χ/Q, from maximum to minimum, is relatively small – of one order of magnitude (a factor of 10).

Our analysis of the tracer and meteorological data collected during the tracer experiment indicates that the experiment was well conducted. The meteorological data collected at three stations indicate, as expected, large wind velocity variability and strong turbulence.

Our analysis of the pollution roses indicate that the tracer gases travel, as expected, mostly along the main wind direction, and are affected by strong horizontal diffusion and some recirculation features.

As exhibited from wind and stability class comparisons, the two months that were selected for the tracer experiment are very representative of average conditions in the region. This indicates that the two-month average χ/Q values from the tracer experiment represent well the annual average values.

4.4 Comparison with ISCST3 and AERMOD

To further base our decision to make direct use of dispersion factors derived from the tracer experiment, we ran two EPA dispersion models, ISCST3[64] and AERMOD[65], for the time period of the tracer experiment to predict concentrations from the line source PMCP (corresponding to the New Drill Site, see Figure 4-1). For these runs, we assumed a unit emission rate (1 g/s), and therefore the two-month average concentrations produced by the model can be directly interpreted as χ/Q. Only hours between 8 AM – 4 PM were considered in the averages.

64 http://www.epa.gov/scram001/dispersion_alt.htm.
65 http://www.epa.gov/scram001/dispersion_prefrec.htm#aermod.

Average concentrations produced from ISCST3 driven by LAX surface winds compared to those measured during the experiment are shown in Figure 4-20. As seen, the model fails to capture the observed pattern. The plumes are directed from west to east, following the LAX prevailing wind. They are also narrow. The observed concentration pattern, on the other hand, appears to be directed to the north-northeast and exhibits more lateral spread.

Average concentrations produced from ISCST3 driven by on-site hourly-averaged surface winds from meteorological measurement Site M2 (Figure 4-1) are shown in Figure 4-21. The model now better captures the directional orientation of the plume, although the plume is still too narrow.

Finally, the average concentrations produced from AERMOD using winds and sigma-theta measurements from Site M2 are shown in Figure 4-22. AERMOD is currently the preferred model for regulatory use by EPA. Its main advantage over ISCST3 is the ability to better characterize the local dispersion from on-site wind and turbulence inputs. This is especially important in urban areas downwind of tall buildings, since these meteorological inputs are generally very unique to the site. As can be seen, the comparison between the AERMOD predictions and observations is quite good, effectively capturing the broad lateral extent of the plume.

It is thus concluded that a sophisticated model driven by inputs of on-site measured winds and turbulence are critical if one is to use the standard EPA regulatory modeling approach to predict dispersion of air pollutants onto BHHS in the years since around the mid-1970s (when the tall buildings of Century City were completed). Such measurements, however, are not regularly available during these years, and it would be a difficult task to attempt to synthesize these inputs from off-site wind measurements (for example, from LAX winds) during arbitrary time periods in the past. This is another reason, in addition to those mentioned in Section 4.1, why direct use of the tracer dispersion factors is preferable to the use of standard air pollution models for simulating long-term average concentrations at BHHS.

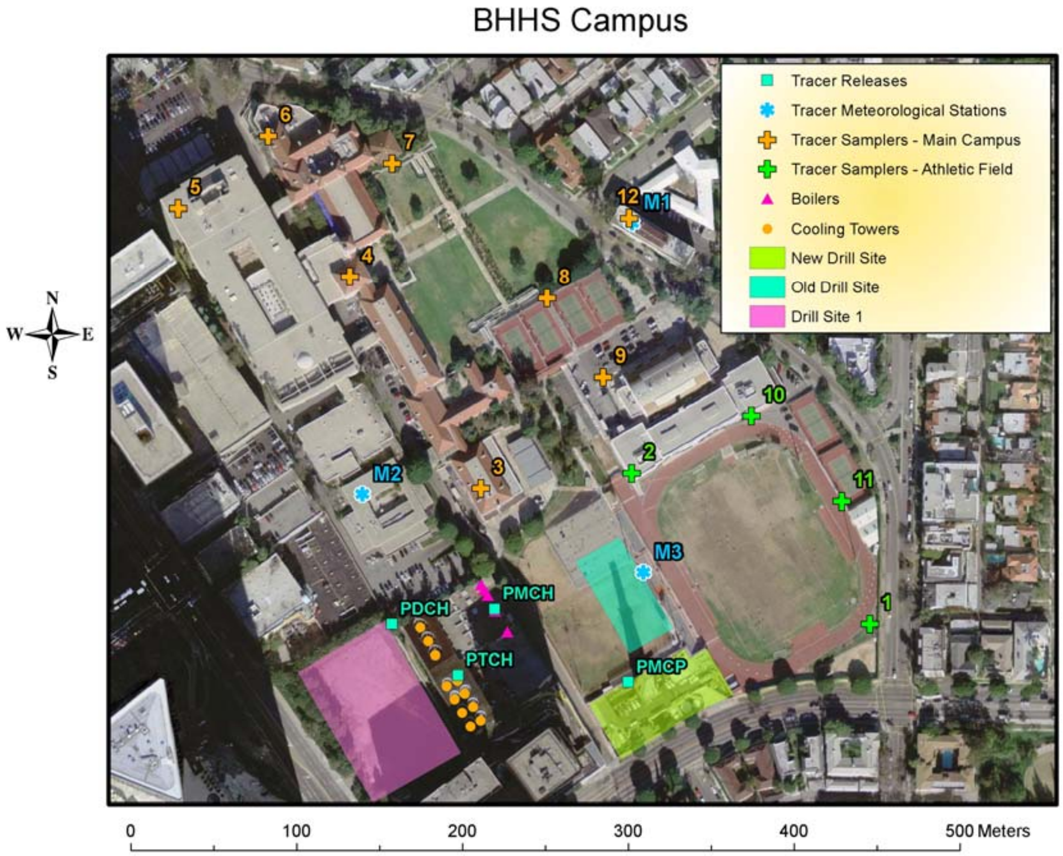

Figure 4-1: Map of Beverly Hills High School along with facilities operated by defendants, tracer experiment release sites, measurement receptors, and meteorological stations.

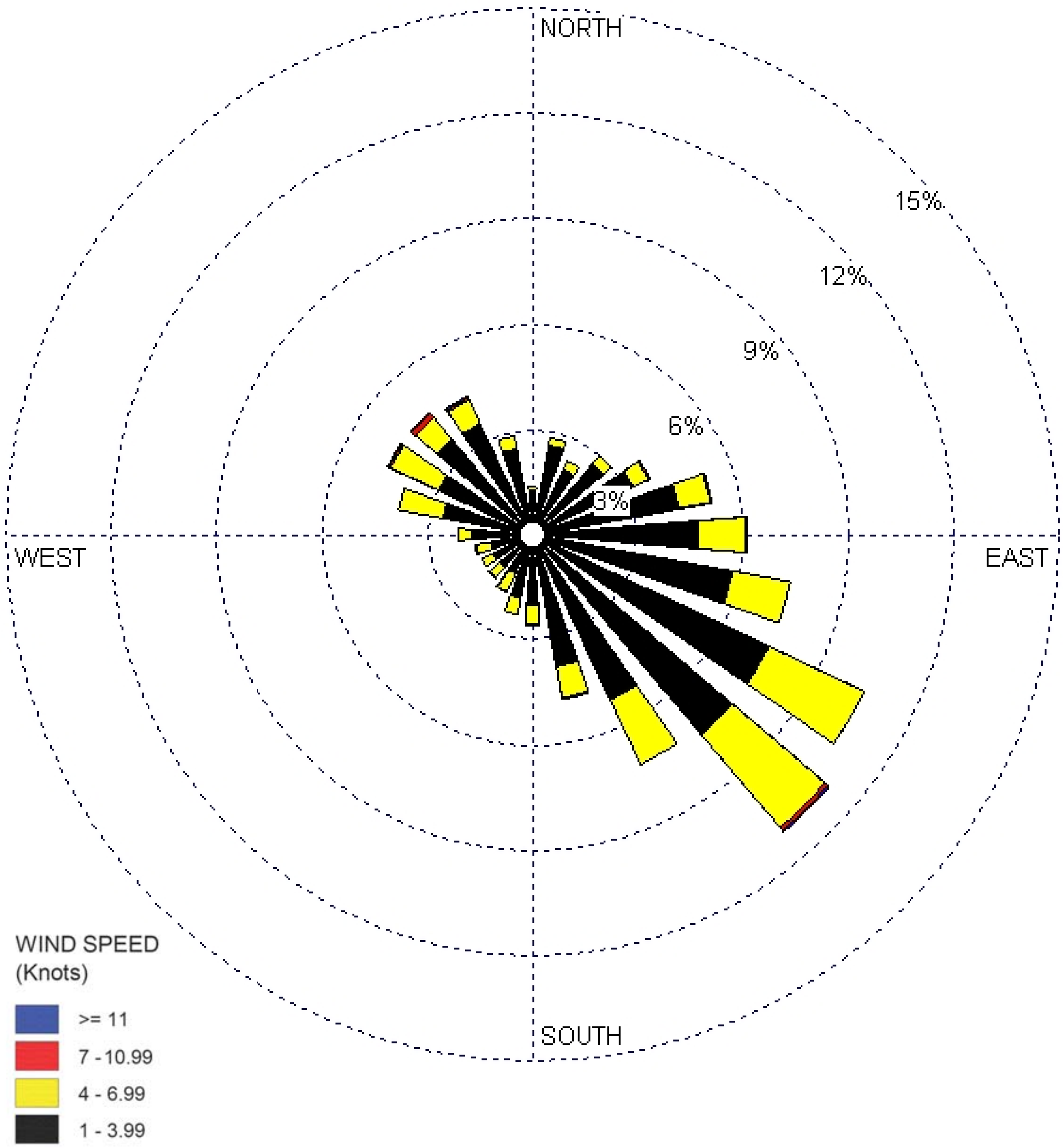

Figure 4-2: Wind rose of 5-minute wind measurements on Beverly Hills High School Girls Athletic Field (Station M3) taken during the tracer experiment. Data are for hours 8 AM – 4 PM during the period Feb. 25 – Apr. 30, 2005. Average speed = 3.62 knots. % calms = 0.39%.

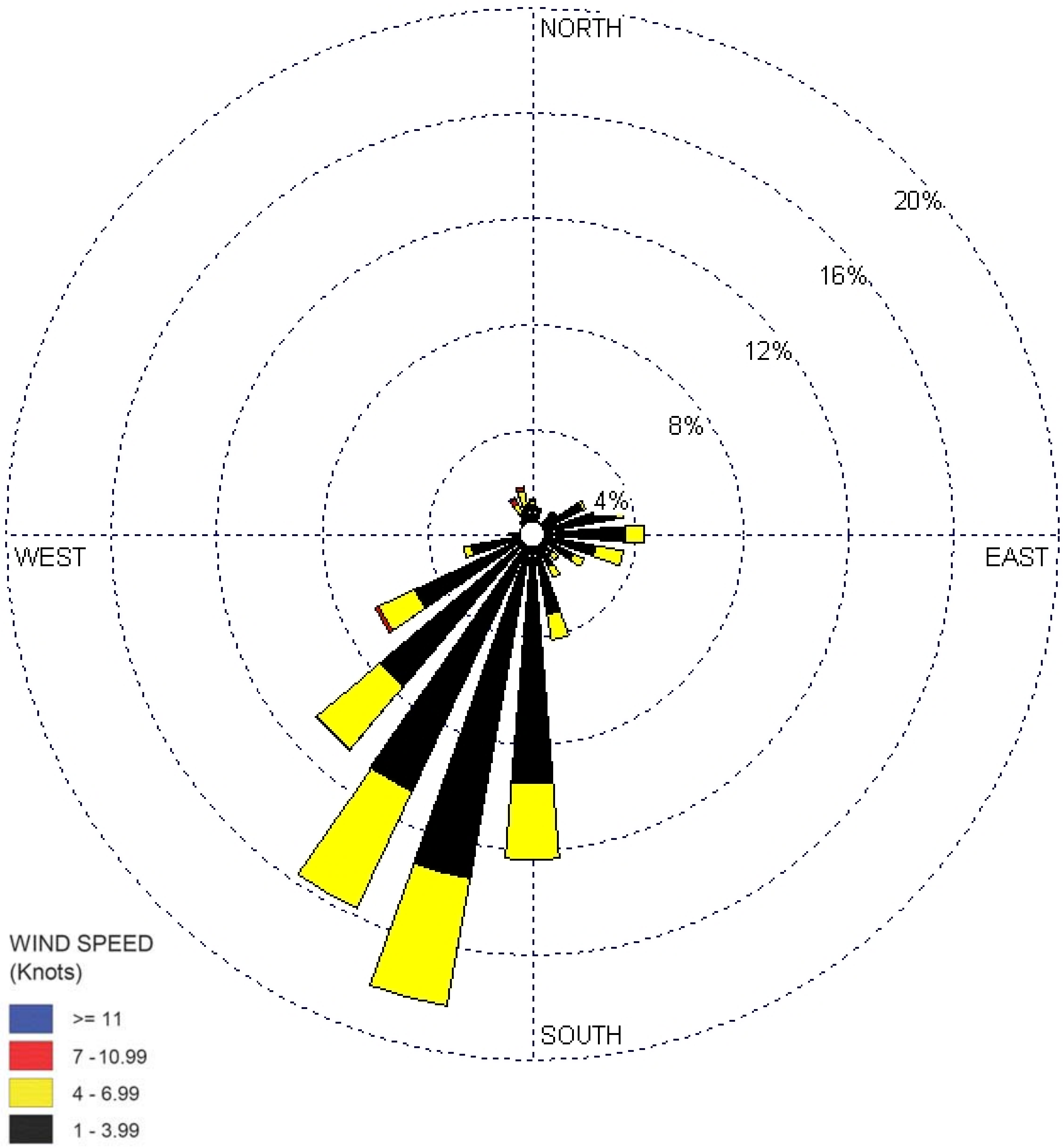

Figure 4-3: Wind rose of 5-minute wind measurements on Beverly Hills High School Building C (Station M2) taken during the tracer experiment. Data are for hours 8 AM – 4 PM during the period Feb. 25 – Apr. 30, 2005. Average speed = 3.50 knots. % calms = 0.74%.

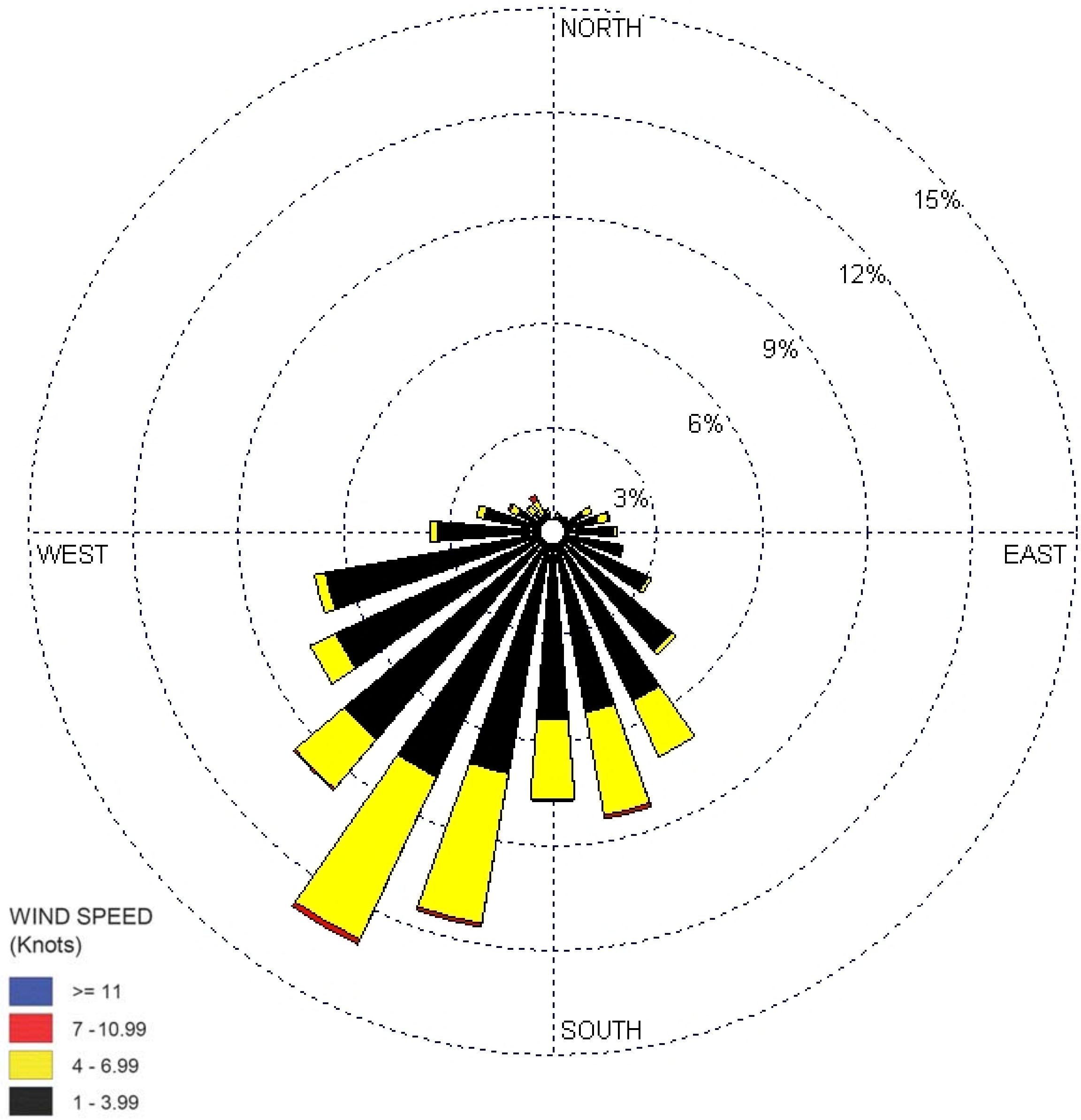

Figure 4-4: Wind rose of 5-minute wind measurements on Beverly Hills High School Administration Building (Station M1) taken during the tracer experiment. Data are for hours 8 AM – 4 PM during the period Feb. 25 – Apr. 30, 2005. Average speed = 3.37 knots. % calms = 1.24%.

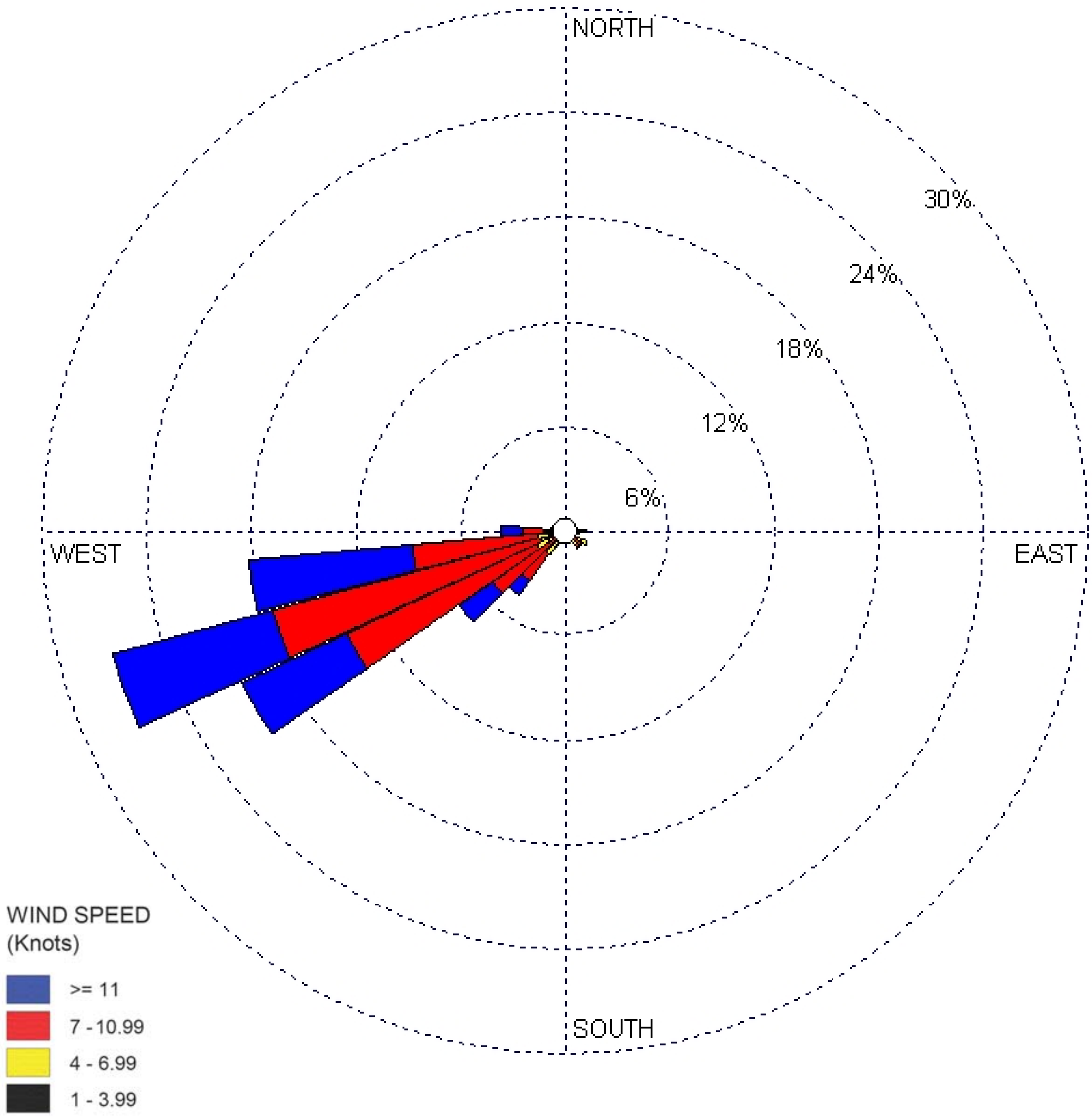

Figure 4-5: Wind rose of hourly wind measurements at Los Angeles International Airport taken during the tracer experiment. Data are for hours 8 AM – 4 PM during the period Feb. 25 – Apr. 30, 2005. Average speed = 10.12 knots. % calms = 4.95%.

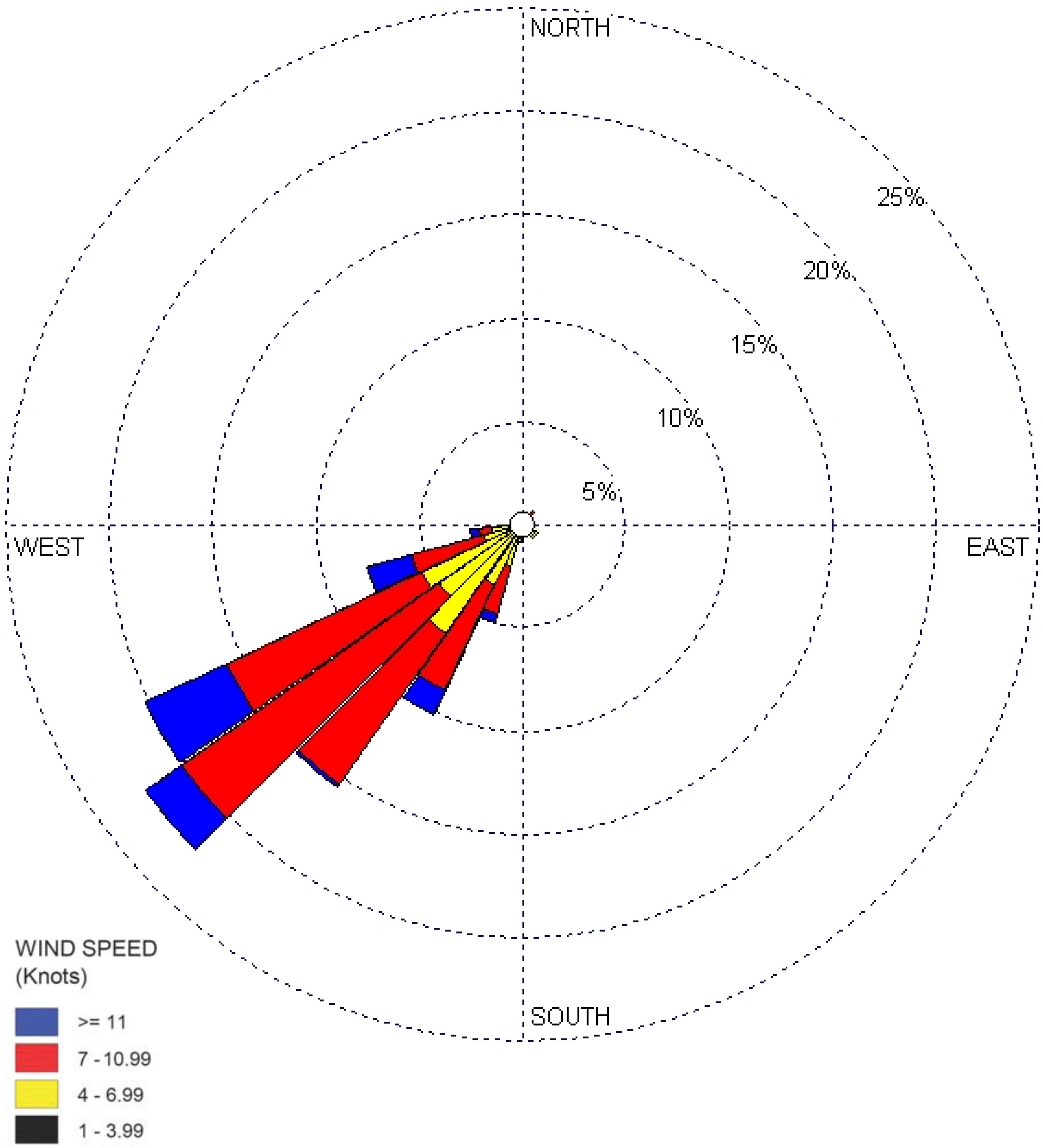

Figure 4-6: Wind rose of hourly wind measurements at Santa Monica Airport taken during the tracer experiment. Data are for hours 8 AM – 4 PM during the period Feb. 25 – Apr. 30, 2005. Average speed = 7.95 knots. % calms = 6.48%.

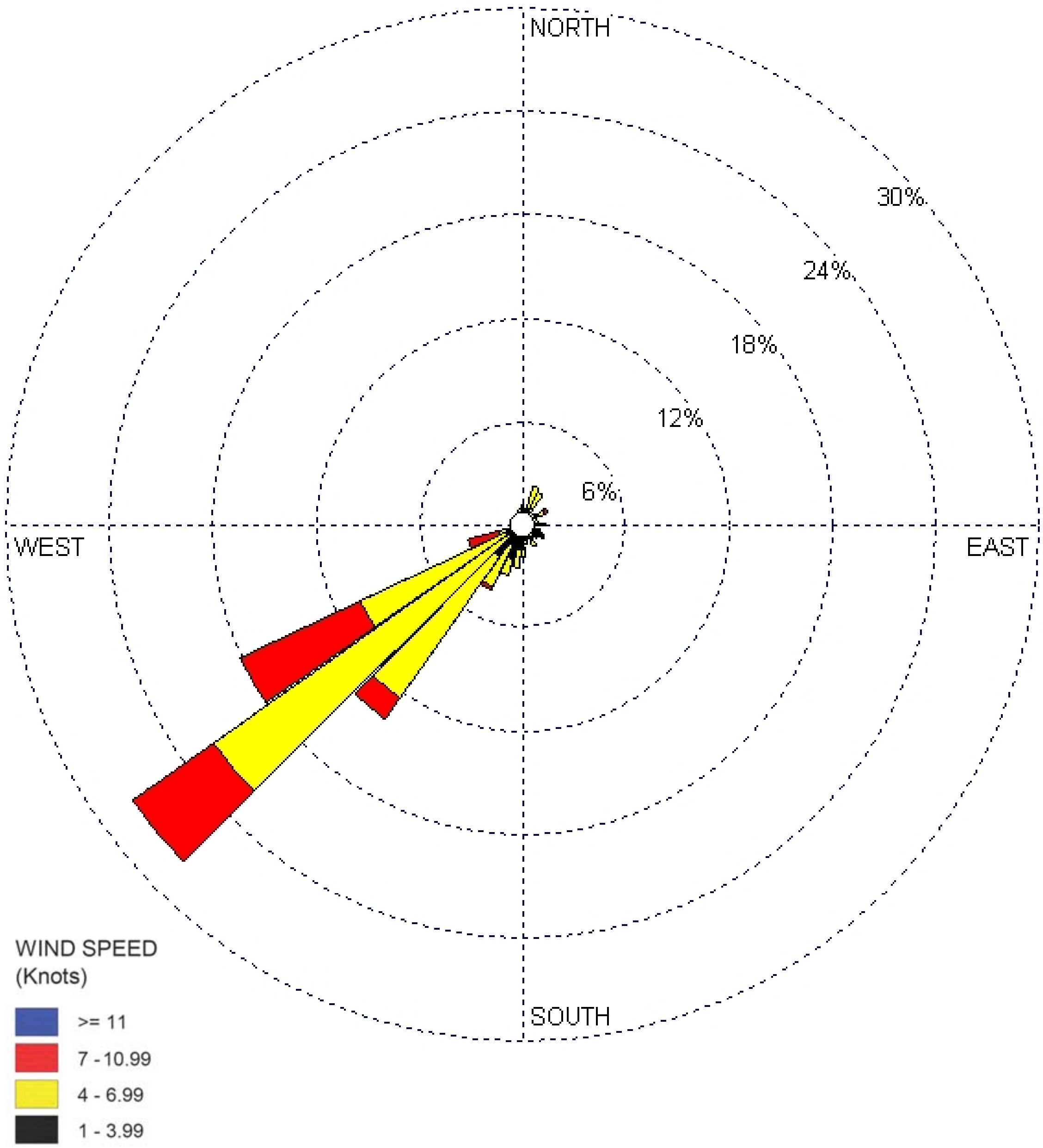

Figure 4-7: Wind rose of hourly wind measurements at Santa Monica CIMIS taken during the tracer experiment. Data are for hours 8 AM – 4 PM during the period Feb. 25 – Apr. 30, 2005. Average speed = 5.38 knots. % calms = 0.00%.

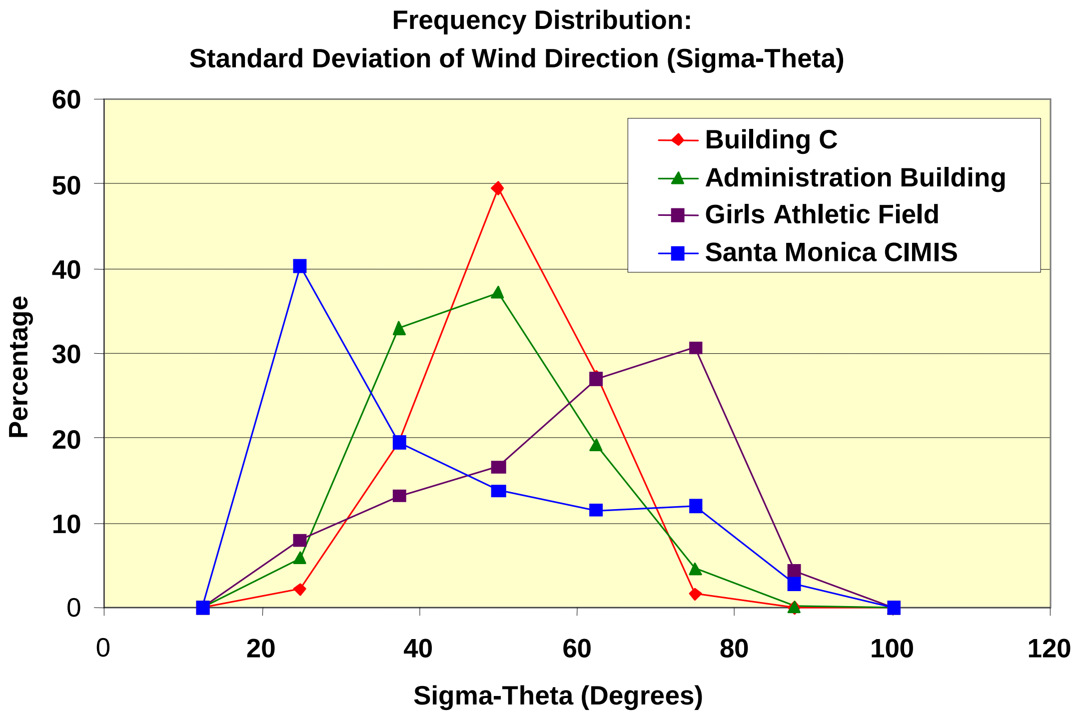

Figure 4-8: Frequency distribution of standard deviation of wind direction (sigma-theta) for tracer experiment meteorological stations (hourly averages of 5-minute average values) versus that from Santa Monica CIMIS Station (1-hour averages) measurements.

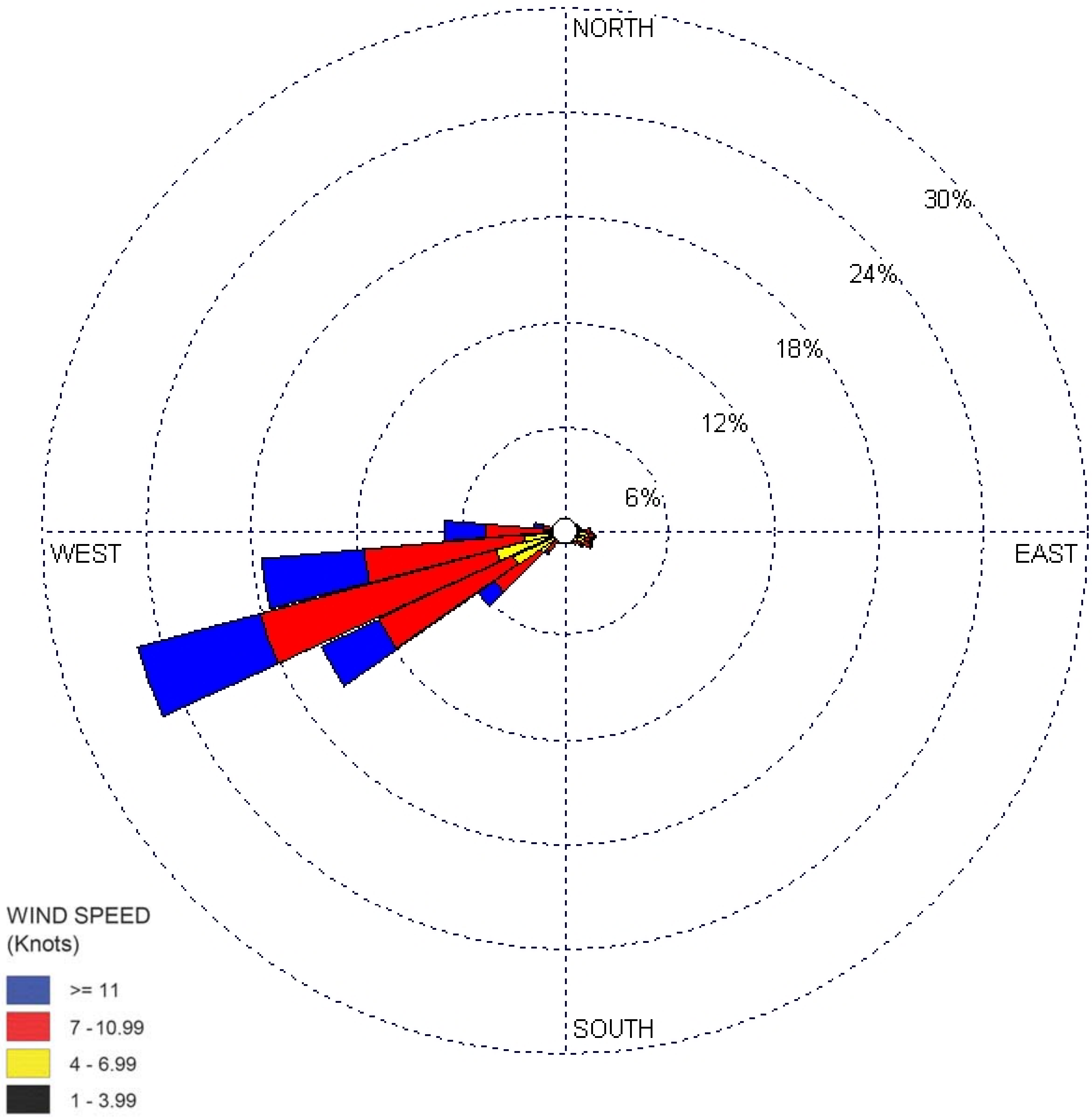

Figure 4-9: Wind rose for Los Angeles International Airport for 20 years of hourly wind data. Data are for hours 8 AM – 4 PM during the period Dec. 1, 1985 – Nov. 30, 2005. Average speed = 9.06 knots, % calms = 2.64%.

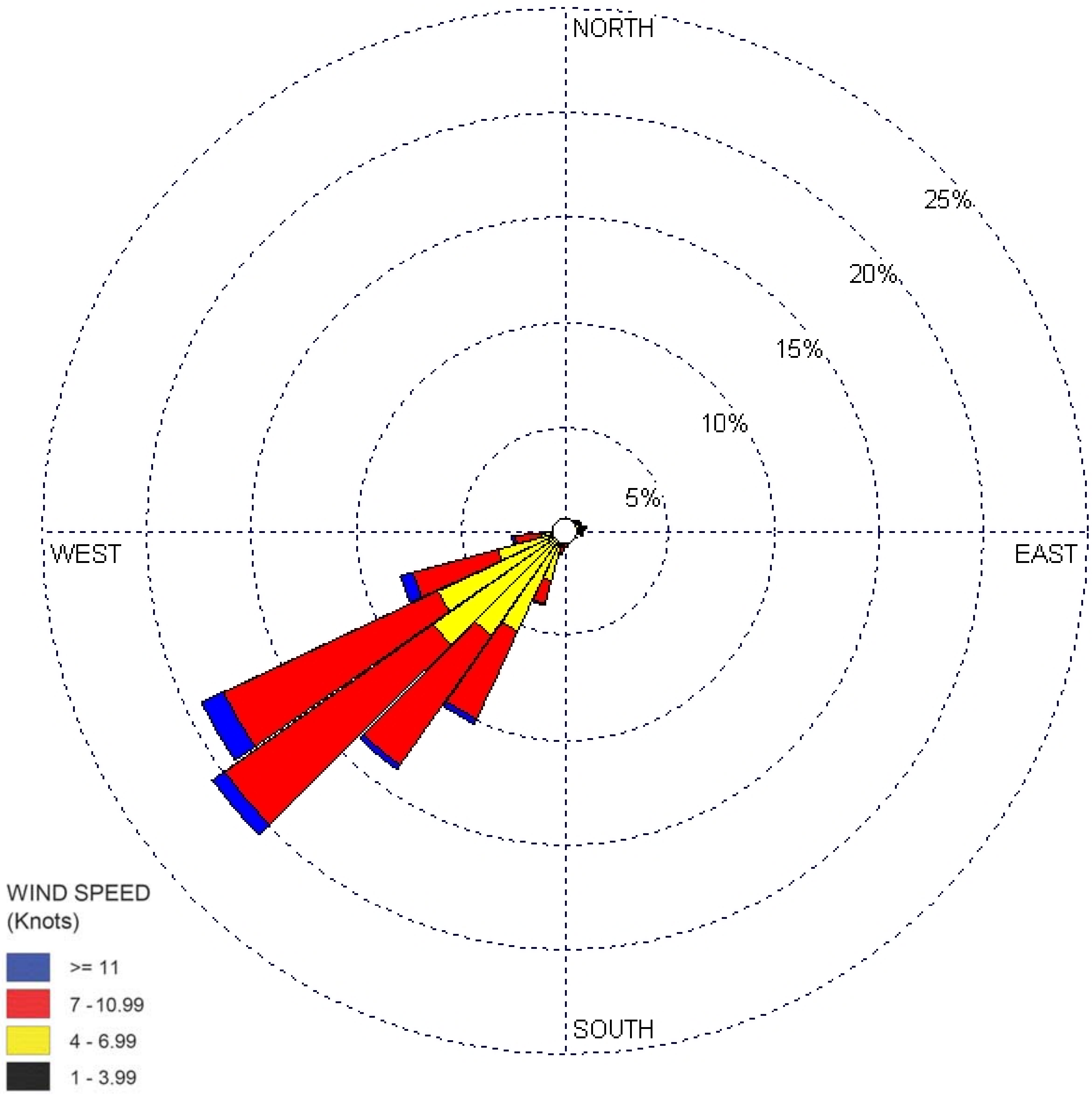

Figure 4-10: Wind rose for Santa Monica Airport for five years of hourly wind data. Data are for hours 8 AM – 4 PM during the period Dec. 1, 2000 – Nov. 30, 2005. Average speed = 7.16 knots, % calms = 6.19%.

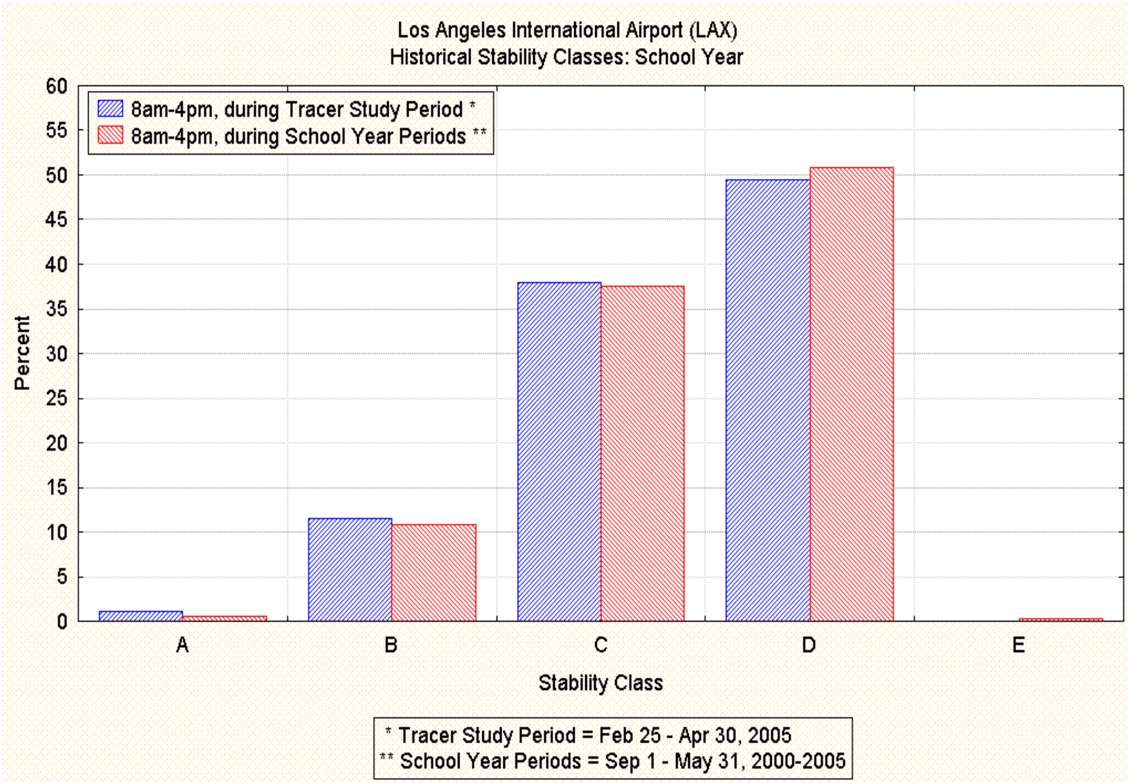

Figure 4-11: Stability classes derived from hourly meteorological measurements from Los Angeles International Airport during time of tracer experiment (blue) and during the months September through May for 2000-2005 (red). Only hours 8 AM – 4 PM considered.

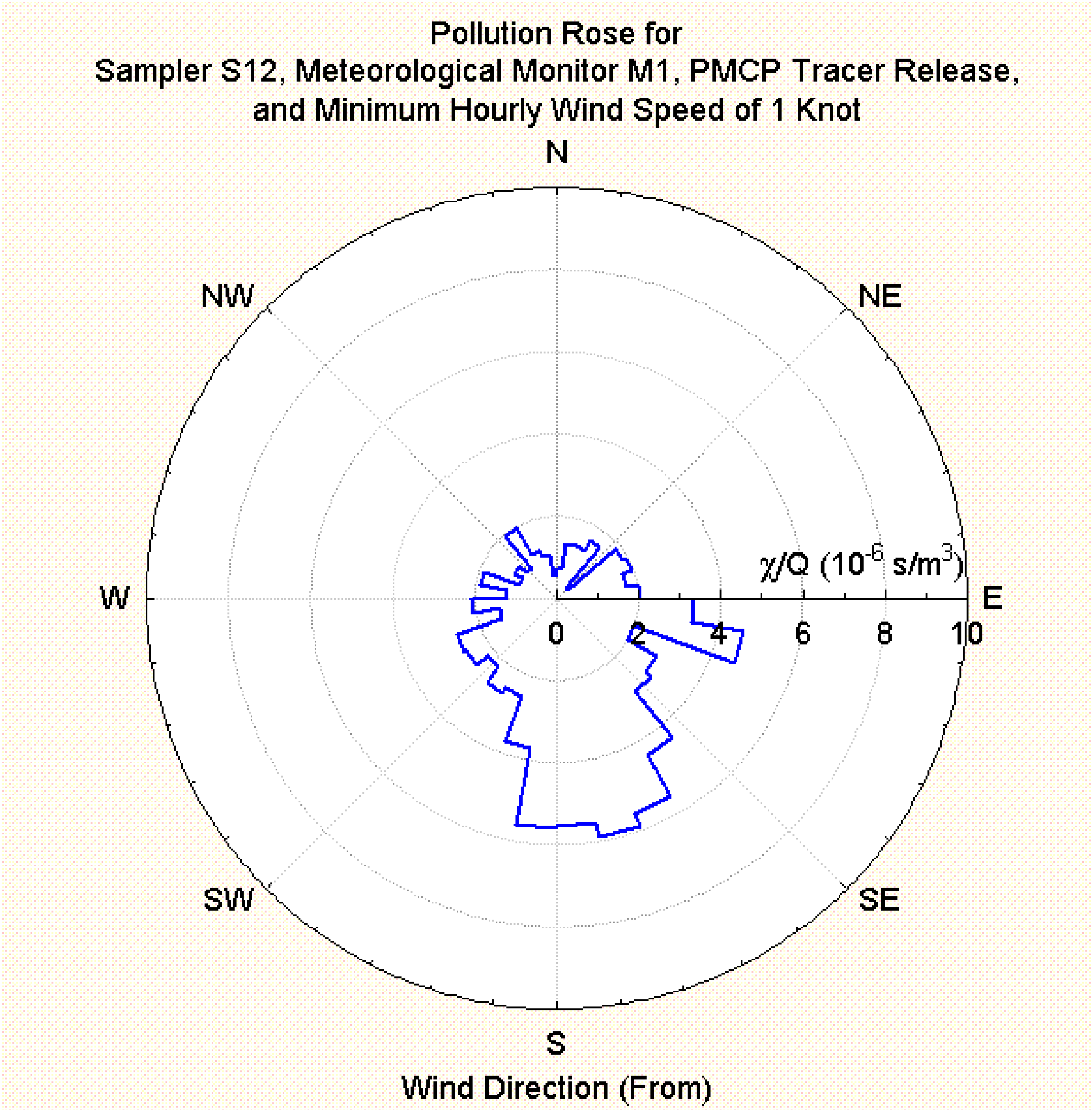

Figure 4-12: Pollution rose for tracer release from Site PMCP, corresponding to fugitive emissions from New Drill Site. Tracer concentration measured at Receptor 12 and wind measured at meteorological Station M1. Hours with winds less than one knot not included.

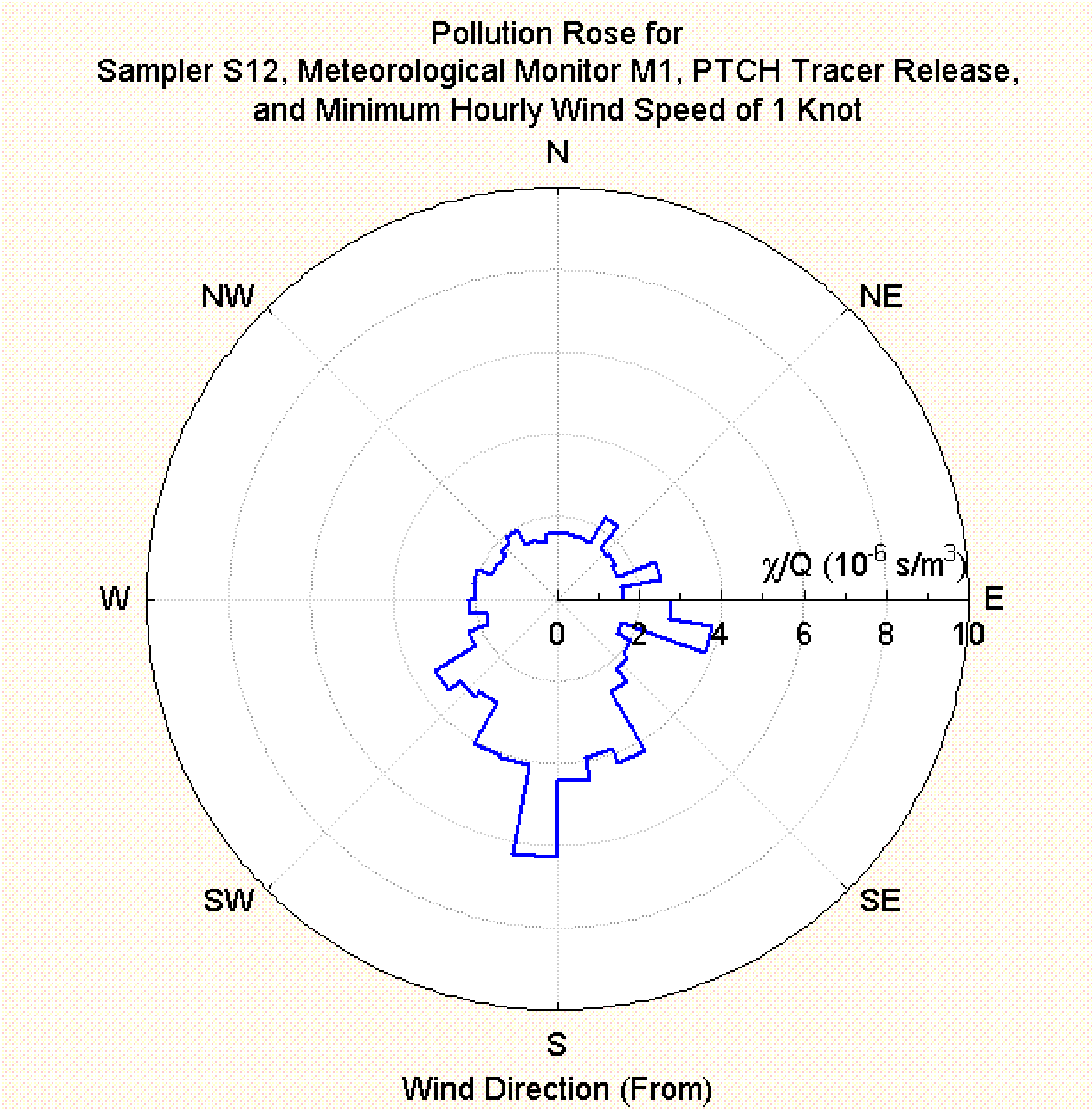

Figure 4-13: Pollution rose for tracer release from Site PTCH, corresponding to emissions from the Central Plants Cooling Towers. Tracer concentration measured at Receptor 12 and wind measured at meteorological Station M1. Hours with winds less than one knot not included.

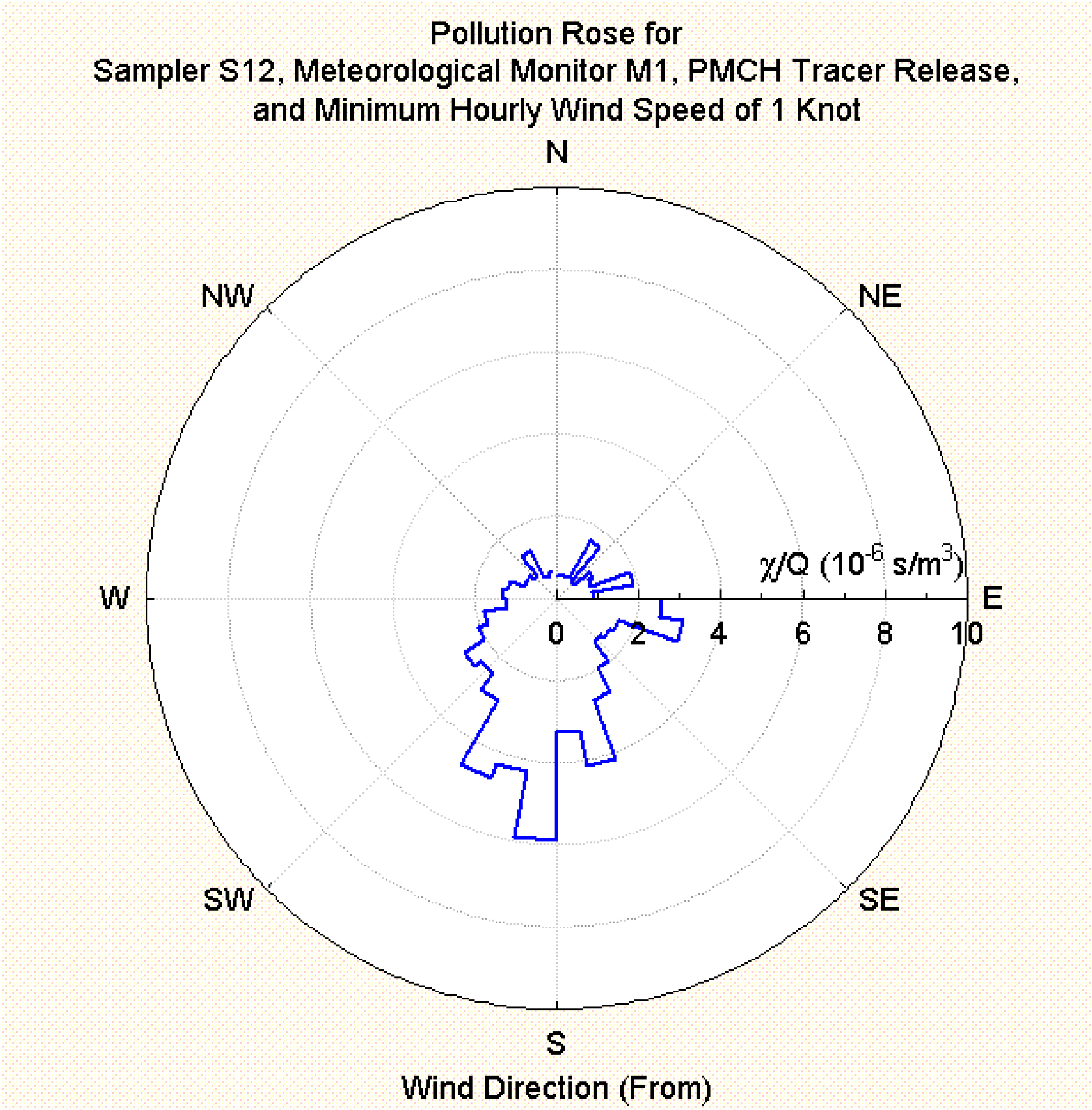

Figure 4-14: Pollution rose for tracer release from Site PMCH, corresponding to emissions from the Central Plants Boilers. Tracer concentration measured at Receptor 12 and wind measured at meteorological Station M1. Hours with winds less than one knot not included.

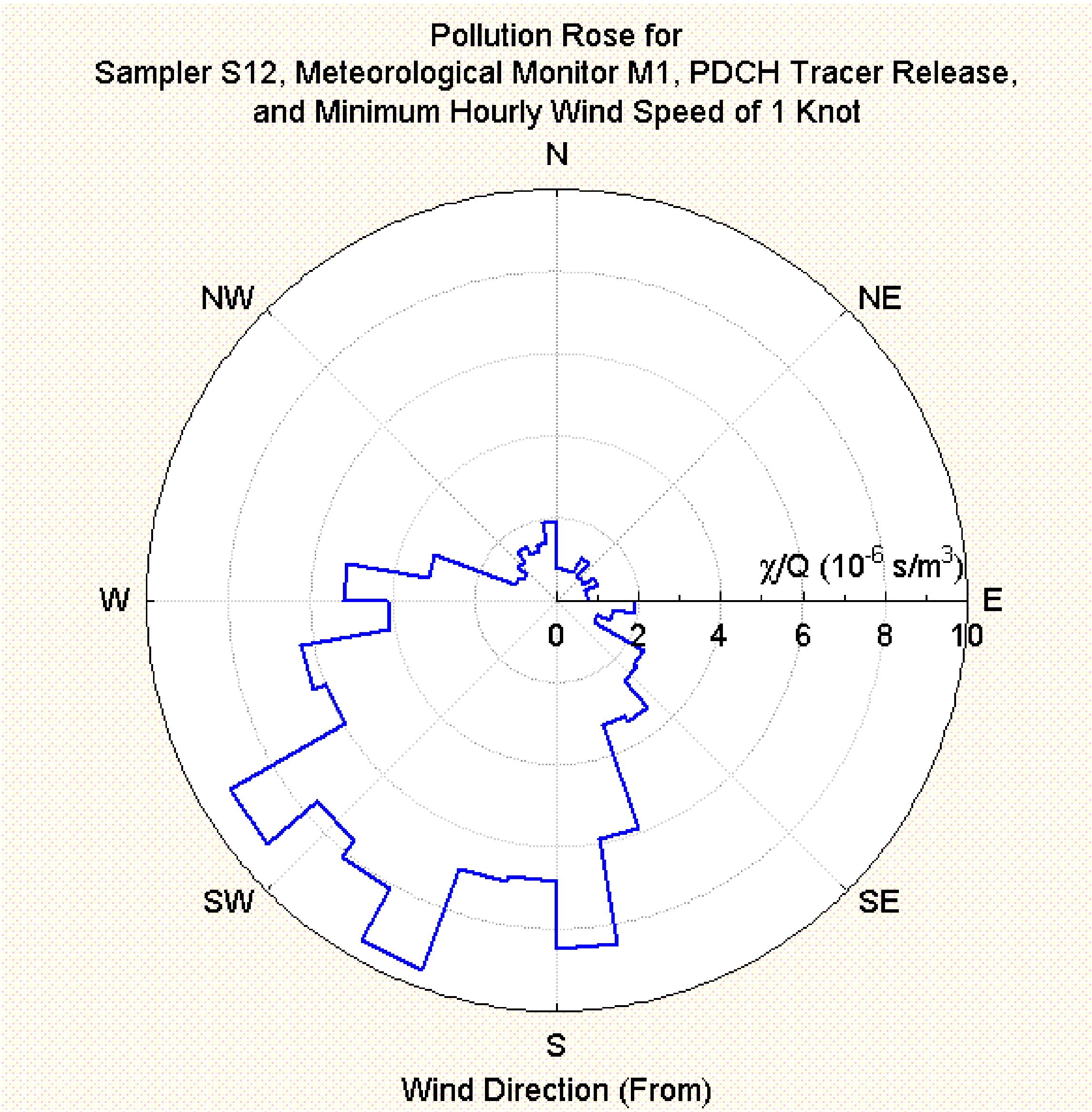

Figure 4-15: Pollution rose for tracer release from Site PDCH, corresponding to fugitive emissions from Drill Site #1. Tracer concentration measured at Receptor 12 and wind measured at meteorological Station M1. Hours with winds less than one knot not included.

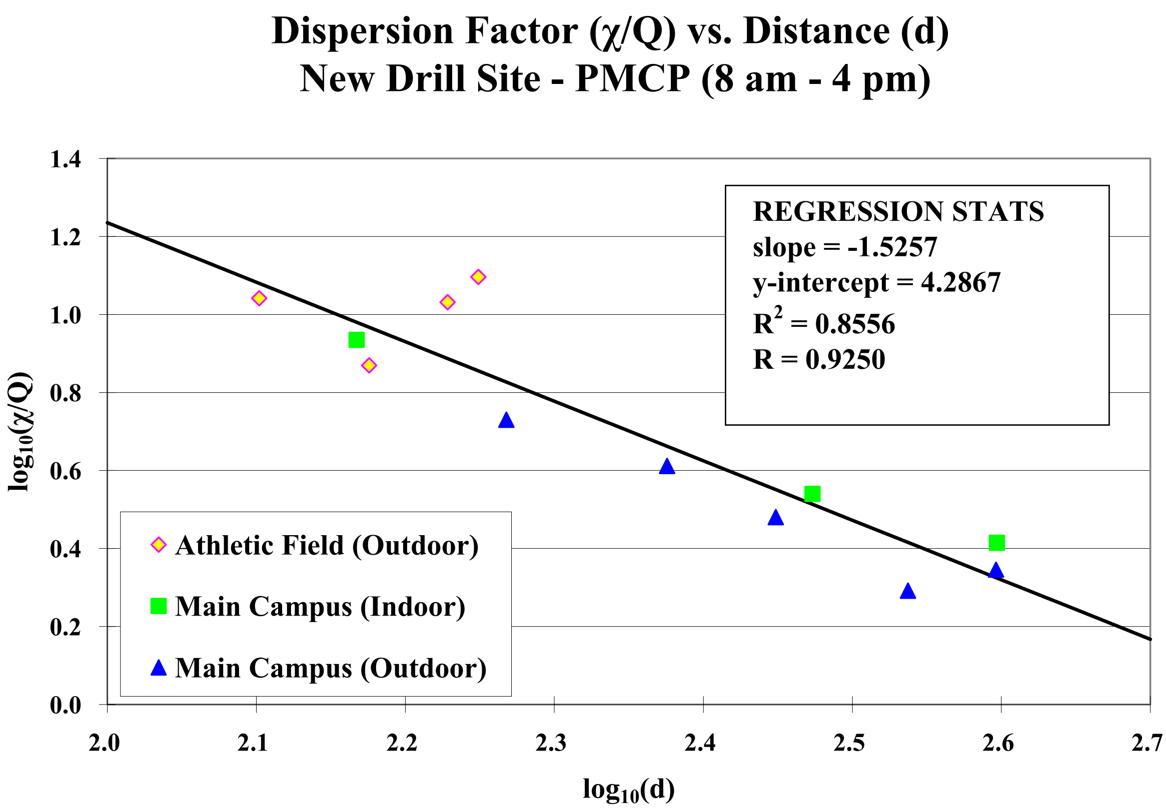

Figure 4-16: Logarithm of dispersion factor (μs/m^3) versus logarithm of distance (d) from source (in meters) for tracer release PMCP, corresponding to fugitive emissions from New Drill Site. Also shown is least-squares regression line and corresponding statistics.

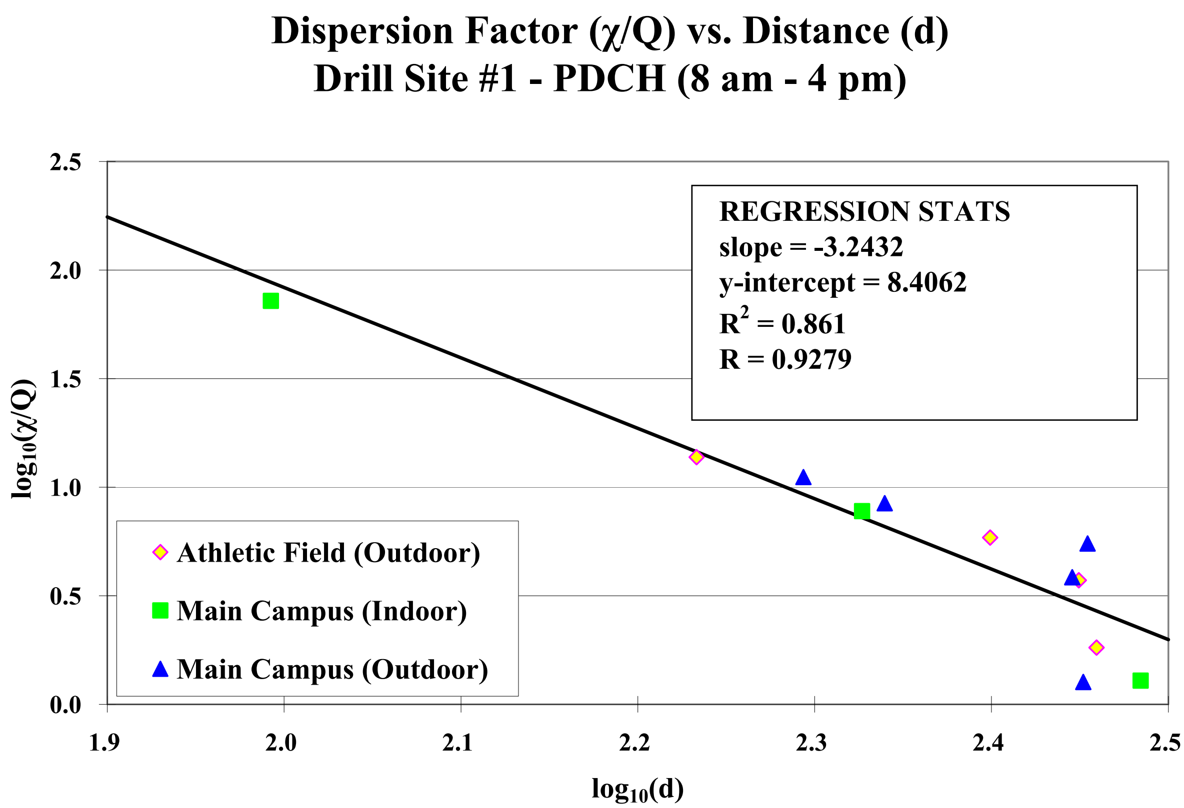

Figure 4-17: Logarithm of dispersion factor (μs/m^3) versus logarithm of distance (d) from source (in meters) for tracer release PDCH, corresponding to fugitive emissions from Drill Site #1. Also shown is least-squares regression line and corresponding statistics.

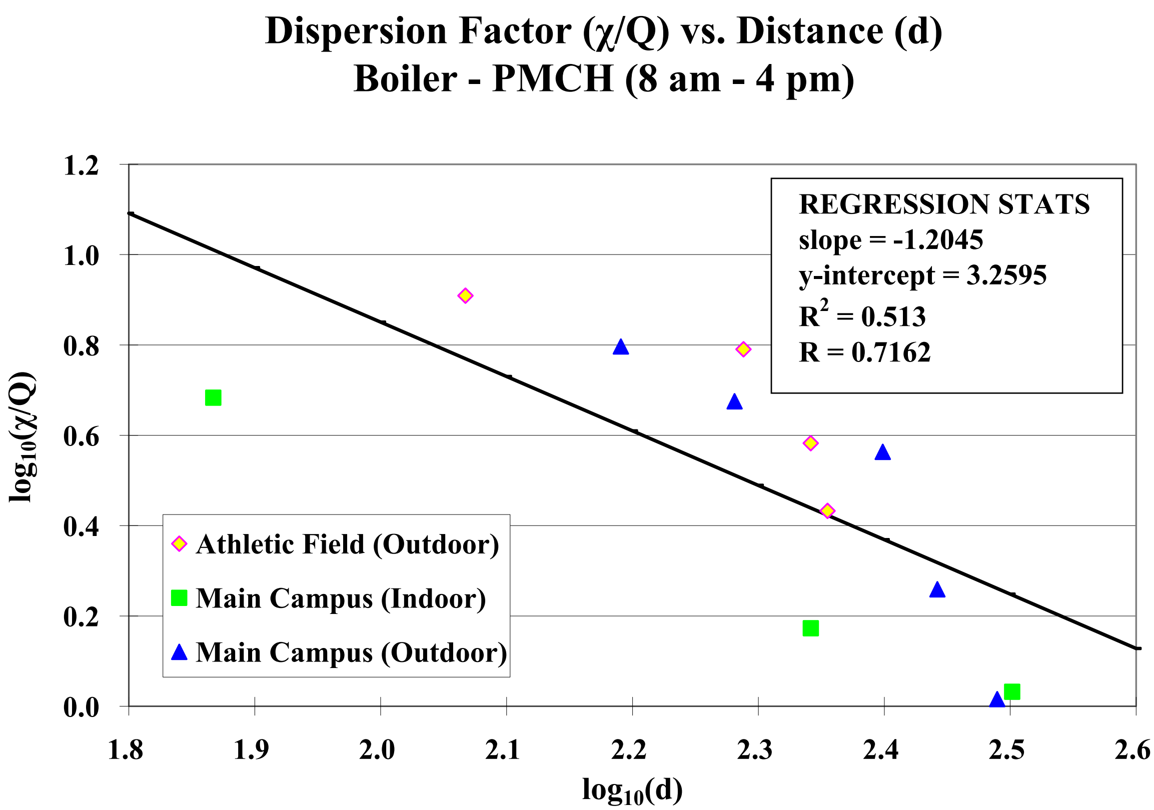

Figure 4-18: Logarithm of dispersion factor (μs/m^3) versus logarithm of distance (d) from source (in meters) for tracer release PMCH, corresponding to emissions from the Central Plants Boilers. Also shown is least-squares regression line and corresponding statistics.

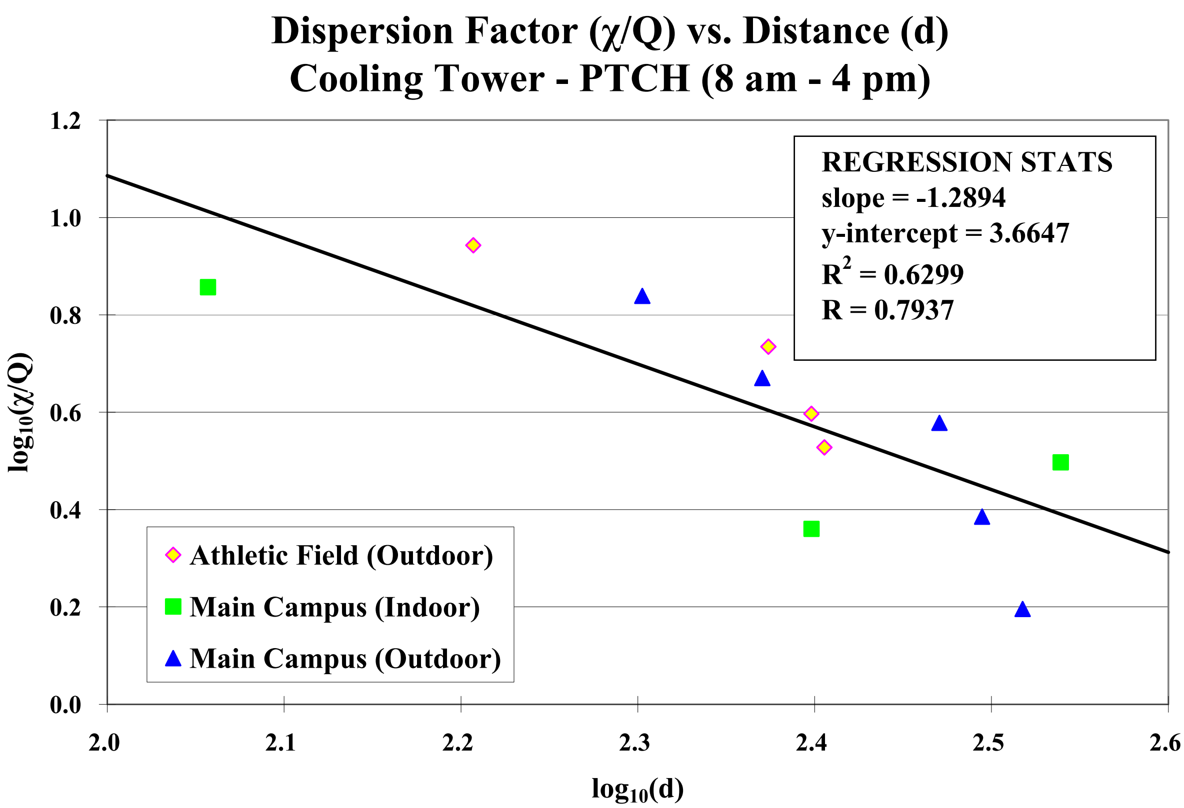

Figure 4-19: Logarithm of dispersion factor (μs/m^3) versus logarithm of distance (d) from source (in meters) for tracer release PTCH, corresponding to emissions from the Central Plants Cooling Towers. Also shown is least-squares regression line and corresponding statistics.

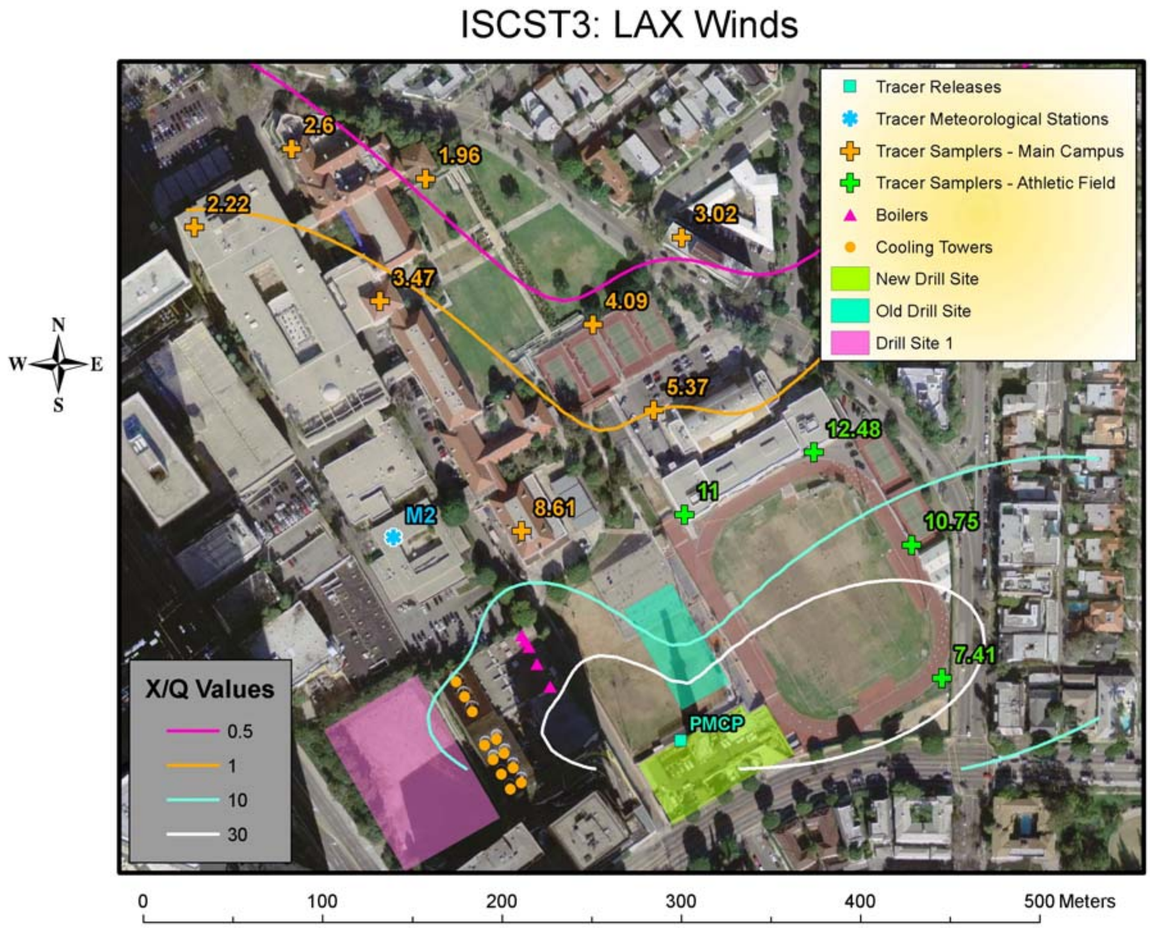

Figure 4-20: Contours of dispersion factor (μs/m^3) predictions of ISCST3 for tracer release PMCP versus observations from tracer experiment. ISCST3 run for period February 25 – April 30, 2005 with a unit emission rate, and dispersion factors calculated from the average concentration produced by ISCST3 during hours 8 AM – 4 PM. Wind inputs from Los Angeles International Airport.

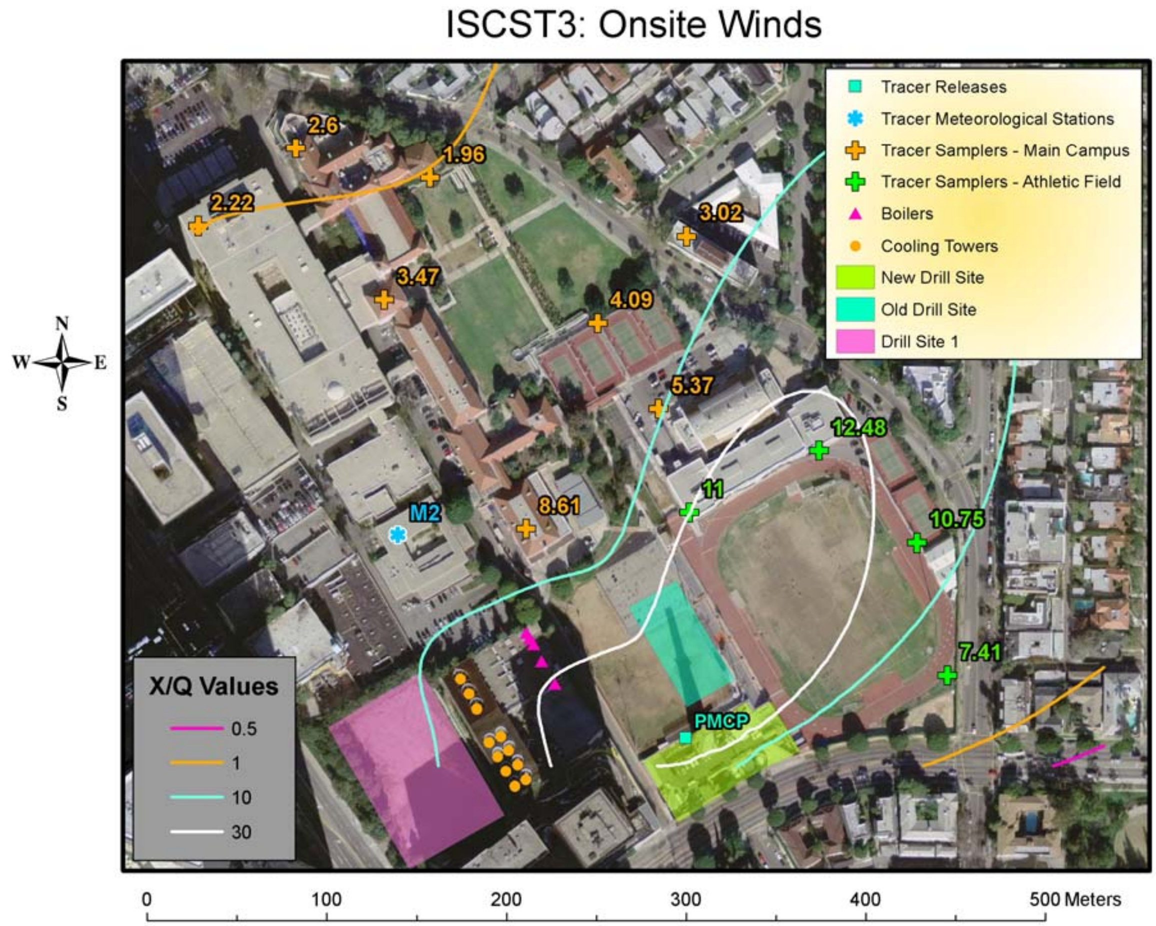

Figure 4-21: Contours of dispersion factor (μs/m^3) predictions of ISCST3 for tracer release PMCP versus observations from tracer experiment. ISCST3 run for period February 25 – April 30, 2005 with a unit emission rate, and dispersion factors calculated from the average concentration produced by ISCST3 during hours 8 AM – 4 PM. Wind inputs from on-site measurements at meteorological Site M2.

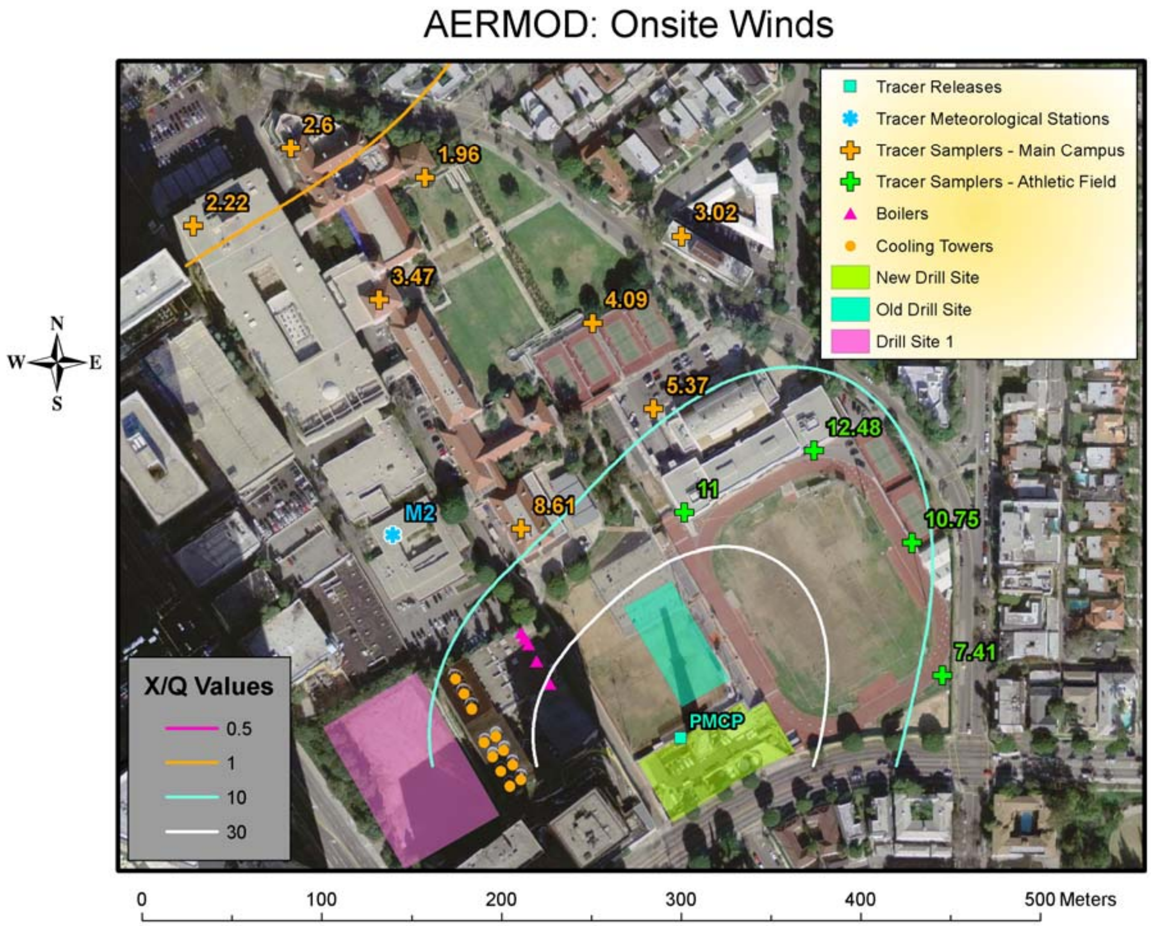

Figure 4-22: Contours of dispersion factor (µs/m^3) predictions of AERMOD for tracer release PMCP versus observations from tracer experiment. AERMOD for period February 25 – April 30, 2005 with a unit emission rate, and dispersion factors calculated from the average concentration produced by AERMOD during hours 8 AM – 4 PM. Wind inputs from on-site measurements at meteorological Site M2.

5 Examination of the Emission Rates

5.1 Drill Sites

Annual total emissions (in pounds) of benzene and formaldehyde from the drill sites were provided to us by Ms. Wilson. These data were provided for the New Drill Site, Old Drill Site, Drill Site #1 and “Wolfskill”, which was a drill site located near Drill Site #1 that operated during the late-1940s through early-1960s.

From this information, we computed emission rates (in milligrams per second) for these sources over each calendar year for which we were provided emissions. These are plotted in Figure 5-1 and Figure 5-2 for benzene and formaldehyde, respectively. For comparison, also plotted on these figures are the following “reference” emission rates: 1) estimated emission rates for a half mile by half mile area of Los Angeles area background benzene emissions, 2) estimated benzene emission rates for a half-mile section of Santa Monica Blvd. in Beverly Hills, and 3) estimated emission rates from construction events that occurred in Century City during the early 1970s. The first two of these estimates were performed by us, while the third were supplied to us by Ms. Wilson. Details on how these reference estimates were calculated are given in Appendix D.

5.2 Central Plants

The emission rates from the Central Plants Boilers and Cooling Towers were provided to us by Mr. Gary Rubenstein (Sierra Research).

5.2.1 Cr^{+6} Emissions (Cooling Towers)

Cr^{+6} emission rates are plotted in Figure 5-3. The emission rate varies from 0.07 mg/s to 0.22 mg/s from 1966 to 1991. These emission rates represent the PM_{10} portion of the Cr^{+6} emissions.

This size distribution of the droplets emitted from the Cooling Towers is shown in Figure 5-4. The mass-weighted mean droplet diameter is approximately 370 µm.

5.2.2 Boiler Emissions

The Boiler emissions are comprised of the following hydrocarbon species and metals: arsenic, benzene, chromium, formaldehyde, nickel, polycyclic aromatic hydrocarbons (PAHs), poly-chlorinated biphenyls (PCBs) and poly-chlorinated dibenzodioxins (PCDDs). Plots of the emission rates for these species are shown in Figure 5-5 through Figure 5-12. These emission rates were calculated by Sierra Research from emission factors for each species obtained from source stack measurements recently conducted by SCEC. These source measurements yielded no detectable levels of poly-chlorinated dibenzofurans (PCDFs).

5.3 Comparison with Mr. Tarr's Emissions[66]

The long-term concentrations used by expert designated by plaintiffs Dr. Clark (Section 2.7) in his exposure calculations for each plaintiff for all species except PCBs and PCDFs resulted from the maximum emission rates for each species employed by Mr. Tarr (Section 2.5). For benzene in the years 1980 and 1985, these came from Mr. Tarr's "Scenario 2" maximum emission rates for the New Drill Site, and from Mr. Tarr's "Scenario 1" maximum emission rates for Drill Site #1. In both cases, these benzene emission rates were the maximum available.

The maximum benzene emission rates calculated by Mr. Tarr for each source and each of the six years considered (1975, 1980, 1985, 1990, 1995, and 2000) are significantly larger than those calculated by Ms. Wilson. For the New Drill Site, for example, Mr. Tarr's "Scenario 2" maximum emission rate equals 66,960 lbs/yr. This converts to 964 mg/s, approximately four orders of magnitude greater than that calculated by Ms. Wilson for the New Drill Site in 1985 (which is about 0.1 mg/s – see Figure 5-1). Similar differences exist for other years, other sources, and other species.

A check on the accuracy of Mr. Tarr's maximum benzene emission rates can be made by comparing benzene concentrations measured on-site by Camp, Dresser and McKee, Inc. (CDM)

[66] All reported values for Mr. Tarr's emission rates are taken from the Emission Inventory sections of his reports. These reports are referenced in Footnote 24 through Footnote 26.

during several campaigns since 2003 with Mr. Tarr's concentration predictions for 2000[67]. Since Dr. Clark uses Mr. Tarr's long-term concentrations for a given year to represent that year and the following four, this comparison to observations on campus is appropriate. Using his maximum benzene emission rates, Mr. Tarr estimates a long-term average benzene concentration for 2000 (PLEXJT-042579 and 042580) of approximately 4.1 ppb in the area of the athletic field near the New Drill Site[68]. Measurements in the area by CDM, contrarily, yield 8-hour averaged benzene concentrations on the order of the LA background - approximately 1 ppb - with a maximum measured value of 1.6 ppb. Additional measurements[69] of ambient benzene taken by the South Coast Air Quality Management District (SCAQMD) are consistent with the background values measured by CDM.

Mr. Tarr's maximum benzene emission rate for 2000 is therefore inconsistent with these measurements. If Mr. Tarr's emissions were correct, some of CDM's ambient 8-hour averaged benzene measurements would have resulted in values well above the urban background, for example in the range of 2-8 ppb. This never occurred during CDM's measurement campaigns. We thus believe that Mr. Tarr's maximum emission rates are erroneous, representing a gross overestimation of the correct benzene emission rates.

Mr. Tarr did not estimate emission rates for formaldehyde from the drill sites; therefore, no comparison with Ms. Wilson's rates can be made.

Mr. Tarr's PM_{10}-based Cr^{+6} emission rates from the Central Plants Cooling Towers range from 155.9 lbs/yr (1985) to 538.6 lbs/yr (1975)[70]. These convert to 2.2–7.8 mg/s, which as seen from

67 The CDM measurements are summarized in "Summary of Findings Ambient Air Investigation", Camp Dresser and McKee, Inc. (CDM), November 21 2005. CDM measured concentrations of 49 hydrocarbon species during several campaigns over the years 2003-2005. These campaigns include those occurring in April 2003, July 2003, December 2003, February 2005 and June 2005. Measurement sites were spread over the campus, with several on the athletic field area near the New Drill Site. Roughly 100 8-hour averaged benzene samples were collected when summed over all of the measurement campaigns.

68 This value was calculated by us by averaging the values reported by Mr. Tarr for Receptors 42, 45, and 47 and dividing by 3.26 to convert from micrograms per cubic meter to parts-per-billion (ppb).

69 E.g.: SCAQMD (2003) Progress Report – Air Quality Study at Beverly Hills High School and Vicinity. May 16, 2003.

70 We take these emission rates from Mr. Tarr's "Supplement" report.

Figure 5-3 are over an order of magnitude larger than the emission rates calculated by Sierra Research.

Mr. Tarr employs the following ranges of maximum emission rates from the Central Plants Boilers over all of his considered years (units are mg/s): 56–70 (benzene), 61–76 (formaldehyde), 0.25–0.31 (PAHs), 1.17–1.46 (chromium), 1.22–1.52 (nickel), 0.06–0.08 (arsenic), 16.3–20.4 (TEQ PCBs), 0.053–0.066 (TEQ PCDFs[71]). These PCBs and PCDF maximum emission rates are taken from Mr. Tarr's "Scenario D", which is what Dr. Clark used in his exposure calculations. By comparing with Figure 5-5 through Figure 5-11, it can be seen that Mr. Tarr's estimates are between one and three orders of magnitude higher than those derived by Sierra Research from on-site measured data collected by SCEC[72]. For PCDFs, Mr. Tarr employs emission rates that are orders of magnitude higher than the highest values one could compute from the on-site measurements performed by SCEC[73].

In summary, the emission rates estimated by the experts designated by plaintiffs are much larger (orders of magnitude) than those calculated or measured by the experts designated by defendants. From comparison of Mr. Tarr's long-term average benzene concentrations with recently measured ambient benzene concentrations at BHHS, we believe that Mr. Tarr's benzene emission rates from the drill sites are erroneously large. In addition, we reviewed the reports and depositions of the various experts involved in determining emission rates and have reached the following conclusions:

71 TEQs are toxic equivalents; see: http://www.epa.gov/tri/tridata/teq/teqmodrule.html#q2.

72 For PCBs, this comparison needs to be clarified. Mr. Tarr used TEQ PCBs emissions, while Sierra Research provided to us PCBs emissions in pounds per year, without the toxic equivalency factors. That means that the differences between the PCB emission rates provided by Mr. Tarr and by Sierra Research are much larger than the "one to three orders of magnitude" reported in the body of the text.

73 More precisely (Sierra Research personal communication): SCEC collected a stack gas sample and sent the sample to Alta labs for analysis. SCEC reported the furan PCDF emissions at the detection limit. Sierra Research recalculated the value to zero, based on the AB2588 guidance and the lab data contained in SCEC's test report. Using one half of the furan detection limits and annual natural gas use for each year, Sierra Research calculated the maximum annual emission rate of $1.73\ 10^{-7}$ pounds TEQ PCDF per year, for the period 1966-2003. This rate corresponds to $2.5\ 10^{-9}$ mg/s TEQ PCDF, which is seven orders of magnitude lower that the value used by Mr. Tarr.

- For drill site emissions of benzene, we concur with Ms. Wilson's determination that Mr. Tarr's emissions are unrealistically high[74]. For example, Mr. Tarr's emission rates would require concentrations of benzene in the crude oil that are not present in nature and/or not observed on-site.

- For Cr^{+6} emissions from the Cooling Towers, we noted the main difference between the experts' opinions is the different drift rates. We chose the emission rates calculated by Sierra Research since they are based on source test measurements, whereas the emission rates calculated by Matson and Associates were not. Moreover, the drift rates calculated by Matson and Associates are based on a drift factor of 0.2%, which exceeds by more than a factor of 10 the value measured on-site by ESC (report of March 2005).

- We reviewed the on-site measurements of the emission factors of chemicals from the Boilers recently made by SCEC, and used by Sierra Research to calculate emission rates. We chose the emission rates calculated by Sierra Research since they are based on source test measurements of emission factors, whereas the emission rates calculated by Mr. Tarr and Mr. Dellinger are not based on source measurements.

[74] "Benzene and Formaldehyde Airbourn Emissions from Oil Field Operations in Proximity to Beverly Hills High School 1946-2002.", prepared by Mary Jane Wilson, WZI Inc., February 6, 2006.

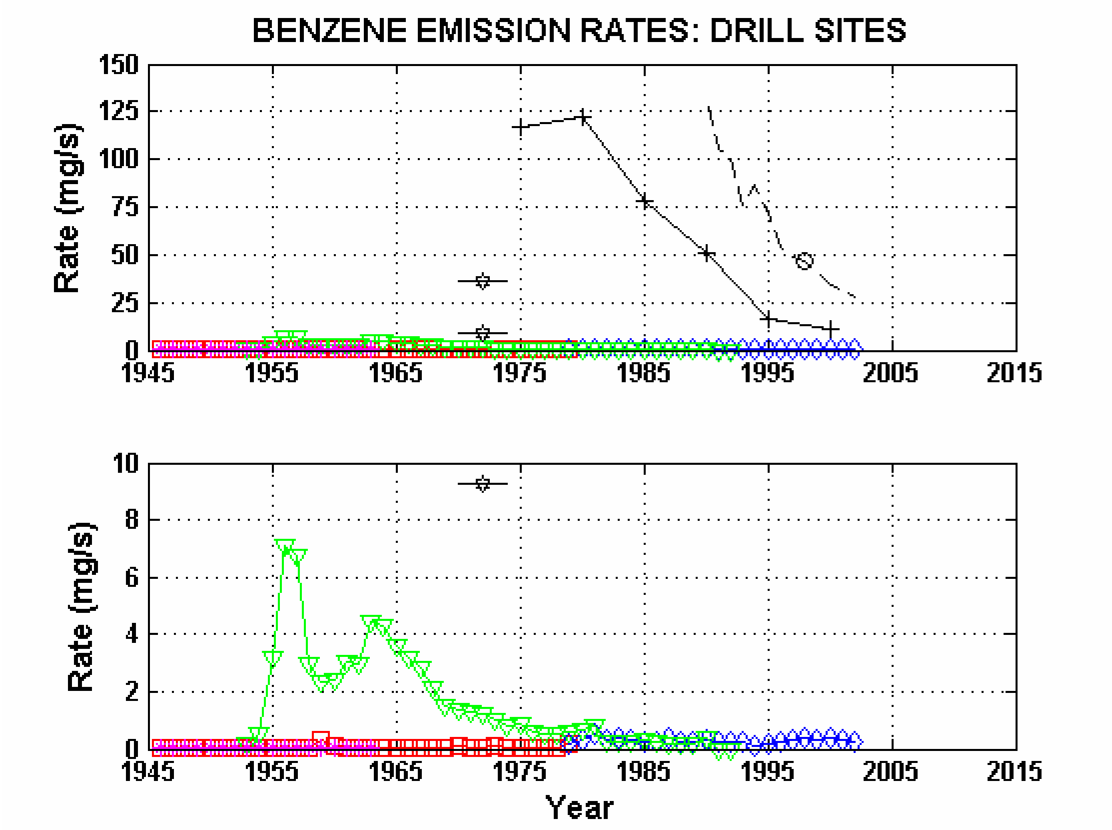

Figure 5-1: Benzene emission rates versus year for drill sites, as supplied to us by Ms. Wilson. Emissions are totals over calendar years. Blue diamonds: New Drill Site; green triangles: Drill Site #1; Red squares: Old Drill Site; Magenta stars: Wolfskill. Also plotted are Los Angeles area reference values from road traffic (black circle, dashed line, dashed-plus line) and construction activity (hexagons), as described in the text and Appendix D.

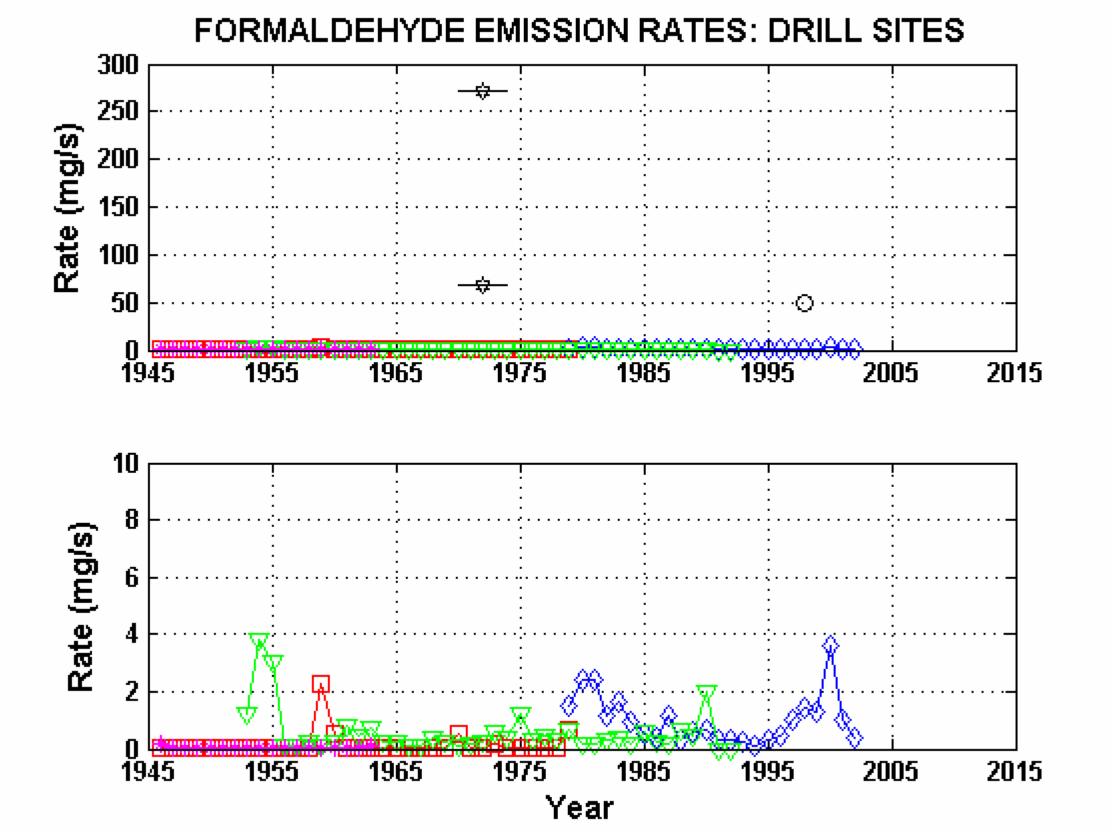

Figure 5-2: Formaldehyde emission rates versus school year for drill sites, as supplied to us by Ms. Wilson. Emissions are totals over calendar years. Blue diamonds: New Drill Site; green triangles: Drill Site #1; Red squares: Old Drill Site; Magenta stars: Wolfskill. Also plotted are Los Angeles area reference values from road traffic (black circle) and construction activity (hexagons), as described in the text and Appendix D.

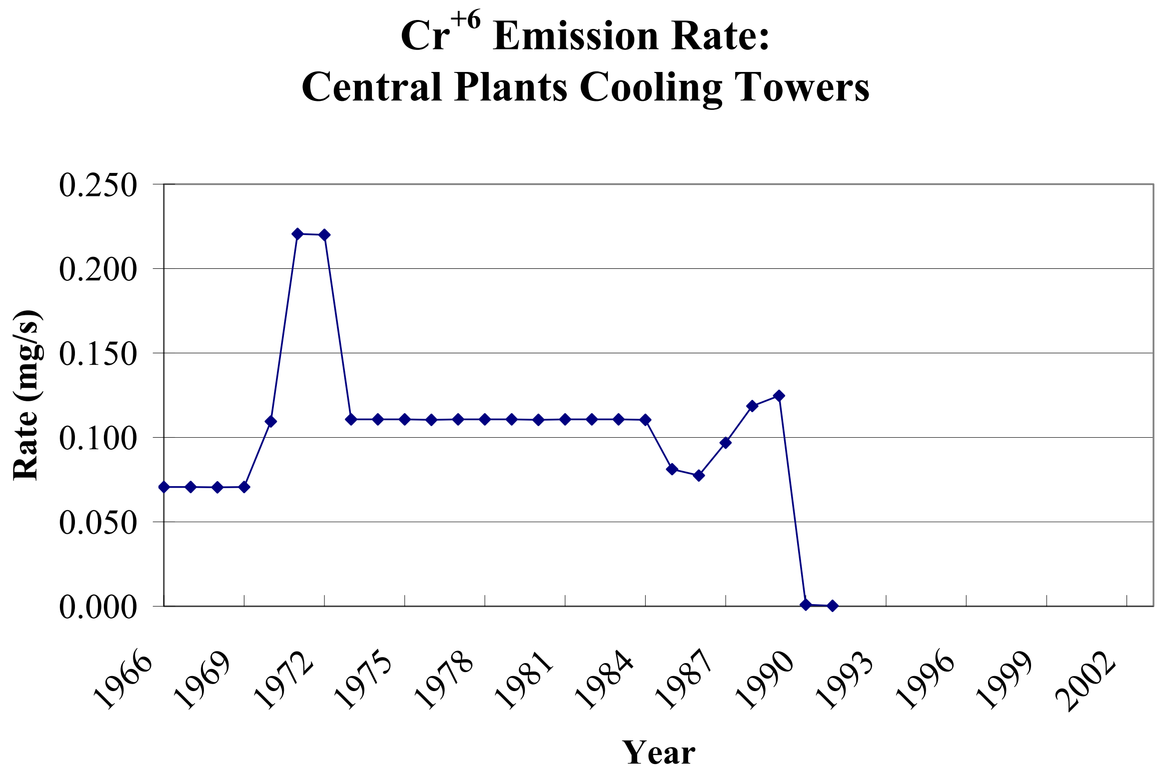

Figure 5-3: Cr^{+6} emission rates versus year from Cooling Towers, as supplied by Sierra Research.

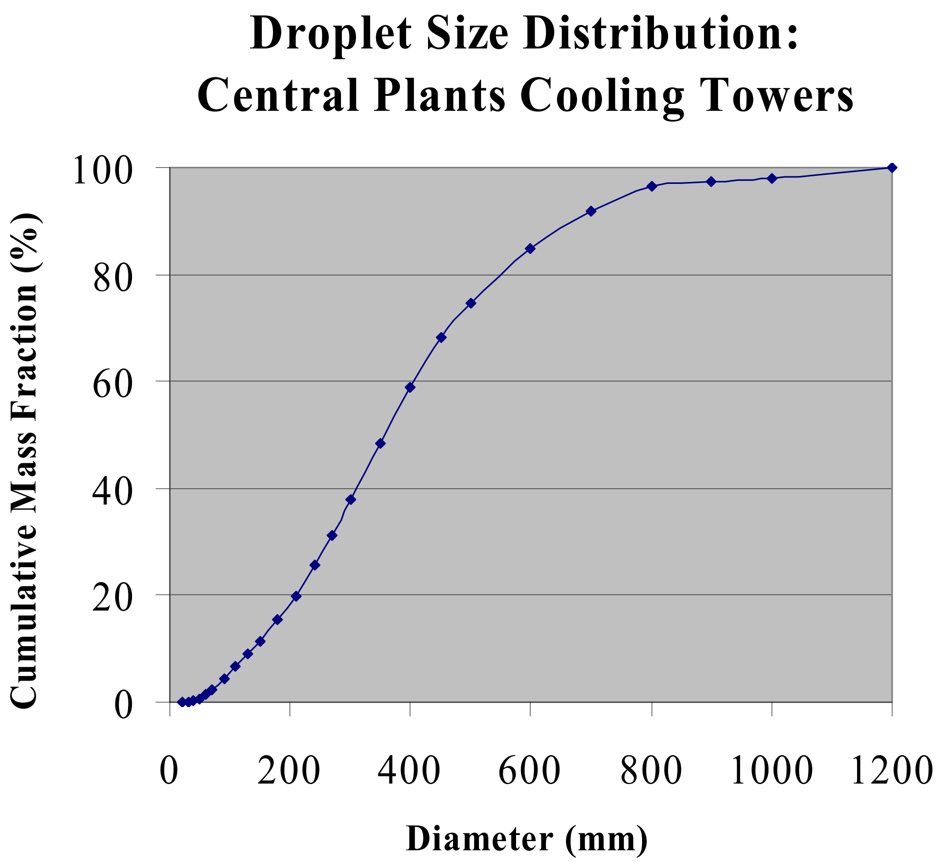

Figure 5-4: Cumulative mass-weighted size distribution for droplets emitted from Cooling Towers.

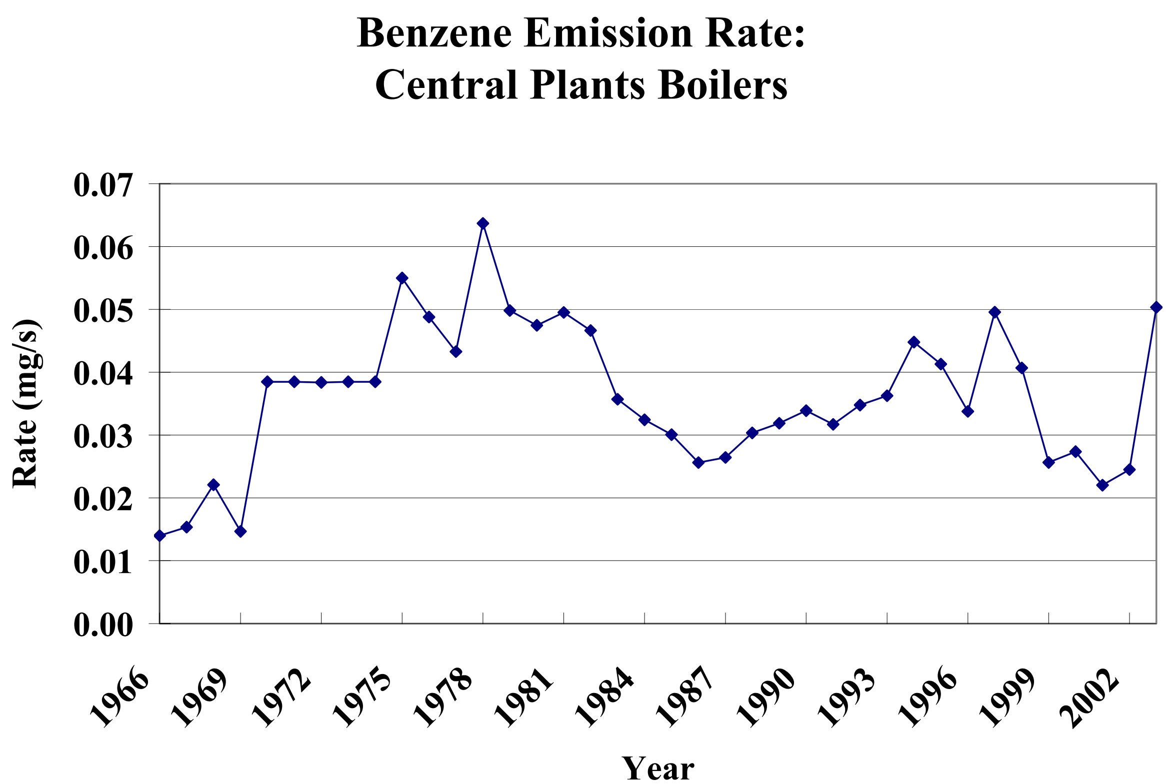

Figure 5-5: Benzene emission rates versus year from Boilers, as supplied by Sierra Research.

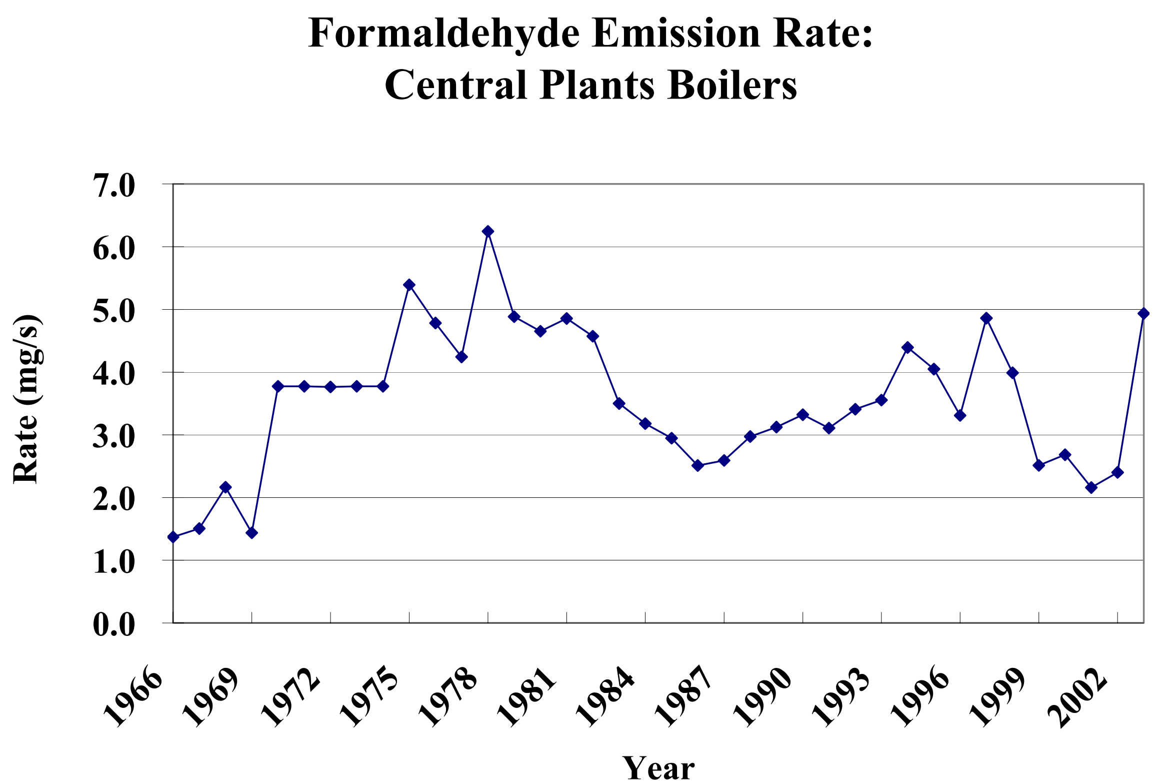

Figure 5-6: Formaldehyde emission rates versus year from Boilers, as supplied by Sierra Research.

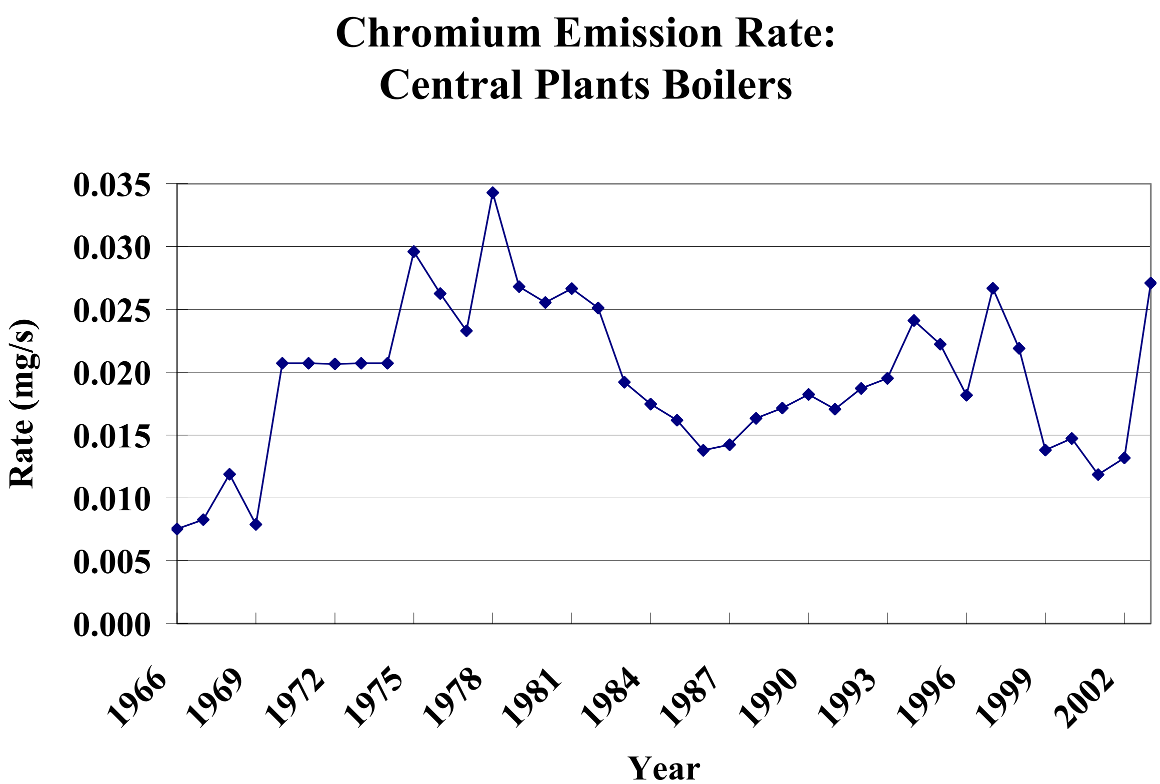

Figure 5-7: Chromium emission rates versus year from Boilers, as supplied by Sierra Research.

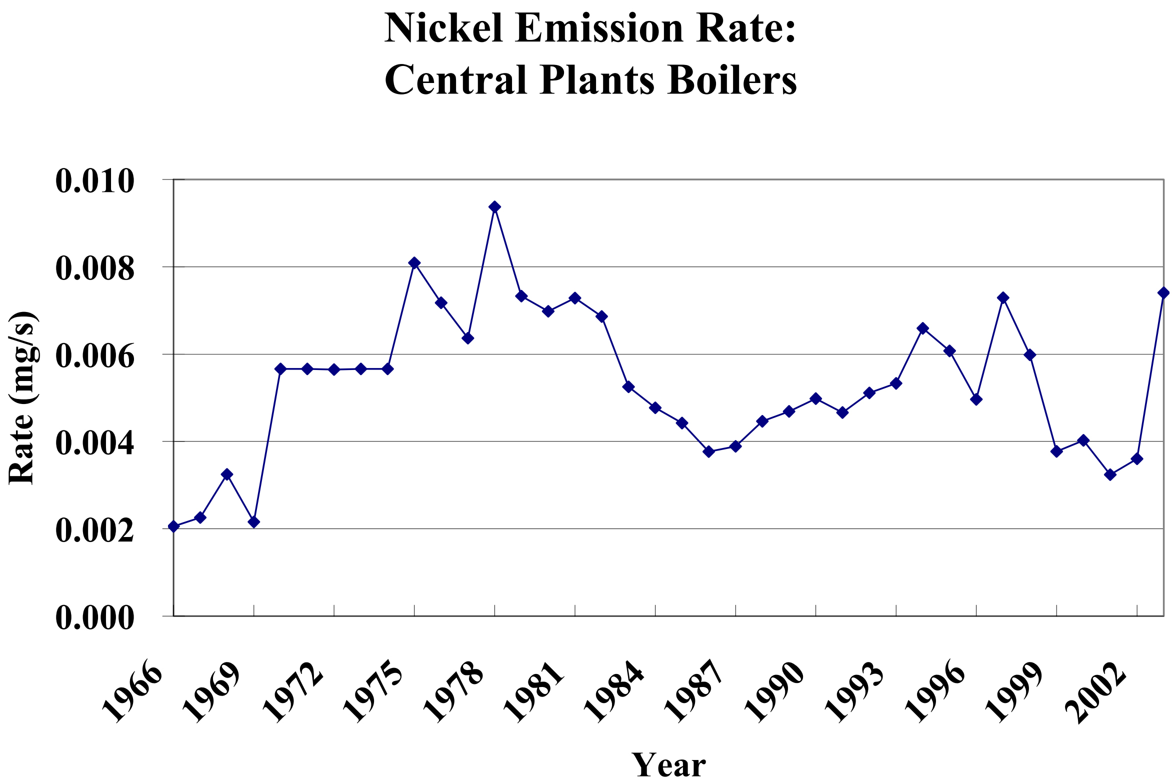

Figure 5-8: Nickel emission rates versus year from Boilers, as supplied by Sierra Research.

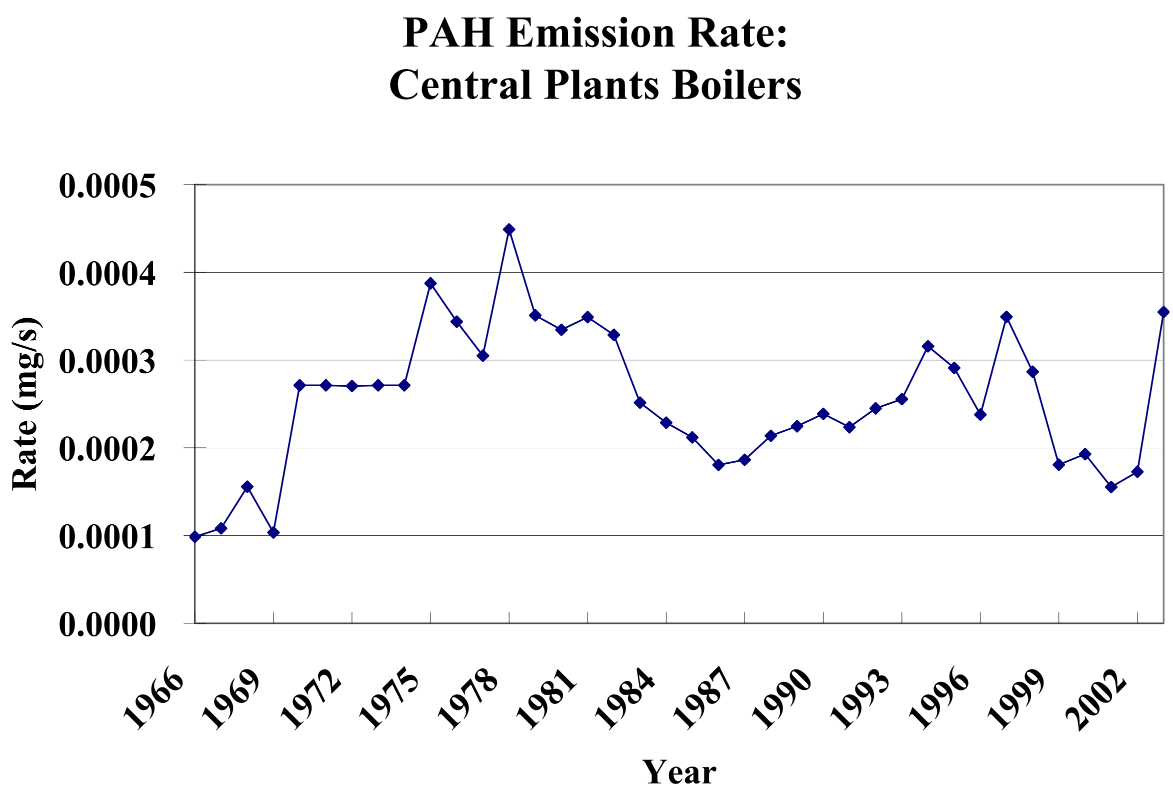

Figure 5-9: Polyaromatic hydrocarbon (PAH) emission rates versus year from Boilers, as supplied by Sierra Research.

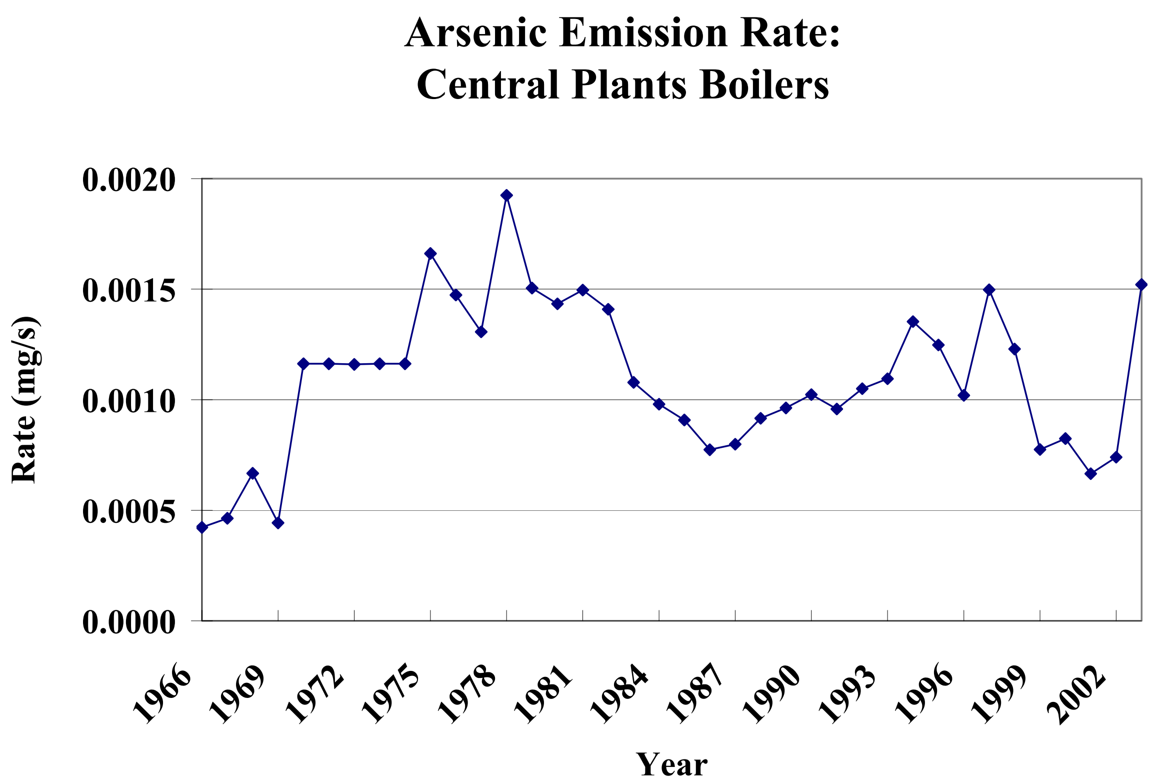

Figure 5-10: Arsenic emission rates versus year from Boilers, as supplied by Sierra Research.

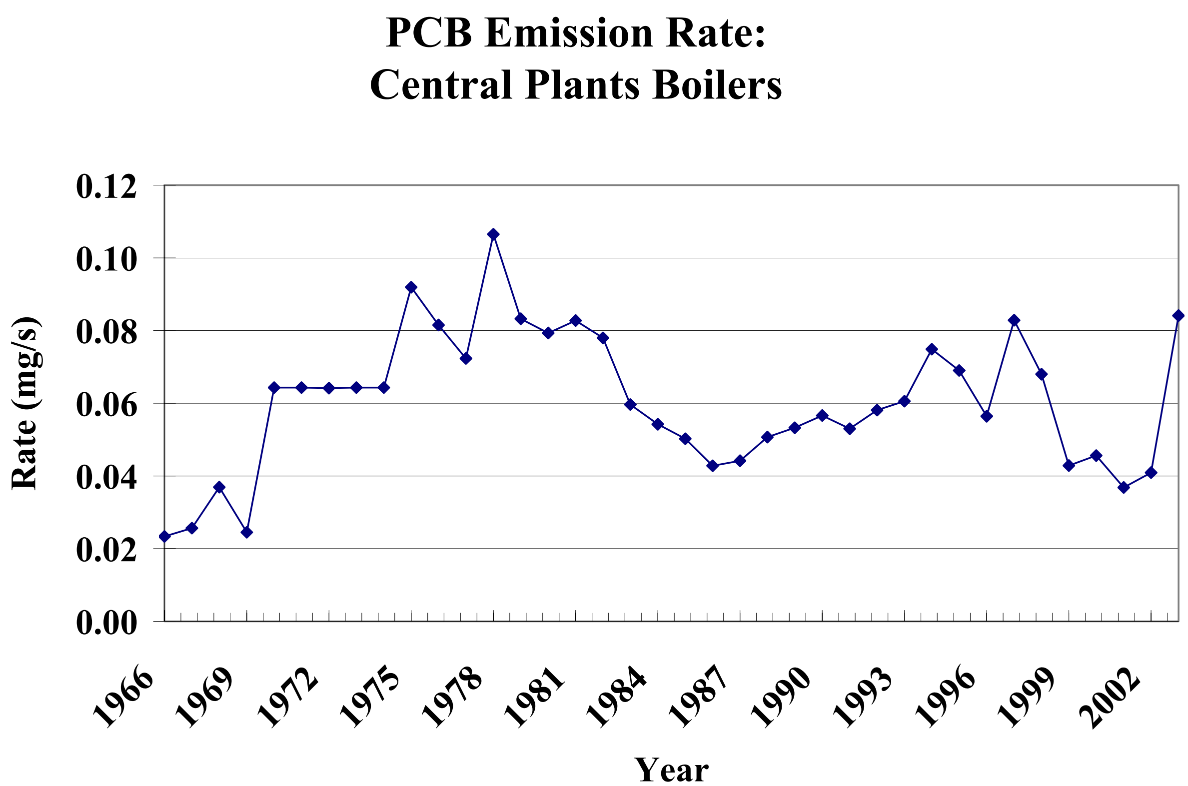

Figure 5-11: PCB emission rates versus year from Boilers, as supplied by Sierra Research.

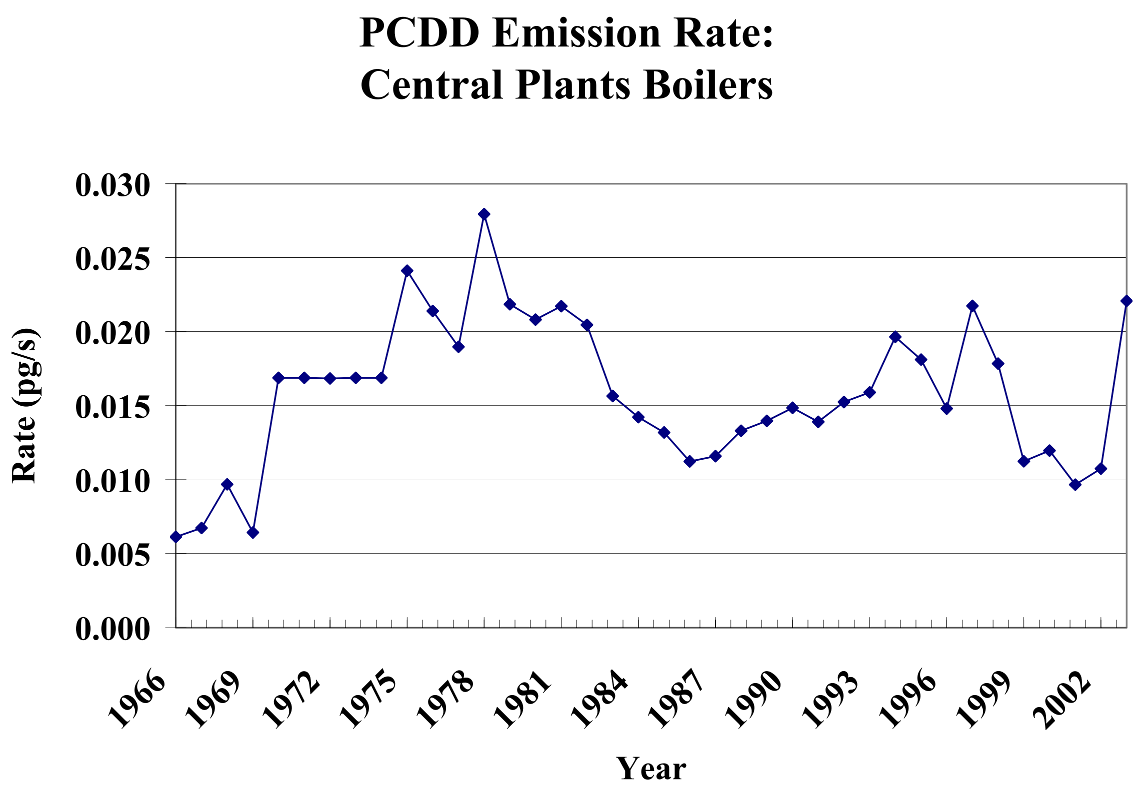

Figure 5-12: TEQ PCDD emission rates versus year from Boilers, as supplied by Sierra Research.

6 EnviroComp Modeling Approach (Tracer-Based Dispersion Modeling) and Results

6.1 Introduction

It is clear that the two-month tracer experiment at BHHS provides very reliable estimates of the actual dispersion rates in this unique environment. These site-specific dispersion rates are scientifically superior to the generic dispersion rates used in standard air pollution models such as ISC3.

It is well established in the scientific and regulatory communities that tracer data represent the highest level of information about atmospheric diffusion. Tracer data are actually the "benchmark" against which air pollution models are expected to be compared for full scientific credibility, as discussed, for example, in the recent EPA Final Rule[75].

As discussed in Section 4.1, we can directly use the average D values calculated from the tracer data, for each source and each receptor location, and multiply this value by the average emission rate, Q, to compute long-term average concentration χ in a straightforward manner, without the use of a dispersion model

$$\chi = Q \cdot D \tag{6.1}$$

This is the simple, basic formulation of our approach – a Tracer-Based Dispersion Model, as discussed below more completely.

6.2 Formulation

The main output of the Tracer-Based Dispersion Model is the annual average concentration to which a plaintiff is exposed while at BHHS or nearby areas. This is obtained by multiplying the

[75] Section 6.1 of 40 CFR Part 51 - Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and Other Revisions; Final Rule, November 9, 2005. Federal Register / Vol. 70, No. 216 / Wednesday, November 9, 2005 / Rules and Regulations. http://www.epa.gov/scram001/guidance/guide/appw_05.pdf.

average concentrations estimated to exist on campus by the fraction of hours over the averaging time that a plaintiff claims exposure. We call this concentration the "exposure concentration", and denote it as χ_e. We use dispersion factors, χ/Q, measured during the tracer experiment (Section 4) and the emission rates supplied to us by Ms. Wilson for the drill sites and Mr. Rubenstein of Sierra Research (Boilers and Cooling Tower) for the Central Plants (Section 5) to estimate the average concentrations on campus. Information supplied by plaintiffs on questionnaires, during depositions and from other information was used to determine the number of hours spent on campus, which we refer to below as "plaintiff hours".

We classify the long-term concentrations and plaintiff hours as four types:

- Main Campus, School Year
- Main Campus, Summer School
- Athletic Field, School Year
- Athletic Field, Summer School.

"School Year" (SY) is defined as the period of time comprising fall and spring semesters, and "Summer School" (SS) the period of time comprising summer school. "Athletic Field" (AF) is the area of campus comprising the lower and upper athletic fields, track, bleachers and two tennis courts immediately east of the football field, and "Main Campus" (MC) is the remaining portion of the campus – generally to the north and west of the athletic area. See Figure 6-1 for a map depicting these areas. The exposure concentration is then calculated as

$$\chi_e = \frac{h_{MC}^{SY}\chi_{MC}^{SY} + h_{MC}^{SS}\chi_{MC}^{SS} + h_{AF}^{SY}\chi_{AF}^{SY} + h_{AF}^{SS}\chi_{AF}^{SS}}{H} \qquad (6.2)$$

where h denotes the plaintiff hours, χ is the long-term average concentration, and H is the number of hours in a year (8,760 for typical years, 8,784 for leap years). The sub- and superscripts ‘MC’, ‘AF’, ‘SY’, ‘SS’ on *h* and χ refer to which combination of MC/AF and SY/SS is being represented.

Equation 6.2 is computed for each plaintiff for every “school year” he or she claims to have spent time on campus. We define a school year to be the summer and fall semesters of a given year and the spring semester of the following year. Therefore, for example, a computed value of χ_e for 1984 is roughly that over the time period June 1984 through the end of May 1985.

The concentrations on the right-hand side Equation 6.2 represent sums of the contributions from all of the sources (New Drill Site, Old Drill Site, Drill Site #1, Wolfskill, Boilers and Cooling Towers). The concentrations resulting from a given source at the MC and AF were calculated as the product of the dispersion factors, χ/Q (s/m^3), for that source at the MC and AF and the emission rate, Q (g/s), for the source, following Equation 6.1.

6.3 Inputs

6.3.1 Dispersion Factors

The dispersion factors estimated from the tracer data for each of the four combinations of MC/AF and SY/SS are presented for each source in Table 6-1. The procedure for computing these is now described.

For the New Drill Site, Drill Site #1, Boilers, and Cooling Towers, we first averaged over the experimental period 25 February–30 April 2005 the 4-hour averaged dispersion factor measurements at each tracer Receptor 1 through 12. This was done for measurements from each of the four corresponding release sites: PMCP (corresponding to fugitive emissions from the New Drill Site), PDCH (corresponding to fugitive emissions from Drill Site #1), PMCH (corresponding to emissions from the Boilers) and PTCH (corresponding to emissions from the Cooling Towers). This step results in single long-term average dispersion factors from each source at each Receptor 1 through 12. The SY factors were obtained by carrying out this procedure using the 4-hour averages measured each day from 0800-1200 and 1200-1600 LST, while for SS we used those measured from 0800-1200 LST. These times reflect the typical times of day spent by students on campus during school year and summer school periods, respectively.

The MC factors for each source were then obtained by averaging the long-term average factors from each source at Receptors 3, 4, 5, 6, 7, 8, 9, and 12, while the AF factors were obtained by taking the maximum of the average factors at Receptors 1, 2, 10, and 11. Figure 6-1 depicts this grouping of receptors. As seen, the receptors chosen to represent MC are spread fairly evenly throughout the main campus area, and therefore the choice to take the average dispersion factor over these receptors is reasonable. For AF, on the other hand, the fact that the receptors chosen to represent the athletic area have limited coverage of the area close to the sources makes taking the average over these receptors inappropriate to represent the entire field. The choice to take the maximum of the average dispersion factors at the four AF receptors is therefore made since, while still most likely underestimating dispersion factors close to the sources, the maximum value overestimates dispersion factors in the athletic field area surrounding the three receptors that are not the maximum. Any bias introduced by not having receptors on the athletic field close to the sources will thus be reduced.

For the Old Drill Site we applied the same procedure as just described, except that, since no tracer release corresponds to the Old Drill Site, we had to approximate the long-term average dispersion factors at the 12 receptors resulting from this source. We did this by applying a linear relationship for the logarithm of dispersion factor versus logarithm of the distance of receptor to source. The linear relationship is derived by fitting the long-term average dispersion factors for the New Drill Site. The regression lines and New Drill Site dispersion factors used to generate them are depicted in Figure 6-2 and Figure 6-3. The lines fit an equation of the form,

$$\log_{10}\left(\frac{\chi}{Q}\right) = a\log_{10}(\mathrm{d}) + b \qquad (6.3)$$

where d is the distance from source to receptor. The values for the fitting parameters are a = -1.53 and b = 4.29 for the SY line (Figure 6-2) and a = -0.99 and b = 3.01 for the SS line (Figure 6-3). The values of dispersion factors at each of the 12 receptors from the Old Drill Site is then computed from Equation 6.3 by plugging in for d the distance from the center of the Old Drill Site to each of the 12 receptors. The rationale for using the New Drill Site as a basis for approximating dispersion factors from the Old Drill Site is that both sites are non-buoyant, fugitive area sources in close proximity to one another. We therefore expect similar dispersion characteristics for the two sources.

For Wolfskill, we apply the dispersion factors computed for Drill Site #1. The two drill sites were close to one another, and therefore dispersion characteristics should be similar. In our modeling, reference to "Drill Site #1" therefore corresponds to concentrations resulting from emissions from both Drill Site #1 and Wolfskill.

The methodology described above was applied for the following plaintiffs: Mr. Davidson, Mr. Gordon, Ms. Lee, Ms. Revel, Ms. Shapiro, Ms. Shore, Mr. Tackaberry, Mr. Frankel, Ms. Gross, and Ms. Day. These plaintiffs were all students at BHHS, and therefore we refer to them as "student plaintiffs".

For plaintiffs Ms. Busch and Mr. Laurie, we modified the approach in following ways to account for special conditions of their time spent in the area.

Christine Busch

In 1994, Ms. Busch worked at the Century City Doctor's Hospital, which is located on Olympic Blvd. just south of Drill Site #1 and Central Plants, and just west of the New Drill Site. No receptor was placed at this location during the tracer experiment. We therefore used dispersion factors from Receptor 3 because a) it is among those of the approximately the same distance to the emission sources at the time (New Drill Site and Boilers) as the hospital is to these sources, and b) it is indoors, and Ms. Busch spent the majority of time indoors. The average dispersion factors are those over the hours 8 AM - 4 PM. No distinction is made between school year and summer school since her time at the hospital corresponded to a work rather than student schedule.

John Laurie

Mr. Laurie reported that he spent the majority his time on campus in the gym and front lawn areas. We therefore derived the dispersion factors for each source as the average values over Receptors 7, 8, 9, and 12 (see Figure 6-1). Since his time on campus was primarily during after-school hours (he was a YMCA instructor and basketball referee), the average dispersion factors at these receptors were those over the hours 4 PM – 8 PM[76]. Calculations of exposure concentration were made using the maximum number of hours he reported that he spent on campus.

6.3.2 Emission Rates

The emission rates applied in our modeling for each plaintiff and source are tabulated in Appendix A.

The total emissions of benzene and formaldehyde from the drill sites for each plaintiff were supplied to us by Ms. Wilson. They are based on the total emissions over each calendar year plotted in Figure 5-1 and Figure 5-2, but made plaintiff-dependent by Ms. Wilson for use in these calculations by only considering emissions that occurred during the time period corresponding to each plaintiff's 'plaintiff hours', discussed in the next subsection. We computed emission rates from these total emissions by dividing by the time period corresponding to the plaintiff hours.

Emission rates were supplied to us for the Central Plants Boilers and Cooling Towers by Sierra Research. The emission rates are plotted in Figure 5-3 and Figure 5-5 through Figure 5-10. The emission rates in these figures represent averages over calendar years, while our model requires averages over a "school year period", covering June 1 of a given year through May 31 of the following year. The emissions applied in our modeling for a given school-year for the Boilers and Cooling Towers are therefore the sum of the emissions supplied to us for the corresponding calendar year multiplied by 7/12 (7 months, June through December) and those supplied to us for the following calendar year multiplied by 5/12 (five months, January through May). The

[76] We recalculated the regression line for Mr. Laurie using the same method illustrated in Equation 6-3 using the data from 4 to 8 PM. We obtained a = -1.90 and b = 5.17 with a R value equal to 0.89.

resulting emission rates are applied equally for SY and SS. These emission rates are tabulated in Appendix A.

6.3.3 Plaintiff Hours

For each plaintiff and each year of claimed exposure, we estimated the number of hours of exposure. For student plaintiffs, the hours were partitioned into each of the four MC/AF and SY/SS categories. The number of hours was estimated from information provided by plaintiffs on their responses to questionnaires, during their depositions and from other available information. The hours as well as the spreadsheets showing the assumptions behind their calculations are presented in Appendix B.

Although we tallied the hours for plaintiff Ms. Busch according to time spent indoors and outdoors, our concentration calculations do not distinguish between indoors and outdoors.

6.4 Results

The values of χ_e calculated from Equation 6.2 for each emitted species, each student plaintiff and each year of claimed exposure are listed in Table 6-2. The same are listed for Ms. Busch and Mr. Laurie in Table 6-3.

The maximum annual average benzene exposure for each plaintiff, as reported in Table 6-2 and Table 6-3, is less than 5 parts-per-trillion (ppt) and often less than 1 ppt. By comparison, the Los Angeles area background concentration for benzene ranges from approximately 40 ppb in the 1960s to approximately 1 ppb today (Figure 6-4). Based on this, exposure to benzene caused by the facilities around BHHS is negligible in comparison to exposure to the Los Angeles background. Also, as a reference, average indoor benzene concentration, based upon 2,128 data points, was estimated by the US EPA[77] to be 5.2 ppb.

77 Shah, J.J. and Heyerdahl, E.K. (1988). "National Ambient Volatile Organic Compounds (VOCs) Data Base Update," EPA/600/3-88-010a, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, March 1988.

The maximum annual average formaldehyde exposure for each plaintiff, as reported in Table 6-2 and Table 6-3, is less than 20 ppt and often less than 10 ppt. By comparison, the Los Angeles area background concentrations have been on the order of 5-10 ppb since around 1989 (Figure 6-5). We expect similar or higher values in earlier years, since a primary source of formaldehyde and its precursors is motor vehicle exhaust, similar to benzene. Based on this, exposure to formaldehyde caused by the facilities around BHHS is negligible in comparison to exposure to the Los Angeles background.

The maximum annual average arsenic exposure for each plaintiff, as reported in Table 6-2 and Table 6-3, is less than 2 picogram per cubic meter (pg/m^3)[78]. By comparison, the Los Angeles area background concentrations for arsenic are around 1 nanogram[79] (ng) per cubic meter (Figure 6-6), which equals 1,000 pg/m^3. Based on this, exposure to arsenic caused by the facilities is roughly 1,000 times less than the Los Angeles background, and is therefore negligible.

The maximum annual average nickel exposure for each plaintiff, as reported in Table 6-2 and Table 6-3, is less than 10 pg/m^3. By comparison, the Los Angeles area background concentration for nickel is approximately 6 ng/m^3 (Figure 6-7). Based on this, exposure to nickel caused by the facilities is roughly 1,000 times less than the Los Angeles background, and is therefore negligible.

The maximum annual average chromium exposure for each plaintiff, as reported in Table 6-2 and Table 6-3, is less than 40 pg/m^3. By comparison, the Los Angeles area background concentration for chromium is approximately 6 ng/m^3 (Figure 6-8). Based on this, exposure to chromium caused by the facilities is roughly 100 times less than the Los Angeles background, and is therefore negligible.

The maximum annual average PAH exposure for each plaintiff, as reported in Table 6-2 and Table 6-3, is less than 0.5 pg/m^3. By comparison, the Los Angeles area background

78 1 picogram = 10^{-12} gram.
79 1 nanogram = 10^{-9} gram.

concentration for PAH is approximately between 1 and 3 ng/m^3 (Figure 6-9)[80]. Based on this, exposure to PAH caused by the facilities is roughly between 1,000 and 10,000 times less than the Los Angeles background, and is therefore negligible.

The maximum annual average PCB exposure for each plaintiff, as reported in Table 6-2 and Table 6-3, is less than 0.1 pg/m^3. This value is orders of magnitude lower than a typical urban background[81].

The maximum annual average TEQ PCDD exposure for each plaintiff, as reported in Table 6-2 and Table 6-3, is less than 0.03 attograms (ag) per cubic meter (ag/m^3)[82]. This value is orders of magnitude lower than a typical urban background[83].

The annual average hexavalent chromium (Cr^{+6}) exposure for each plaintiff, as reported in Table 6-2 and Table 6-3, is less than 200 pg/m^3 and often less than 100 pg/m^3. By comparison, the Los Angeles area background concentration for Cr^{+6} is approximately between 0.1 and 0.4 nanograms per cubic meter (Figure 6-10), or in other words 100-400 pg/m^3. Based on this, exposure to Cr^{+6} caused by the facilities is comparable with the Los Angeles background.

Mr. Tarr computes long-term average concentrations for these chemicals that are much higher - in the case of benzene generally between three and four orders of magnitude higher - than what we obtain. For example, for the value of long-term average benzene concentrations that Dr. Clark takes from Mr. Tarr's modeling results for his 1985 Zone 1 (athletic field) exposure calculation is 33.26 µg/m^3 = 10.2 ppb[84]. The long-term average benzene concentration we

80 The background values plotted for PAH in Figure 6-8 are the sum the six PAH species measured by CARB ATN. These measurements are reported at http://www.arb.ca.gov/adam/toxics/sitesubstance.html. The summed species are: benzo(a)pyrene, benzo(b)fluoroanthene, benzo(g,h,i)perylene, benzo(k)fluoroanthene, dibenz(a,h)anthracene and indeno(1,2,3-cd)pyrene.

81 http://www.arb.ca.gov/aqa/dioxin/cadamp.html and Table 1 of http://www.delta-institute.org/publications/EisenreichWP.pdf.

82 1 attogram = 10^{-18} gram.

83 http://www.arb.ca.gov/aqa/dioxin/cadamp.html; http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=54886; and http://www.deh.gov.au/settlements/publications/chemicals/dioxins/report-4/appendix-f.html.

84 This is reported in Dr. Clark's spreadsheet "Master Annual Benzene (Version 1)" in the worksheet entitled "NDS(2)-DS(1)".

compute for 1985 on the athletic field, on the other hand, is about 0.0038 μg/m^3 = 0.0012 ppb[85]. As discussed in Section 5.3, Mr. Tarr's maximum benzene emission rate from the New Drill Site for 1985 (Mr. Tarr's primary source of benzene for this year) is 964 mg/s; whereas, Ms. Wilson's emission rate for this year is about 0.3 mg/s (Appendix A). Mr. Tarr's long-term average benzene concentrations and emission rates in this case are therefore both between three and four orders of magnitudes higher than the benzene concentrations we compute and the emission rates Ms. Wilson computes for this case. Since concentrations are proportional to emission rates, the difference in emission rates explains the difference between Mr. Tarr's and our long-term concentration values for this case. A check for other years and other chemicals yields the same conclusion.

In contrast, unlike the differences in emission rates between Mr. Tarr and Ms. Wilson - which are huge - the differences in the dispersion factors used by Mr. Tarr (which result from Dr. Neff's wind tunnel calculations) and by us are relatively minor. Therefore, the overwhelming majority of the difference between Mr. Tarr's long-term concentrations and ours is due to the use of very different emission rates.

85 This is calculated by multiplying the dispersion factor given for the New Drill Site in Table 6-1 for "Athletic Field" and "School Year" by the benzene emission rate for 1985-1986 School Year for Ms. Melissa Gross (Appendix A). The New Drill Site is the primary source of benzene emissions on the athletic field during 1985.

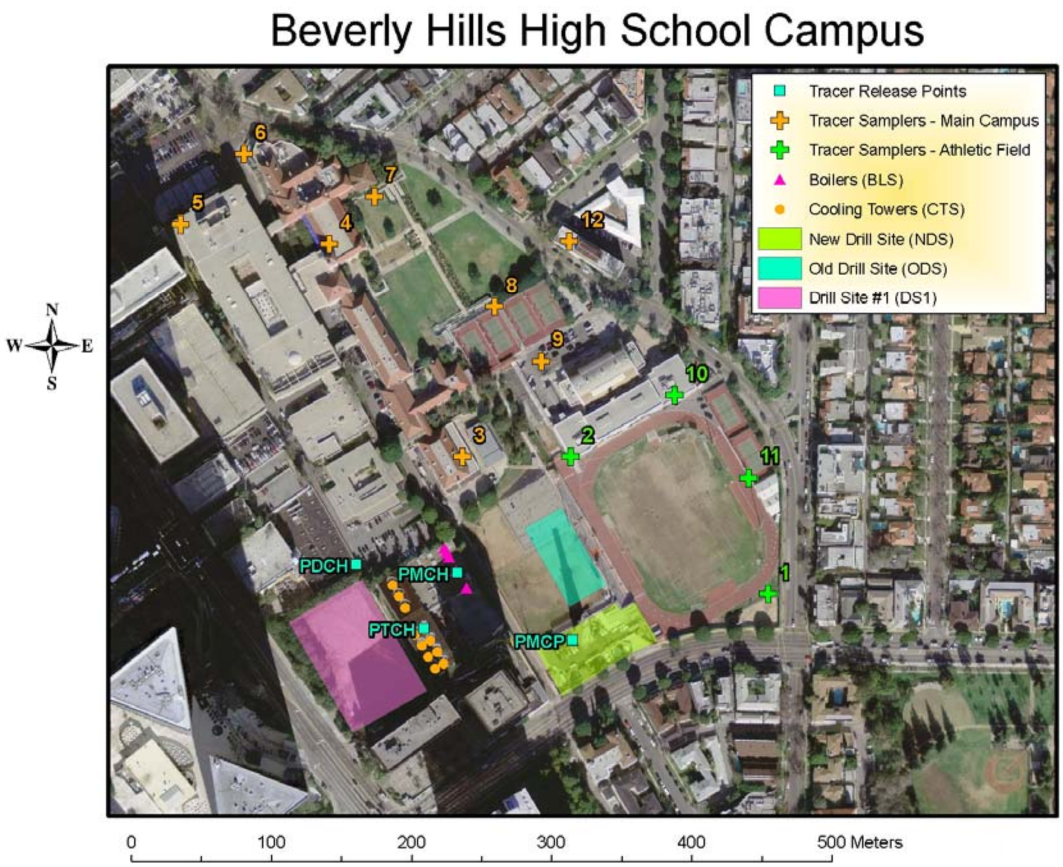

Figure 6-1: Map of Beverly Hills High School depicting Main Campus and Athletic Field Area, as well as tracer experiment receptors.

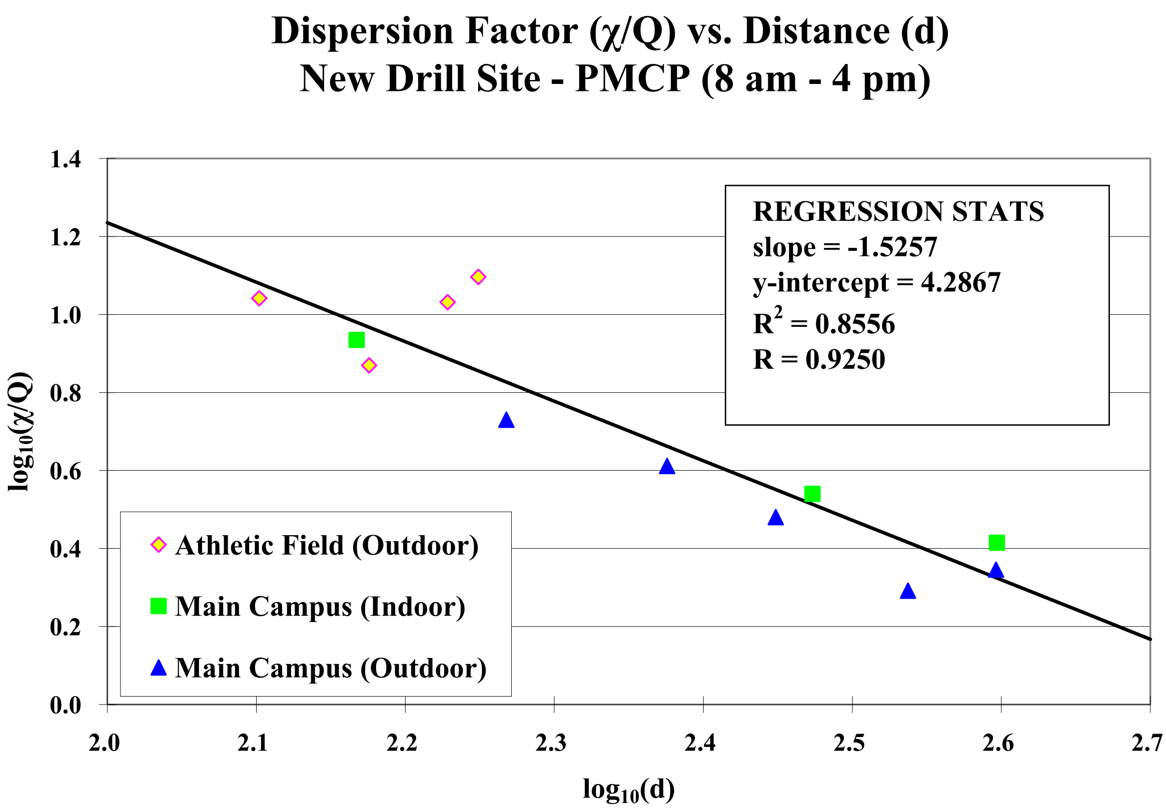

Figure 6-2: Logarithmic plot of observed dispersion factors (μs/m^3) versus distance (m) along with least-squares regression line for tracer experimental data from release Site PMCP, corresponding to fugitive emissions from the New Drill Site. Plot of data for period 0800-1600 LST.

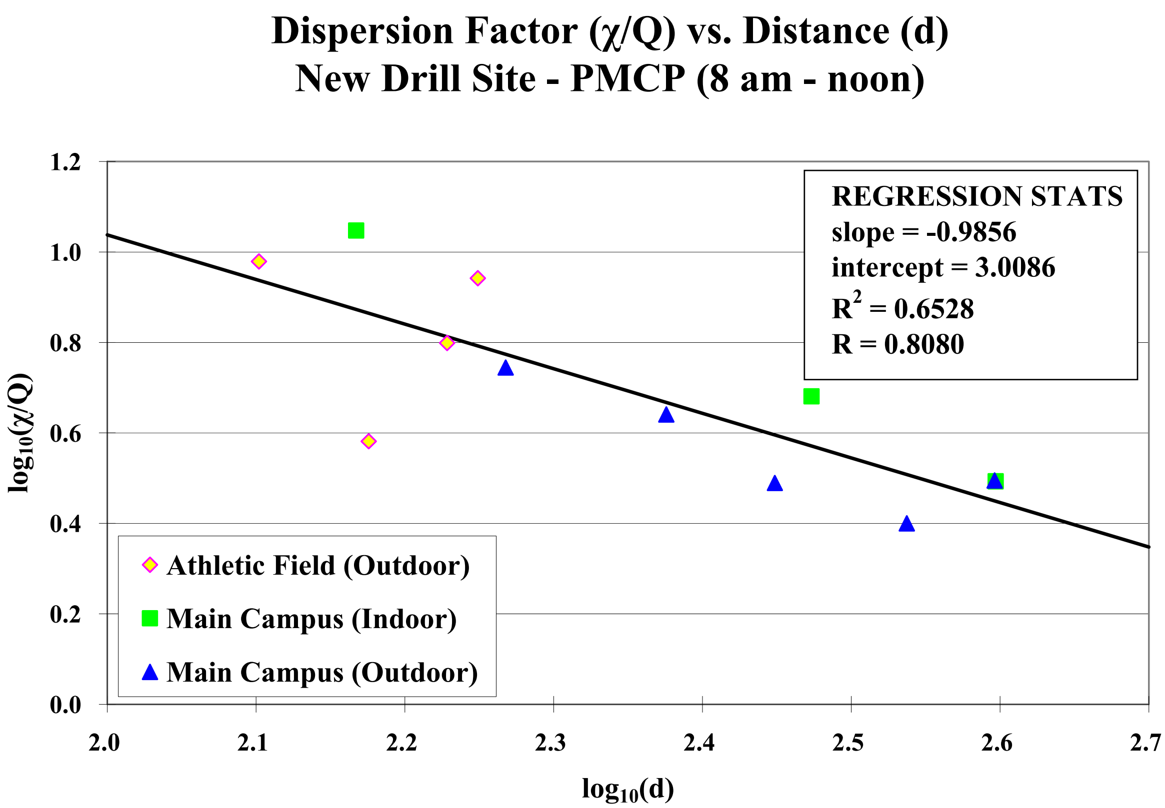

Figure 6-3: As Figure 6-2, but for observations during the hours 0800-1200 LST.

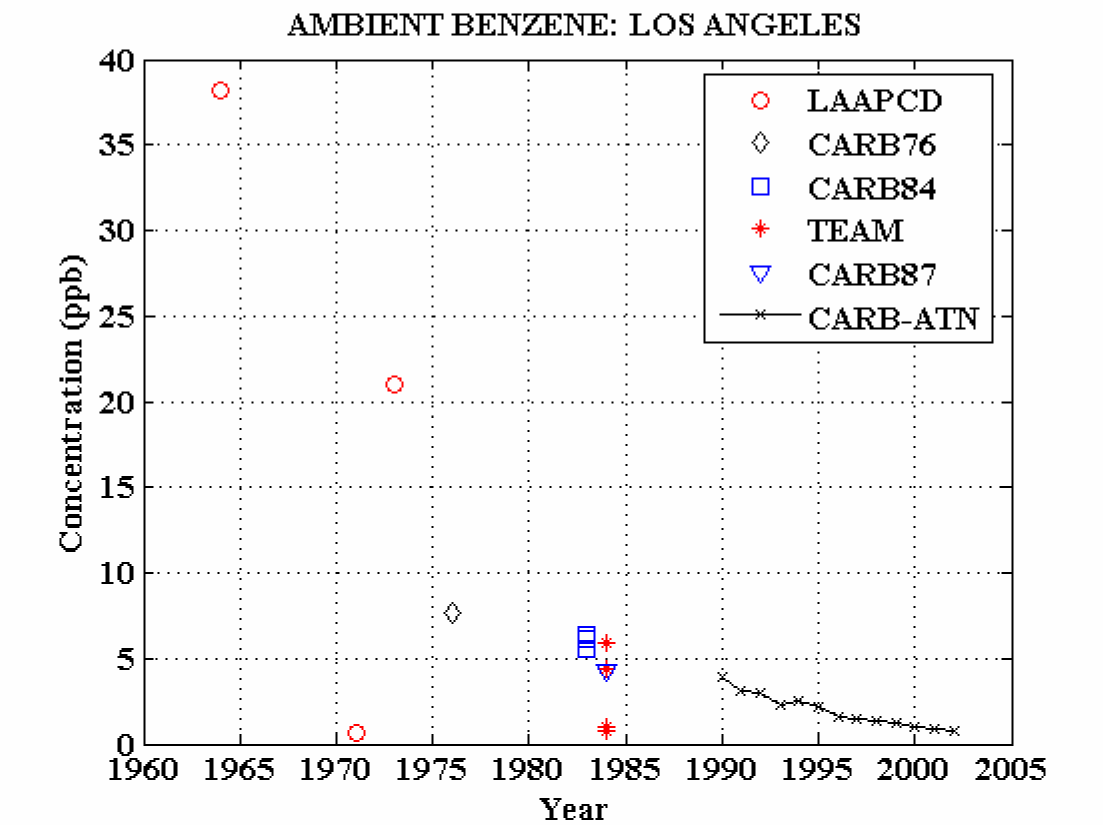

Figure 6-4: Ambient benzene concentrations in Los Angeles area, as taken from data from California Air Resources Board Air Toxic Network, California Air Resources Board reports, and various other literature sources. See Appendix C for references and further details.

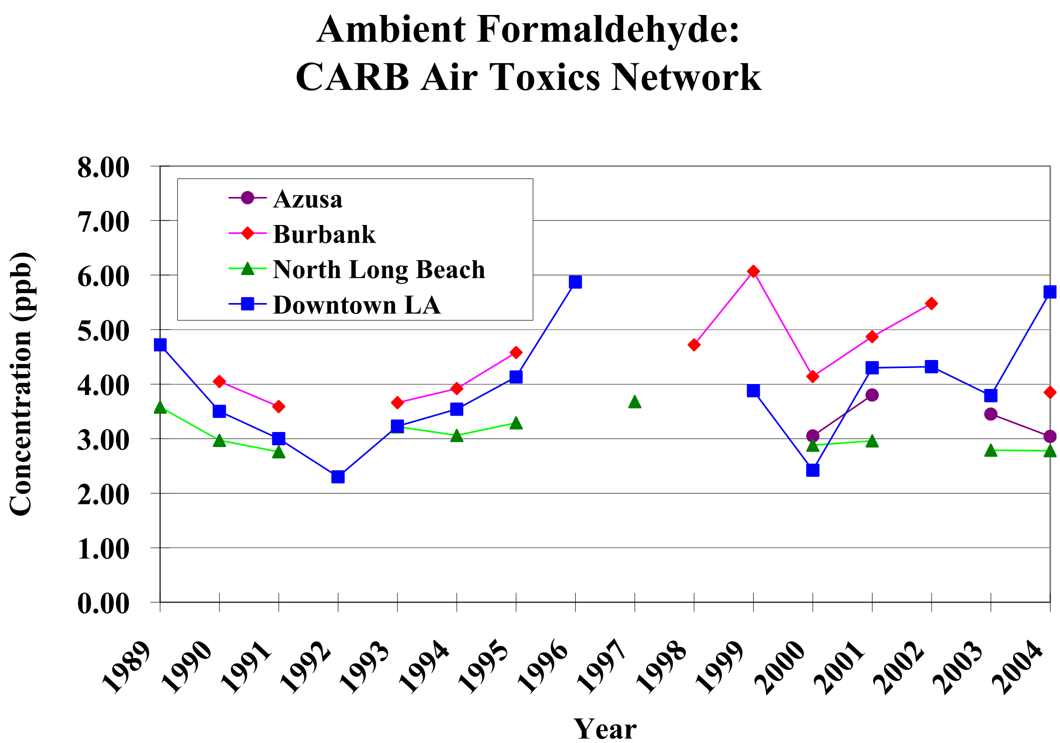

Figure 6-5: Annual averaged ambient formaldehyde concentration at selected stations in the California Air Resources Board Air Toxics Network.

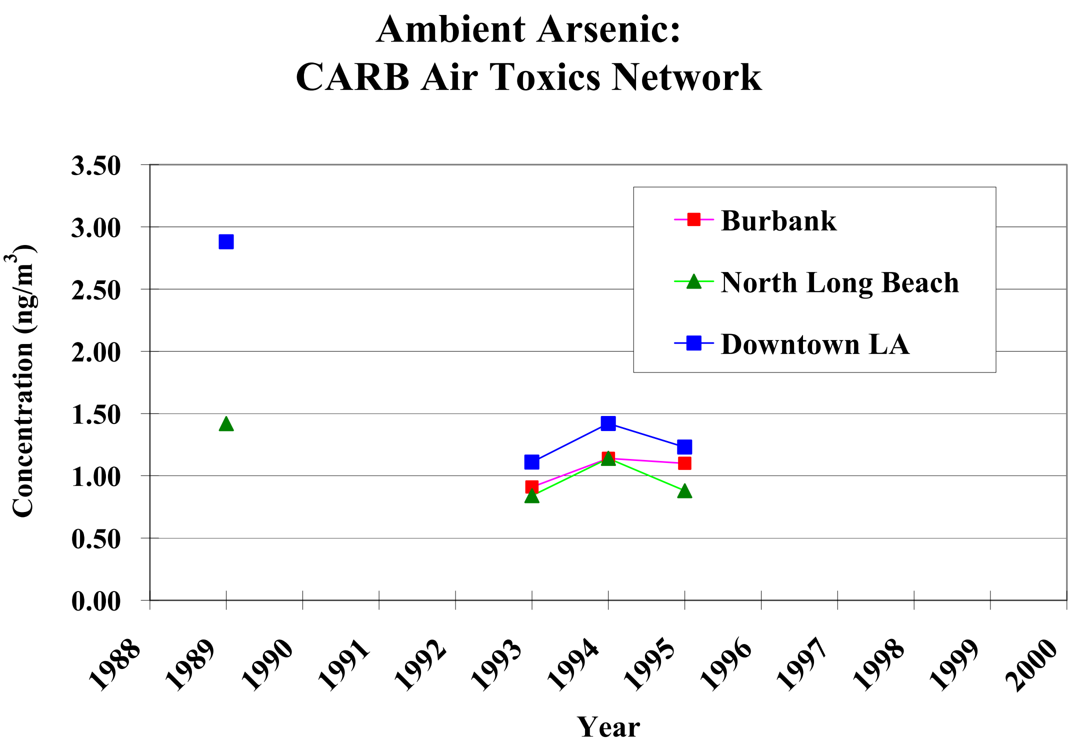

Figure 6-6: Annual averaged ambient arsenic concentration at selected stations in the California Air Resources Board Air Toxics Network.

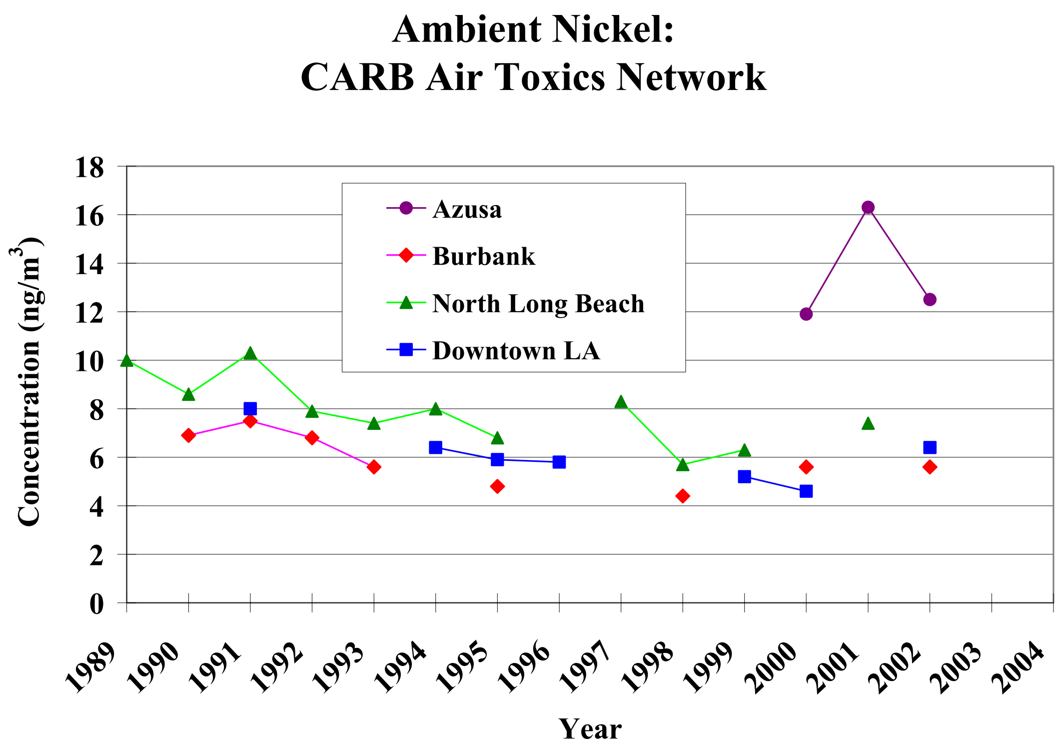

Figure 6-7: Annual averaged ambient nickel concentration at selected stations in the California Air Resources Board Air Toxics Network.

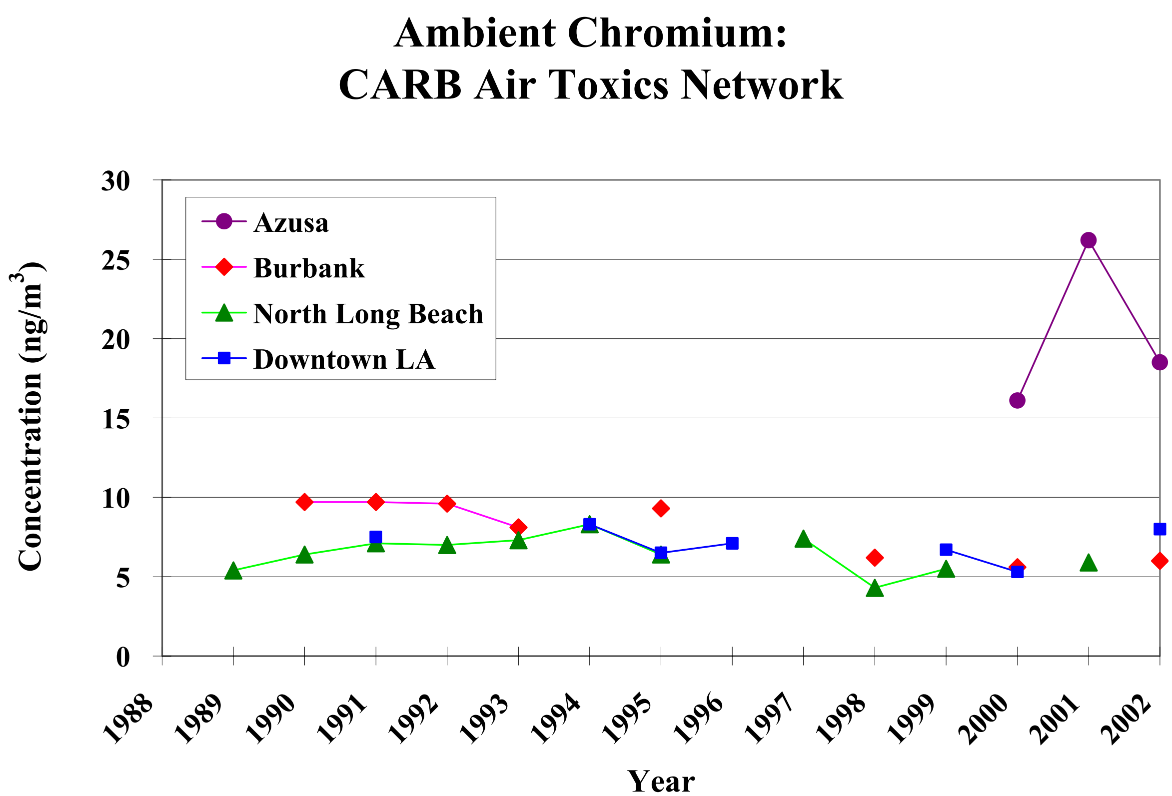

Figure 6-8: Annual averaged ambient chromium concentration at selected stations in the California Air Resources Board Air Toxics Network.

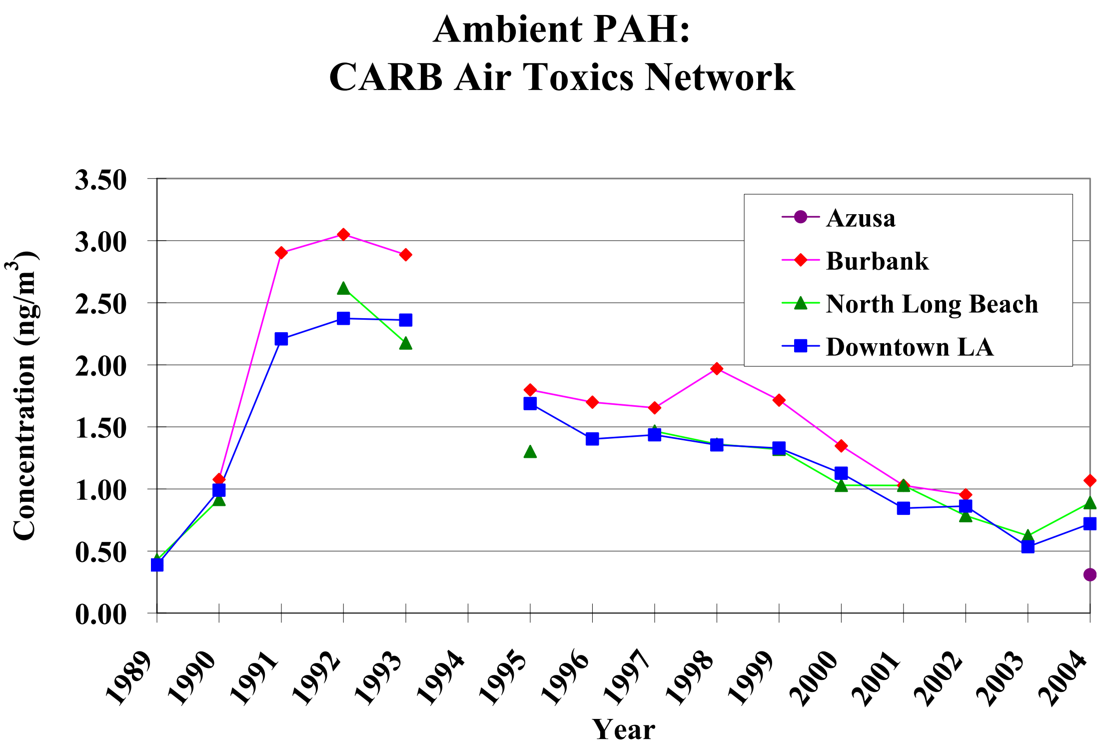

Figure 6-9: Annual averaged ambient concentration of polyaromatic hydrocarbon (PAH) at selected stations in the California Air Resources Board Air Toxics Network.

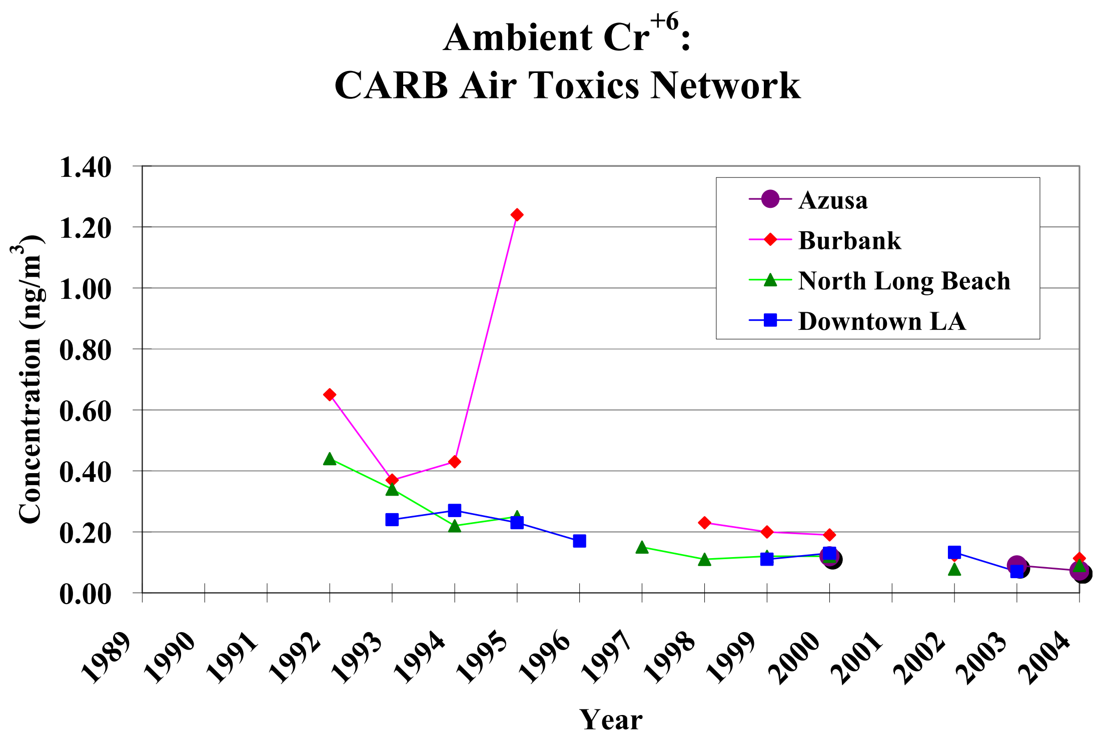

Figure 6-10: Annual averaged ambient concentration of hexavalent chromium (Cr^{+6}) at selected stations in the California Air Resources Board Air Toxics Network.

Table 6-1: Dispersion factors (μs/m^3) calculated from average concentrations measured at Beverly Hills High School during the field experiment conducted by Tracer ES&T (Footnote 50, Section 4). Dispersion factors are shown for the five facilities operated by the defendants that have been incorporated into our Tracer-Based Dispersion Model (described in Section 6); and for the twelve plaintiffs (ten student plaintiffs, denoted "Students", Ms. Busch, and Mr. Laurie). Abbreviations denote the dispersion factors used to represent the following: SY – School Year, SS – Summer School, MC – Main Campus, AF – Athletic Field. See Section 0 for additional details.

Students

Dispersion Factor	New Drill Site	Old Drill Site	Drill Site #1	Boilers	Cooling Towers
$(\chi/Q)^{SY}_{MC}$	3.916	6.298	13.913	3.111	3.999
$(\chi/Q)^{SY}_{AF}$	12.483	27.054	13.742	8.107	8.771
$(\chi/Q)^{SS}_{MC}$	4.712	5.429	8.437	2.607	3.158
$(\chi/Q)^{SS}_{AF}$	9.533	14.609	5.948	4.942	5.804

Busch

Dispersion Factor	New Drill Site	Boilers
χ/Q	8.607	4.820

Laurie

Dispersion Factor	New Drill Site	Old Drill Site	Drill Site #1	Boilers	Cooling Towers
χ/Q	3.491	6.819	13.521	2.285	3.146

Table 6-2: Annually averaged concentrations to which each student plaintiff was exposed for each considered species, as calculated by our Tracer-Based Dispersion Model using dispersion factors calculated from the tracer experiment (“Students” entry of Table 6-1). See Section 6 for additional details. (PCDD is expressed as TEQ).

Plaintiff	Year*	Benzene (ppt)	Formaldehyde (ppt)	Arsenic (pg/m^3)	Chromium (pg/m^3)	Nickel (pg/m^3)	PAH (pg/m^3)	PCB (pg/m^3)	PCDD (ag/m^3)	PCDF	Cr^{+6} (pg/m^3)
Melissa Gross	1984	0.545	8.029	0.894	15.932	4.355	0.209	0.049	0.013	---	108.209
	1985	0.452	5.814	0.868	15.459	4.225	0.202	0.048	0.013	---	94.448
	1986	0.436	5.263	0.752	13.406	3.664	0.176	0.042	0.011	---	95.433
	1987	0.572	8.993	0.511	9.099	2.487	0.119	0.028	0.007	---	76.904
Monica Revel	1989	0.879	16.606	0.564	10.049	2.747	0.132	0.031	0.008	---	51.352
	1990	0.704	7.681	0.533	9.497	2.596	0.124	0.029	0.008	---	0.417
	1991	0.105	2.434	0.569	10.143	2.772	0.133	0.031	0.008	---	0.115
	1992	0.069	1.840	0.573	10.207	2.790	0.134	0.032	0.008	---	---
	1994	0.007	0.414	0.151	2.698	0.738	0.035	0.008	0.002	---	---
	2001	0.012	0.259	0.059	1.057	0.289	0.014	0.003	0.001	---	---
Gary Davidson	1981	0.778	8.999	1.799	32.048	8.760	0.420	0.100	0.026	---	155.246
Janet Lee Day	1977	0.000	0.031	0.012	0.206	0.056	0.003	0.001	0.000	---	0.887
	1980	1.092	10.204	1.549	27.594	7.542	0.361	0.086	0.022	---	139.495
	1981	0.780	7.187	1.450	25.837	7.062	0.338	0.080	0.021	---	132.058
	1982	0.602	8.700	1.296	23.081	6.309	0.302	0.072	0.019	---	134.772
	1983	0.536	6.815	1.079	19.222	5.254	0.252	0.060	0.016	---	137.490
Jeffrey Frankel	1985	0.330	3.914	0.523	9.323	2.548	0.122	0.029	0.008	---	60.113
	1986	0.341	3.949	0.484	8.625	2.358	0.113	0.027	0.007	---	64.911
	1987	0.516	8.395	0.548	9.771	2.671	0.128	0.030	0.008	---	84.198
	1988	0.319	5.194	0.609	10.849	2.965	0.142	0.034	0.009	---	96.873
Richard Gordon	1978	0.591	7.037	1.494	26.623	7.277	0.349	0.083	0.022	---	111.885
	1979	0.985	13.735	1.255	22.350	6.109	0.293	0.069	0.018	---	111.274
	1980	0.871	9.609	1.260	22.452	6.137	0.294	0.070	0.018	---	112.945
	1981	0.610	6.656	1.241	22.111	6.044	0.289	0.069	0.018	---	111.355
Karen Lee	1961	2.052	0.428	---	---	---	---	---	---	---	---
	1962	2.860	6.780	---	---	---	---	---	---	---	---
	1963	3.070	1.024	---	---	---	---	---	---	---	---
	1964	2.827	2.032	---	---	---	---	---	---	---	---
Jaimie Shapiro	1973	0.660	3.942	0.639	11.378	3.110	0.149	0.035	0.009	---	74.399
	1974	0.950	11.185	0.793	14.133	3.863	0.185	0.044	0.012	---	78.359
	1975	0.506	4.079	0.908	16.168	4.420	0.212	0.050	0.013	---	77.519
	1976	0.505	5.131	0.810	14.430	3.944	0.189	0.045	0.012	---	77.945
Linnea Shore	1975	0.551	4.262	0.982	17.502	4.784	0.229	0.054	0.014	---	83.699
	1976	0.554	5.441	0.927	16.515	4.514	0.216	0.051	0.013	---	88.945
	1977	0.496	4.737	1.049	18.684	5.107	0.245	0.058	0.015	---	90.562
	1978	0.645	7.452	1.640	29.218	7.986	0.383	0.091	0.024	---	122.085
Stace Tackaberry	1951	---	---	---	---	---	---	---	---	---	---
	1952	---	---	---	---	---	---	---	---	---	---
	1953	0.012	0.209	---	---	---	---	---	---	---	---
	1954	---	---	---	---	---	---	---	---	---	---
	1955	4.274	6.252	---	---	---	---	---	---	---	---
	1956	5.565	0.454	---	---	---	---	---	---	---	---
	1957	3.881	1.336	---	---	---	---	---	---	---	---

* “Year” corresponds to the period comprising June 1 of the listed year to May 31 of the following year, for example ‘1984’ refers to the time period June 1, 1984 – May 31, 1985.

Table 6-3**:** Annually averaged concentrations to which plaintiffs Ms. Busch and Mr. Laurie were exposed for each considered species, as calculated by our Tracer-Based Dispersion Model. Dispersion factors applied for these calculations are taken from the corresponding plaintiff's entry in Table 6-1. See Section 6 for additional details. (PCDD is expressed as TEQ).

Christine Busch

Year*	Benzene (ppt)	Formaldehyde (ppt)	Arsenic (pg/m^3)	Chromium (pg/m^3)	Nickel (pg/m^3)	PAH (pg/m^3)	PCB (pg/m^3)	PCDD (ag/m^3)	PCDF	Cr^{+6} (pg/m^3)
1994	0.0428	1.5947	0.475	8.458	2.312	0.111	0.026	0.007	---	---

John Laurie

Year*	Benzene (ppt)	Formaldehyde (ppt)	Arsenic (pg/m^3)	Chromium (pg/m^3)	Nickel (pg/m^3)	PAH (pg/m^3)	PCB (pg/m^3)	PCDD (ag/m^3)	PCDF	Cr^{+6} (pg/m^3)
1973	0.348	0.957	0.237	4.214	1.152	0.055	0.013	0.003	---	31.007
1974	0.385	2.649	0.279	4.967	1.358	0.065	0.015	0.004	---	31.007
1975	0.271	1.319	0.321	5.713	1.561	0.075	0.018	0.005	---	30.838
1976	0.308	1.624	0.382	6.798	1.858	0.089	0.021	0.006	---	41.342
1977	0.285	1.571	0.424	7.560	2.067	0.099	0.023	0.006	---	41.342
1978	0.291	1.735	0.475	8.455	2.311	0.111	0.026	0.007	---	41.342
1980	0.413	2.080	0.397	7.065	1.931	0.092	0.022	0.006	---	41.342
1981	0.326	1.844	0.396	7.055	1.928	0.092	0.022	0.006	---	41.342
1982	0.186	1.730	0.345	6.144	1.679	0.080	0.019	0.005	---	41.342
1983	0.169	1.296	0.280	4.991	1.364	0.065	0.015	0.004	---	41.117

* For Ms. Busch, "Year" corresponds to the calendar year January 1 to December 31. For Mr. Laurie, "Year" corresponds to June 1 of the listed year to May 31 of the following year, for example '1974' refers to the time period June 1, 1974 – May 31, 1975.

7 Tracer-Based Dispersion Model using Wind Tunnel Dispersion Factors

We also calculated the exposure concentration from the dispersion factors derived from Dr. Neff's wind tunnel results. These dispersion factors are listed in Table 7-1. Also shown are dispersion factors derived from Dr. Neff's Study I report.

The dispersion factors were computed from the long-term averages presented in Dr. Neff's Table 39 (Table 2-1) in the following manner. First, for each source and each of Dr. Neff's receptors the factors for each year in the table were averaged. Receptors 38, 41-45, and 47 were then grouped as AF, the remainder as MC (see Figure 2-2 for a map of the receptors) and averages of the factors within these groups were computed to arrive at single MC and AF factors for each source. The determination of AF factors by taking the average of the receptor values (rather than the maximum over them, as was done when using tracer experiment dispersion factors – see Section 6) is appropriate since the chosen Neff-receptors for the athletic field are uniformly spread over the area.

We note that by averaging the dispersion factors over all six years for which Dr. Neff provides wind tunnel results, the effects of variation of these factors from year-to-year are not accounted for in our simulations. This variation arrives from two sources in Dr. Neff's simulations: changing LAX winds from year-to-year (which he uses to perform his long-term averaging) and changes in building configuration applied in each of his six runs. A scan through Table 2-1, however, shows that the variation due to the combination of these sources of variability is, with small exception, within a factor of two. Averaging out this variation therefore does not introduce great error.

The resulting MC and AF dispersion factors are assumed equal for SY and SS. Dr. Neff's annual averages were for the hours 0800-1700 LST (Table 2-1), and are therefore most applicable for a full school day, i.e., SY. The choice to apply them also for morning hours associated with summer school was made for simplicity. We do not expect that any special analysis to recomputed Dr. Neff's long-term averages over just morning hours would significantly change the final concentration results, however, since plaintiffs spend much less time on campus during summer-school hours.

Exposure concentrations were then calculated in the same manner as described in Section 6, i.e., emission rates were multiplied by the dispersion factors for each source, the resulting products summed over all sources, and exposure concentration was calculated via Equation 6.2 using the plaintiff hours.

Exposure concentrations calculated for each student plaintiff and emitted species using the wind tunnel dispersion factors are shown in Table 7-2**.** The concentrations for Ms. Busch and Mr. Laurie are shown in Table 7-3. By visual comparison, it can be seen that these values are similar to the ones in Table 6-2 and Table 6-3.

To elaborate, the ratios of the concentrations calculated using the wind tunnel dispersion factors over those using tracer experiment factors are shown in Table 7-4 and Table 7-5. As seen, the ratios are generally in the range 0.25 - 3.3, or in other words the differences in results are within a factor of approximately three. Therefore, if we use the dispersion factors derived from the wind tunnel results instead of from the tracer experiment, we obtain exposure concentrations for the plaintiffs that are similar.

These differences in results can be due to a number of factors inherent to the design of each experiment. For example, we have mentioned several limitations to Dr. Neff's wind tunnel experiment in replicating real-world dispersion (e.g., lack of static stability and meandering). Although we have not made any specific analysis to check the extent to which his results are affected by these limitations, some of these may explain a portion of the discrepancies between wind tunnel and tracer-study based results.

One difference we can explain is the larger concentrations for plaintiffs Ms. Lee, Ms. Shapiro, Ms. Shore, and Mr. Tackaberry when using the tracer experiment dispersion factors. These plaintiffs spent time on campus prior to around 1977, at which time Drill Site #1 was the primary source of exposure. The tracer experiment did not locate its tracer-release equipment corresponding to this source (PDCH in the tracer report) at the true source; however, but rather adjacent to it closer to the campus. This results in a shorter transport distance from the tracer release to receptors than in reality between Drill Site #1 and these receptors, and hence the Drill Site #1 dispersion factors for the tracer experiment are higher than those computed from the wind tunnel, since Dr. Neff located his release point for Drill Site #1 at its true position.

Since Mr. Tarr uses correction factors to in effect force his long-term concentrations to the wind tunnel concentrations, we can conclude that if we instead used dispersion factors derived from Mr. Tarr’s long-term concentrations (i.e., by dividing his final long-term concentrations by his emission rates) we would also obtain exposure concentrations for the plaintiffs that are relatively similar to those using the tracer experiment factors.

Table 7-1**:** Dispersion factors (μs/m^3) calculated from average concentrations computed by Dr. Neff from data resulting from his wind tunnel experiment. Dispersion factors are shown for the five facilities operated by the defendants that have been incorporated into our Tracer-Based Dispersion Model (described in Section 6); and for the 12 plaintiffs (ten student plaintiffs, denoted "Students", Ms. Busch, and Mr. Laurie). Abbreviations denote the dispersion factors used to represent the following: MC – Main Campus, AF – Athletic Field. See Section 7 for additional details.

Students

Dispersion Factor	New Drill Site	Old Drill Site	Drill Site #1	Boilers	Cooling Towers
$(\chi/Q)_{MC}$	9.143	26.839	5.066	2.420	0.811
$(\chi/Q)_{AF}$	30.283	50.802	5.028	8.102	3.856

Busch

Dispersion Factor	New Drill Site	Boilers
χ/Q	30.703	6.384

Laurie

Dispersion Factor	New Drill Site	Old Drill Site	Drill Site #1	Boilers	Cooling Towers
χ/Q	3.343	5.938	3.865	2.703	1.348

Table 7-1: (cont'd) As those on the previous page, but computed from concentrations reported in Dr. Neff's Draft I report (see Footnote 8, Section 2.2). See Section 7 for details.

Students

Dispersion Factor	New Drill Site	Old Drill Site	Drill Site #1	Boilers	Cooling Towers
$(\chi/Q)_{MC}$	14.223	28.412	N/A	1.423	0.393
$(\chi/Q)_{AF}$	23.296	52.871	N/A	6.977	2.071

Busch

Dispersion Factor	New Drill Site	Boilers
χ/Q	45.499	2.755

Laurie

Dispersion Factor	New Drill Site	Old Drill Site	Drill Site #1	Boilers	Cooling Towers
χ/Q	3.919	7.090	N/A	1.550	0.717

Table 7-2**:** Annually averaged concentrations to which each student plaintiff was exposed for each considered species, as calculated by our Tracer-Based Dispersion Model using dispersion factors calculated from Dr. Neff's wind tunnel experiments ("Students" entry in Table 7.1, Draft II). See Section 7 for additional details. (PCDD is expressed as TEQ).

Plaintiff	Year*	Benzene (ppt)	Formaldehyde (ppt)	Arsenic (pg/m^3)	Chromium (pg/m^3)	Nickel (pg/m^3)	PAH (pg/m^3)	PCB (pg/m^3)	PCDD (ag/m^3)	PCDF	Cr^{+6} (pg/m^3)
Melissa Gross	1984	0.514	7.593	0.847	15.094	4.126	0.198	0.047	0.012	---	37.551
	1985	0.509	6.602	0.826	14.711	4.021	0.193	0.046	0.012	---	33.097
	1986	0.581	6.871	0.701	12.497	3.416	0.164	0.039	0.010	---	32.901
	1987	0.691	10.879	0.459	8.183	2.237	0.107	0.025	0.007	---	23.209
Monica Revel	1989	0.517	9.066	0.474	8.453	2.310	0.111	0.026	0.007	---	13.185
	1990	0.603	5.350	0.445	7.933	2.169	0.104	0.025	0.006	---	0.107
	1991	0.238	3.464	0.479	8.532	2.332	0.112	0.026	0.007	---	0.029
	1992	0.154	2.039	0.479	8.527	2.331	0.112	0.026	0.007	---	---
	1994	0.015	0.435	0.151	2.697	0.737	0.035	0.008	0.002	---	---
	2001	0.027	0.404	0.059	1.056	0.289	0.014	0.003	0.001	---	---
Gary Davidson	1981	0.811	12.336	1.687	30.056	8.216	0.394	0.093	0.024	---	56.725
Janet Lee Day	1977	0.000	0.031	0.012	0.206	0.056	0.003	0.001	0.000	---	0.390
	1980	0.949	16.412	1.366	24.337	6.652	0.319	0.076	0.020	---	42.411
	1981	0.674	8.997	1.261	22.465	6.141	0.294	0.070	0.018	---	38.436
	1982	0.795	12.951	1.135	20.225	5.528	0.265	0.063	0.016	---	40.168
	1983	0.657	9.686	0.945	16.831	4.601	0.220	0.052	0.014	---	40.884
Jeffrey Frankel	1985	0.281	3.409	0.439	7.813	2.136	0.102	0.024	0.006	---	15.589
	1986	0.395	4.690	0.406	7.228	1.976	0.095	0.022	0.006	---	16.833
	1987	0.515	8.189	0.462	8.236	2.251	0.108	0.026	0.007	---	21.824
	1988	0.267	3.679	0.513	9.145	2.500	0.120	0.028	0.007	---	25.109
Richard Gordon	1978	0.403	6.230	1.328	23.657	6.467	0.310	0.073	0.019	---	34.799
	1979	1.125	21.337	1.115	19.860	5.429	0.260	0.062	0.016	---	34.609
	1980	0.884	16.171	1.120	19.946	5.452	0.261	0.062	0.016	---	35.102
	1981	0.582	8.649	1.103	19.650	5.371	0.257	0.061	0.016	---	34.648
Karen Lee	1961	0.814	0.469	---	---	---	---	---	---	---	---
	1962	1.108	2.786	---	---	---	---	---	---	---	---
	1963	1.211	0.686	---	---	---	---	---	---	---	---
	1964	1.149	1.055	---	---	---	---	---	---	---	---
Jaimie Shapiro	1973	0.327	2.529	0.539	9.611	2.627	0.126	0.030	0.008	---	19.788
	1974	0.449	5.466	0.674	12.011	3.283	0.157	0.037	0.010	---	20.797
	1975	0.284	2.962	0.771	13.741	3.756	0.180	0.043	0.011	---	20.574
	1976	0.286	3.261	0.688	12.264	3.352	0.161	0.038	0.010	---	20.687
Linnea Shore	1975	0.301	3.093	0.834	14.858	4.061	0.195	0.046	0.012	---	22.614
	1976	0.317	3.534	0.791	14.092	3.852	0.184	0.044	0.011	---	23.968
	1977	0.300	3.514	0.893	15.918	4.351	0.208	0.049	0.013	---	24.296
	1978	0.427	6.640	1.469	26.178	7.156	0.343	0.081	0.021	---	38.932
Stace Tackaberry	1951	---	---	---	---	---	---	---	---	---	---
	1952	---	---	---	---	---	---	---	---	---	---
	1953	0.004	0.076	---	---	---	---	---	---	---	---
	1954	---	---	---	---	---	---	---	---	---	---
	1955	1.638	2.918	---	---	---	---	---	---	---	---
	1956	2.095	0.535	---	---	---	---	---	---	---	---
	1957	1.478	0.787	---	---	---	---	---	---	---	---

* "Year" corresponds to the period comprising June 1 of the listed year to May 31 of the following year, for example '1984' refers to the time period June 1, 1984 – May 31, 1985.

Table 7-3**:** Annually averaged concentrations to which plaintiffs Ms. Busch and Mr. Laurie were exposed for each considered species, as calculated by our Tracer-Based Dispersion Model using dispersion factors calculated from Dr. Neff's wind tunnel experiments (corresponding plaintiff's entry in Table 7.1, Draft II). See Section 7 for additional details. (PCDD is expressed as TEQ).

Christine Busch

Year*	Benzene (ppt)	Formaldehyde (ppt)	Arsenic (pg/m^3)	Chromium (pg/m^3)	Nickel (pg/m^3)	PAH (pg/m^3)	PCB (pg/m^3)	PCDD (ag/m^3)	PCDF	Cr^{+6} (pg/m^3)
1994	0.142	2.880	0.629	11.202	3.062	0.147	0.035	0.009	---	---

John Laurie

Year*	Benzene (ppt)	Formaldehyde (ppt)	Arsenic (pg/m^3)	Chromium (pg/m^3)	Nickel (pg/m^3)	PAH (pg/m^3)	PCB (pg/m^3)	PCDD (ag/m^3)	PCDF	Cr^{+6} (pg/m^3)
1973	0.109	0.861	0.280	4.985	1.363	0.065	0.015	0.004	---	13.285
1974	0.120	1.436	0.330	5.876	1.606	0.077	0.018	0.005	---	13.285
1975	0.087	1.155	0.379	6.758	1.847	0.088	0.021	0.006	---	13.213
1976	0.102	1.386	0.451	8.042	2.198	0.105	0.025	0.007	---	17.714
1977	0.096	1.477	0.502	8.944	2.445	0.117	0.028	0.007	---	17.714
1978	0.098	1.643	0.561	10.003	2.734	0.131	0.031	0.008	---	17.714
1980	0.156	2.079	0.469	8.358	2.285	0.109	0.026	0.007	---	17.714
1981	0.129	1.810	0.468	8.346	2.281	0.109	0.026	0.007	---	17.714
1982	0.090	1.511	0.408	7.268	1.987	0.095	0.023	0.006	---	17.714
1983	0.079	1.132	0.331	5.904	1.614	0.077	0.018	0.005	---	17.617

* For Ms. Busch, "Year" corresponds to the calendar year January 1 to December 31. For Mr. Laurie, "Year" corresponds to June 1 of the listed year to May 31 of the following year, for example '1974' refers to the time period June 1, 1974 – May 31, 1975.

Table 7-4: Ratio of the exposure concentrations for student plaintiffs calculated using wind tunnel dispersion factors (Table 7-2) over those calculated using tracer experiment dispersion factors (Table 6-2).

Plaintiff	Year*	Benzene	Formaldehyde	Arsenic	Chromium	Nickel	PAH	PCB	PCDD	PCDF	Cr^{+6}
Melissa Gross	1984	0.944	0.946	0.947	0.947	0.947	0.947	0.947	0.947	N/A	0.347025
	1985	1.127	1.136	0.952	0.952	0.952	0.952	0.952	0.952	N/A	0.350422
	1986	1.333	1.306	0.932	0.932	0.932	0.932	0.932	0.932	N/A	0.344752
	1987	1.208	1.210	0.899	0.899	0.899	0.899	0.899	0.899	N/A	0.301797
Monica Revel	1989	0.588	0.546	0.841	0.841	0.841	0.841	0.841	0.841	N/A	0.256757
	1990	0.855	0.697	0.835	0.835	0.835	0.835	0.835	0.835	N/A	0.256750
	1991	2.262	1.423	0.841	0.841	0.841	0.841	0.841	0.841	N/A	0.256757
	1992	2.233	1.108	0.835	0.835	0.835	0.835	0.835	0.835	N/A	N/A
	1994	2.115	1.050	0.999	0.999	0.999	0.999	0.999	0.999	N/A	N/A
	2001	2.352	1.563	0.999	0.999	0.999	0.999	0.999	0.999	N/A	N/A
Gary Davidson	1981	1.042	1.371	0.938	0.938	0.938	0.938	0.938	0.938	N/A	0.365389
Janet Lee Day	1977	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	N/A	0.439608
	1980	0.868	1.608	0.882	0.882	0.882	0.882	0.882	0.882	N/A	0.304035
	1981	0.864	1.252	0.870	0.870	0.870	0.870	0.870	0.870	N/A	0.291057
	1982	1.322	1.489	0.876	0.876	0.876	0.876	0.876	0.876	N/A	0.298042
	1983	1.225	1.421	0.876	0.876	0.876	0.876	0.876	0.876	N/A	0.297358
Jeffrey Frankel	1985	0.852	0.871	0.838	0.838	0.838	0.838	0.838	0.838	N/A	0.259330
	1986	1.157	1.188	0.838	0.838	0.838	0.838	0.838	0.838	N/A	0.259330
	1987	0.997	0.975	0.843	0.843	0.843	0.843	0.843	0.843	N/A	0.259196
	1988	0.838	0.708	0.843	0.843	0.843	0.843	0.843	0.843	N/A	0.259196
Richard Gordon	1978	0.682	0.885	0.889	0.889	0.889	0.889	0.889	0.889	N/A	0.311028
	1979	1.142	1.554	0.889	0.889	0.889	0.889	0.889	0.889	N/A	0.311028
	1980	1.015	1.683	0.888	0.888	0.888	0.888	0.888	0.888	N/A	0.310787
	1981	0.955	1.299	0.889	0.889	0.889	0.889	0.889	0.889	N/A	0.311150
Karen Lee	1961	0.397	1.097	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1962	0.388	0.411	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1963	0.395	0.670	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1964	0.407	0.519	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Jaimie Shapiro	1973	0.495	0.641	0.845	0.845	0.845	0.845	0.845	0.845	N/A	0.265967
	1974	0.473	0.489	0.850	0.850	0.850	0.850	0.850	0.850	N/A	0.265408
	1975	0.562	0.726	0.850	0.850	0.850	0.850	0.850	0.850	N/A	0.265403
	1976	0.567	0.636	0.850	0.850	0.850	0.850	0.850	0.850	N/A	0.265403
Linnea Shore	1975	0.546	0.726	0.849	0.849	0.849	0.849	0.849	0.849	N/A	0.270182
	1976	0.573	0.649	0.853	0.853	0.853	0.853	0.853	0.853	N/A	0.269465
	1977	0.605	0.742	0.852	0.852	0.852	0.852	0.852	0.852	N/A	0.268276
	1978	0.661	0.891	0.896	0.896	0.896	0.896	0.896	0.896	N/A	0.318897
Stace Tackaberry	1951	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1952	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1953	0.366	0.366	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1954	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1955	0.383	0.467	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1956	0.377	1.178	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1957	0.381	0.589	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* “Year” corresponds to the period comprising June 1 of the listed year to May 31 of the following year, for example ‘1984’ refers to the time period June 1, 1984 – May 31, 1985.

Table 7-5: Ratio of the exposure concentrations for plaintiffs Ms. Busch and Mr. Laurie calculated using wind tunnel dispersion factors (Table 7-3) over those calculated using tracer experiment dispersion factors (Table 6-3).

Christine Busch

Year*	Benzene	Formaldehyde	Arsenic	Nickel	Chromium	PAH	PCB	PCDD	PCDF	Cr^{+6}
1994	3.315	1.806	1.324	1.324	1.324	1.324	1.324	1.324	N/A	N/A

John Laurie

Year*	Benzene	Formaldehyde	Arsenic	Nickel	Chromium	PAH	PCB	PCDD	PCDF	Cr^{+6}
1973	0.312	0.900	1.183	1.183	1.183	1.183	1.183	1.183	N/A	0.428
1974	0.311	0.542	1.183	1.183	1.183	1.183	1.183	1.183	N/A	0.428
1975	0.323	0.875	1.183	1.183	1.183	1.183	1.183	1.183	N/A	0.428
1976	0.331	0.854	1.183	1.183	1.183	1.183	1.183	1.183	N/A	0.428
1977	0.336	0.940	1.183	1.183	1.183	1.183	1.183	1.183	N/A	0.428
1978	0.337	0.947	1.183	1.183	1.183	1.183	1.183	1.183	N/A	0.428
1980	0.377	0.999	1.183	1.183	1.183	1.183	1.183	1.183	N/A	0.428
1981	0.395	0.982	1.183	1.183	1.183	1.183	1.183	1.183	N/A	0.428
1982	0.487	0.874	1.183	1.183	1.183	1.183	1.183	1.183	N/A	0.428
1983	0.466	0.874	1.183	1.183	1.183	1.183	1.183	1.183	N/A	0.428

* For Ms. Busch, “Year” corresponds to the calendar year January 1 to December 31. For Mr. Laurie, “Year” corresponds to June 1 of the listed year to May 31 of the following year, for example ‘1974’ refers to the time period June 1, 1974 – May 31, 1975.

8 Additional Modeling for Selected Plaintiffs

Two of the plaintiffs claimed exposure before the tall buildings of Century City were built: Ms. Lee (exposure during the years 1961-1965) and Mr. Tackaberry (exposure during the years 1952-1958). Because of this, the dispersion factors applied in calculating the exposure concentrations for these plaintiffs in Sections 6 and 7 contain a source of inaccuracy since they are characteristic of the dispersion at BHHS in recent years – which is affected by these buildings. The tracer experiment, which based the dispersion factors used in the calculations presented in Section 6, was conducted during two months in 2005, and hence these dispersion factors are affected by buildings. Dr. Neff's wind tunnel experiment, which is used to derive the dispersion factors used in the calculations presented in Section 7, contained the major buildings of Century City on its physical model table, so these too are affected by buildings. As has been discussed in previous sections, the inclusion of these building effects is the primary advantage of using these dispersion factors, and their application to calculate exposure for plaintiffs who were at BHHS since the mid-1970s is necessary. Yet, in the case of Ms. Lee and Mr. Tackaberry, the use of the factors is a source of error.

We therefore carried out additional modeling for these two plaintiffs aimed at estimating their exposure concentrations using dispersion factors not affected by the buildings. We arrived at these dispersion factors by applying the EPA model AERMOD. This model was discussed and referenced in Section 4.4. It is currently the recommended model by EPA for regulatory work dealing with concentration calculations over short distances from point and area sources.

We applied AERMOD semester-by-semester for these two plaintiffs. This involved simulating the 1961 through 1965 for Ms. Lee, and 1952 through 1958 for Mr. Tackaberry. The calculations were driven by hourly surface meteorology from LAX and twice-a-day upper air profiles from San Diego/North Island prior to June 1956 and from San Diego Airport upper profiles after June 1956. From our analysis in Section 3, LAX winds are likely faster than those around the BHHS area by roughly a factor of two. Stations further inland with regular wind measurements during these years unfortunately were unavailable to our knowledge. It may be, however, that LAX winds characterize the local area better in the 1950s and early-1960s than they do in current years, since West Los Angeles was less built-up during this earlier period than it has become since then.

Only three of the considered sources were operating during this period – the Old Drill Site, Drill Site #1, and the adjacent Wolfskill well. Since we are applying the dispersion factors for Drill Site #1 to also represent Wolfskill, only two of these three sources – Old Drill Site and Drill Site #1 – were simulated. A unit emission rate (1 g/s) was applied for both sources. We specified the same receptors as applied by Dr. Neff to calculate concentrations – these are shown in Figure 2-2.

Long-term averaged concentrations at each receptor were calculated by averaging the hourly concentrations calculated by the model over 8 AM – 4 PM. These are output by the model in units of $\mu g/m^3$, and therefore since a unit emission rate was applied the concentrations can be interpreted as dispersion factors in units of $\mu s/m^3$. The fall semester dispersion factors were generated by averaging over the days September 1 – December 31. Spring semester dispersion factors were generated by averaging over the days January 1 – May 31. The factors at each receptor were then averaged over all semesters to obtain a single set of dispersion factors. We applied these factors to calculate exposure concentration in the same manner as we applied Dr. Neff's dispersion factors calculated at these same receptors, which is described in Section 7.

The dispersion factors from these AERMOD runs for both Ms. Lee and Mr. Tackaberry are shown in Table 8-1. A bigger difference between Main Campus and Athletic Field is now seen compared to what was the case with the tracer-study (Table 6-1) and wind tunnel derived factors (Table 7-1). This is because most of the AERMOD plume heads to the east due to the prevailing westerly LAX wind, and also because of the smaller lateral dispersion than in the tracer and wind tunnel experiments due to the lack of building effects in these AERMOD calculations. Both of these effects would lead to much less material dispersing onto the Main Campus than is the case in the tracer and wind tunnel experimental results.

The exposure concentrations calculated for both Ms. Lee and Mr. Tackaberry using these dispersion factors are shown in Table 8-2. Note that results are only shown for benzene and formaldehyde since the Central Plant facilities (which emit the remaining species) were not operating during the years in question. It is seen that the values of exposure concentration are similar to those computed using the tracer-study and wind tunnel dispersion factors. The ratios of the each the wind tunnel and tracer-study exposure concentrations over those computed using the AERMOD dispersion factors are shown in Table 8-3. The ratios are all greater than one, being as high as 1.7 for the wind tunnel to AERMOD ratio and 3.9 for the tracer-study to AERMOD ratio.

In summary, exposure concentrations calculated for Ms. Lee and Mr. Tackaberry using three different methods, each with its own set of advantages and disadvantages, are relatively similar, being roughly within a factor of four of one another.

Table 8-1**:** Dispersion factors (μs/m^3) calculated from average concentrations computed by AERMOD for plaintiffs Ms. Lee and Mr. Tackaberry. Dispersion factors are shown the two facilities operated by the defendants that have been incorporated into our AERMOD simulations to calculate these dispersion factors. Abbreviations denote the dispersion factors used to represent the following: MC – Main Campus, AF – Athletic Field. See Section 8 for additional details.

Lee

Dispersion Factor	Old Drill Site	Drill Site #1
$(\chi/Q)_{MC}$	3.709	2.164
$(\chi/Q)_{AF}$	54.727	6.038

Tackaberry

Dispersion Factor	Old Drill Site	Drill Site #1
$(\chi/Q)_{MC}$	3.875	3.386
$(\chi/Q)_{AF}$	65.504	7.571

Table 8-2**:** Annually averaged concentrations to which plaintiffs Ms. Lee and Mr. Tackaberry were exposed for benzene and formaldehyde, as calculated by our Tracer-Based Dispersion Model using dispersion factors calculated from AERMOD (Table 8-1). See Section 8 for additional details.

Plaintiff	**Year***	**Benzene (ppt)**	**Formaldehyde (ppt)**
Karen Lee	1961	0.541	0.282
	1962	0.739	1.843
	1963	0.805	0.428
	1964	0.761	0.677
Stace Tackaberry	1951	---	---
	1952	---	---
	1953	0.007	0.115
	1954	---	---
	1955	1.496	2.888
	1956	1.901	0.425
	1957	1.266	0.585

* “Year” corresponds to the period comprising June 1 of the listed year to May 31 of the following year, for example ‘1954’ refers to the time period June 1, 1954 – May 31, 1955.

Table 8-3**:** Ratios of the exposure concentrations for plaintiffs Ms. Lee and Mr. Tackaberry calculated using tracer experiment dispersion factors (Table 6-2) over those calculated using AERMOD dispersion factors (Table 8-2).

Plaintiff	**Year***	**Benzene**	**Formaldehyde**
Karen Lee	1961	3.794	1.516
	1962	3.867	3.680
	1963	3.814	2.395
	1964	3.714	3.004
Stace Tackaberry	1951	N/A	N/A
	1952	N/A	N/A
	1953	1.815	1.815
	1954	N/A	N/A
	1955	2.856	2.165
	1956	2.928	1.068
	1957	3.065	2.284

* "Year" corresponds to the period comprising June 1 of the listed year to May 31 of the following year, for example '1954' refers to the time period June 1, 1954 – May 31, 1955.

Table 8-4**:** Ratios of the exposure concentrations for plaintiffs Ms. Lee and Mr. Tackaberry calculated using wind tunnel dispersion factors (Table 7-2) over those calculated using AERMOD dispersion factors (Table 8-2).

Plaintiff	Year*	Benzene	Formaldehyde
Karen Lee	1961	1.505	1.663
	1962	1.499	1.512
	1963	1.505	1.604
	1964	1.510	1.559
Stace Tackaberry	1951	N/A	N/A
	1952	N/A	N/A
	1953	0.664	0.664
	1954	N/A	N/A
	1955	1.095	1.010
	1956	1.102	1.258
	1957	1.167	1.346

* “Year” corresponds to the period comprising June 1 of the listed year to May 31 of the following year, for example ‘1954’ refers to the time period June 1, 1954 – May 31, 1955.

9 Conclusions

From our modeling work as well as our review of the analyses and modeling work of the experts designated by plaintiffs, the following conclusions can be made:

- From our modeling work presented in Section 6, the concentrations on BHHS caused by the emissions from the defendants' facilities, when calculated using emission rates calculated by the defendants' experts (summarized in Section 5), dispersion rates derived from the tracer field experiment, and taking into account the actual time of exposure for each plaintiff, are practically negligible. For benzene, for example, the impact is of the order of 1 ppt (= 0.001 ppb), which is roughly a thousand times lower than the current background concentrations of benzene in the Los Angeles area.

- The difference between these results and those obtained after applying dispersion factors derived from the plaintiffs' expert Dr. Neff's wind tunnel experiment are within a factor of roughly three. Since plaintiff expert Mr. Tarr's modeling work is such to essentially force his long-term concentrations to those of Dr. Neff's wind tunnel results, we can conclude that this same difference applies if we were to apply Mr. Tarr's dispersion factors to our modeling work.

- The differences between the long-term concentrations presented by Mr. Tarr and those that we have calculated are primarily caused by differences in emission rates. Differences in dispersion rates are negligible by comparison.

- Mr. Tarr's short-term concentrations are not physically meaningful since the modeling approach on which they are based (ISC-PRIME with Los Angeles Airport meteorology) is not appropriate when applied to the complex urban environment of BHHS since the mid-1970s.

- Based on a comparison of field measurements of benzene concentrations that have been made over the last few years, Mr. Tarr's maximum emission rates are too large, and not supported by experimental evidence. Since Dr. Clark uses concentrations resulting from these emission rates in his exposure assessments for each plaintiff, Dr. Clark's calculations in turn would yield incorrect results (too high an exposure).

- We reviewed reports and depositions of experts who estimated the emission rates. We agree with the estimates performed by Ms. Wilson and Mr. Rubenstein. On the other hand, we identified major flaws and/or over-estimations in the work performed by Mr. Tarr, Matson and Associates, and Dr. Dellinger.

- The methodology of Dr. Clark's exposure analysis for the plaintiffs contains many errors, inappropriate assumptions, and is designed in such a way so that increased exposure to the plaintiffs due to emissions from defendant facilities cannot be assessed unambiguously from other effects unrelated to these emissions. Because of this, and even putting aside other errors such as the lack of proper emission rates, the values Dr. Clark reports to indicate the increased exposure due to defendant's emissions are artificially high. Specifically, we estimate that most of Dr. Clark's calculated increased exposure due to the emissions from defendant facilities is due to inaccurate assumptions and errors.

Appendix A: Emission Rates

Drill Sites

Christine Busch

SITE AND TIME PERIOD	Emissions Rate (mg/s)	
	Benzene	Formaldehyde
New Drill Site 1994	0.198	0.672

Gary Davidson

SITE AND TIME PERIOD	Emissions Rate (mg/s)	
	Benzene	**Formaldehyde**
Drill Site #1 1981 - 1982 School Year	0.543	0.465
New Drill Site 1981 - 1982 School Year	0.458	2.121

Janet Lee Day

SITE AND TIME FRAME	Emissions Rate (mg/s)	
	Benzene	Formaldehyde
Old Drill Site 1977	0.000	0.000
Old Drill Site 1978	0.000	0.000
Drill Site #1 1977	0.000	0.000
Drill Site #1 1978	0.000	0.000
Drill Site #1 1980 - 1981 School Year	0.785	0.321
Drill Site #1 1981 - 1982 School Year	0.568	0.429
Drill Site #1 1982 - 1983 School Year	0.302	0.484
Drill Site #1 1983 - 1984 School Year	0.288	0.406
New Drill Site 1980 - 1981 School Year	0.595	4.376
New Drill Site 1981 - 1982 School Year	0.453	1.989
New Drill Site 1982 - 1983 School Year	0.653	3.476
New Drill Site 1983 - 1984 School Year	0.512	2.435

Jeffrey Frankel

SITE AND TIME FRAME	Emissions Rate (mg/s) Benzene	Formaldehyde
Drill Site #1 1985 - 1986 School Year	0.350	1.006
Drill Site #1 1986 - 1987 School Year	0.287	0.722
Drill Site #1 1987 - 1988 School Year	0.481	2.494
Drill Site #1 1988 - 1989 School Year	0.332	1.636
Drill Site #1 1987 Summer School Year	0.210	0.105
Drill Site #1 1988 Summer School Year	0.105	0.105
New Drill Site 1985 - 1986 School Year	0.315	0.997
New Drill Site 1986 - 1987 School Year	0.531	1.975
New Drill Site 1987 - 1988 School Year	0.551	2.765
New Drill Site 1988 - 1989 School Year	0.254	0.586
New Drill Site 1987 Summer School Year	1.470	9.240
New Drill Site 1988 Summer School Year	0.630	2.835

Richard Gordon

SITE AND TIME FRAME	Emissions Rate (mg/s) Benzene	Formaldehyde
Old Drill Site 1978 - 1979 School Year	0.106	0.356
Old Drill Site 1979 - 1980 School Year	0.098	0.674
Drill Site #1 1978 - 1979 School Year	0.621	1.136
Drill Site #1 1979 - 1980 School Year	0.757	1.613
Drill Site #1 1980 - 1981 School Year	0.712	0.405
Drill Site #1 1981 - 1982 School Year	0.525	0.540
New Drill Site 1979 - 1980 School Year	0.803	5.914
New Drill Site 1980 - 1981 School Year	0.750	5.517
New Drill Site 1981 - 1982 School Year	0.479	2.306

Melissa Gross

SITE AND TIME FRAME	Emissions Rate (mg/s) Benzene	Emissions Rate (mg/s) Formaldehyde
Drill Site #1 1984 - 1985 School Year	0.490	1.983
Drill Site #1 1985 - 1986 School Year	0.330	0.881
Drill Site #1 1986 - 1987 School Year	0.274	0.633
Drill Site #1 1987 - 1988 School Year	0.580	2.898
Drill Site #1 1984 Summer School Year	0.252	0.000
Drill Site #1 1985 Summer School Year	0.401	1.546
Drill Site #1 1986 Summer School Year	0.504	2.268
Drill Site #1 1987 Summer School Year	0.252	0.000
New Drill Site 1984 - 1985 School Year	0.334	1.291
New Drill Site 1985 - 1986 School Year	0.299	0.874
New Drill Site 1986 - 1987 School Year	0.488	1.730
New Drill Site 1987 - 1988 School Year	0.671	3.214
New Drill Site 1984 Summer School Year	0.504	2.520
New Drill Site 1985 Summer School Year	0.687	3.494
New Drill Site 1986 Summer School Year	0.252	0.000
New Drill Site 1987 Summer School Year	3.276	22.176

Karen Lee

SITE AND TIME FRAME	Emissions Rate (mg/s) Benzene	Emissions Rate (mg/s) Formaldehyde
Wolfskill 1961 - 1962 School Year	0.016	0.073
Wolfskill 1962 - 1963 School Year	0.016	0.073
Wolfskill 1963 - 1964 School Year	0.032	0.225
Old Drill Site 1961 - 1962 School Year	0.041	0.073
Old Drill Site 1962 - 1963 School Year	0.041	0.073
Old Drill Site 1963 - 1964 School Year	0.056	0.072
Old Drill Site 1964 - 1965 School Year	0.073	0.073
Drill Site #1 1961 - 1962 School Year	2.671	0.073
Drill Site #1 1962 - 1963 School Year	3.762	3.272
Drill Site #1 1963 - 1964 School Year	3.962	0.217
Drill Site #1 1964 - 1965 School Year	3.705	0.955

John Laurie

SITE AND TIME FRAME	Emissions Rate (mg/s) Benzene	Formaldehyde
Old Drill Site 1973-1974	0.065	0.097
Old Drill Site 1974-1975	0.065	0.065
Old Drill Site 1975-1976	0.065	0.065
Old Drill Site 1976-1977	0.073	0.048
Old Drill Site 1977-1978	0.073	0.061
Old Drill Site 1978-1979	0.073	0.061
Drill Site #1 1973-1974	0.905	0.291
Drill Site #1 1974-1975	1.002	1.922
Drill Site #1 1975-1976	0.695	0.452
Drill Site #1 1976-1977	0.582	0.448
Drill Site #1 1977-1978	0.533	0.315
Drill Site #1 1978-1979	0.545	0.339
Drill Site #1 1980-1981	0.727	0.170
Drill Site #1 1981-1982	0.557	0.218
Drill Site #1 1982-1983	0.267	0.400
Drill Site #1 1983-1984	0.254	0.315
New Drill Site 1980-1981	0.400	2.411
New Drill Site 1981-1982	0.376	1.527
New Drill Site 1982-1983	0.400	0.884
New Drill Site 1983-1984	0.327	0.436

Monica Revel

SITE AND TIME FRAME	Emissions Rate (mg/s) Benzene	Formaldehyde
Drill Site #1 1989 - 1990 School Year	1.254	8.549
Drill Site #1 1990 - 1991 School Year	0.856	3.264
Drill Site #1 1989 Summer School Year	0.105	0.105
New Drill Site 1989 - 1990 School Year	0.428	1.990
New Drill Site 1990 - 1991 School Year	0.786	1.632
New Drill Site 1991 - 1992 School Year	0.435	1.603
New Drill Site 1992 - 1993 School Year	0.289	0.567
New Drill Site 1989 Summer School Year	0.210	0.000
New Drill Site 1991 Summer School Year	0.210	0.000
New Drill Site 1994	0.101	0.101
New Drill Site 2001-2002	0.274	0.959

Jaimie Shapiro

SITE AND TIME FRAME	Emissions Rate (mg/s) Benzene	Emissions Rate (mg/s) Formaldehyde
Old Drill Site 1973 - 1974 School Year	0.070	0.090
Old Drill Site 1974 - 1975 School Year	0.071	0.091
Old Drill Site 1975 - 1976 School Year	0.071	0.092
Old Drill Site 1976 - 1977 School Year	0.071	0.092
Old Drill Site 1974 Summer School Year	0.105	0.105
Old Drill Site 1975 Summer School Year	0.105	0.105
Old Drill Site 1976 Summer School Year	0.105	0.105
Drill Site #1 1973 - 1974 School Year	1.021	1.331
Drill Site #1 1974 - 1975 School Year	1.467	5.435
Drill Site #1 1975 - 1976 School Year	0.763	0.987
Drill Site #1 1976 - 1977 School Year	0.743	1.700
Drill Site #1 1974 Summer School Year	0.630	2.835
Drill Site #1 1975 Summer School Year	0.210	0.105
Drill Site #1 1976 Summer School Year	0.525	1.890

Linnea Shore

SITE AND TIME FRAME	Emissions Rate (mg/s) Benzene	Emissions Rate (mg/s) Formaldehyde
Old Drill Site 1975 - 1976 School Year	0.072	0.081
Old Drill Site 1976 - 1977 School Year	0.072	0.081
Old Drill Site 1977 - 1978 School Year	0.070	0.079
Old Drill Site 1978 - 1979 School Year	0.100	0.334
Old Drill Site 1976 Summer School Year	0.105	0.105
Old Drill Site 1977 Summer School Year	0.105	0.105
Drill Site #1 1975 - 1976 School Year	0.743	0.868
Drill Site #1 1976 - 1977 School Year	0.716	1.494
Drill Site #1 1977 - 1978 School Year	0.595	0.717
Drill Site #1 1978 - 1979 School Year	0.640	1.067
Drill Site #1 1976 Summer School Year	0.525	1.890
Drill Site #1 1977 Summer School Year	0.945	5.670

Stace Tackaberry

SITE AND TIME FRAME	Emissions Rate (mg/s) Benzene	Emissions Rate (mg/s) Formaldehyde
Wolfskill 1952	0.000	0.000
Wolfskill 1953	0.000	0.000
Wolfskill 1954	0.000	0.000
Wolfskill 1955	0.000	0.000
Wolfskill 1955 - 1956 School Year	0.015	0.067
Wolfskill 1956 - 1957 School Year	0.015	0.067
Wolfskill 1957 - 1958 School Year	0.015	0.069
Wolfskill 1955 Summer School Year	0.000	0.105
Wolfskill 1956 Summer School Year	0.000	0.105
Old Drill Site 1952	0.000	0.000
Old Drill Site 1953	0.000	0.000
Old Drill Site 1954	0.000	0.000
Old Drill Site 1955	0.000	0.000
Old Drill Site 1955 - 1956 School Year	0.037	0.067
Old Drill Site 1956 - 1957 School Year	0.037	0.067
Old Drill Site 1957 - 1958 School Year	0.038	0.069
Old Drill Site 1955 Summer School Year	0.000	0.105
Old Drill Site 1956 Summer School Year	0.000	0.105
Drill Site #1 1954	0.560	3.640
Drill Site #1 1955	0.000	0.000
Drill Site #1 1955 - 1956 School Year	5.158	2.493
Drill Site #1 1956 - 1957 School Year	6.760	0.067
Drill Site #1 1957 - 1958 School Year	4.804	0.505
Drill Site #1 1955 Summer School Year	1.260	8.610
Drill Site #1 1956 Summer School Year	0.105	0.105

Central Plants[86]

Year*	Benzene (mg/s)	Formaldehyde (mg/s)	Arsenic (μg/s)	Chromium (μg/s)	Nickel (μg/s)	PAH (μg/s)	PCB (μg/s)	PCDD (pg/s)	PCDF (pg/s)	Cr^{+6} (μg/s)
1966	0.015	1.43	0.44	7.83	2.14	0.10	0.024	0.006	0.000	70.63
1967	0.018	1.78	0.55	9.76	2.67	0.13	0.030	0.008	0.000	70.44
1968	0.019	1.87	0.57	10.24	2.80	0.13	0.032	0.008	0.000	70.63
1969	0.025	2.41	0.74	13.24	3.62	0.17	0.041	0.011	0.000	86.82
1970	0.038	3.77	1.16	20.71	5.66	0.27	0.064	0.017	0.000	155.76
1971	0.038	3.76	1.16	20.66	5.65	0.27	0.064	0.017	0.000	219.96
1972	0.038	3.77	1.16	20.71	5.66	0.27	0.064	0.017	0.000	174.78
1973	0.038	3.77	1.16	20.71	5.66	0.27	0.064	0.017	0.000	110.68
1974	0.045	4.45	1.37	24.42	6.67	0.32	0.076	0.020	0.000	110.68
1975	0.052	5.13	1.58	28.16	7.70	0.37	0.087	0.023	0.000	110.38
1976	0.047	4.56	1.41	25.06	6.85	0.33	0.078	0.020	0.000	110.68
1977	0.052	5.08	1.56	27.87	7.62	0.36	0.087	0.023	0.000	110.68
1978	0.058	5.68	1.75	31.17	8.52	0.41	0.097	0.025	0.000	110.68
1979	0.049	4.78	1.47	26.24	7.17	0.34	0.081	0.021	0.000	110.38
1980	0.048	4.74	1.46	26.04	7.12	0.34	0.081	0.021	0.000	110.68
1981	0.048	4.74	1.46	26.01	7.11	0.34	0.081	0.021	0.000	110.68
1982	0.042	4.13	1.27	22.65	6.19	0.30	0.070	0.018	0.000	110.68
1983	0.034	3.36	1.04	18.45	5.04	0.24	0.057	0.015	0.000	110.38
1984	0.031	3.09	0.95	16.95	4.63	0.22	0.053	0.014	0.000	98.38
1985	0.028	2.77	0.85	15.18	4.15	0.20	0.047	0.012	0.000	79.58
1986	0.026	2.54	0.78	13.97	3.82	0.18	0.043	0.011	0.000	85.46
1987	0.028	2.75	0.85	15.08	4.12	0.20	0.047	0.012	0.000	105.72
1988	0.031	3.04	0.94	16.69	4.56	0.22	0.052	0.014	0.000	121.30
1989	0.033	3.21	0.99	17.60	4.81	0.23	0.055	0.014	0.000	73.06
1990	0.033	3.23	1.00	17.74	4.85	0.23	0.055	0.014	0.000	0.63
1991	0.033	3.23	0.99	17.72	4.84	0.23	0.055	0.014	0.000	0.16
1992	0.035	3.47	1.07	19.07	5.21	0.25	0.059	0.016	0.000	
1993	0.040	3.90	1.20	21.43	5.86	0.28	0.067	0.017	0.000	
1994	0.043	4.25	1.31	23.33	6.38	0.31	0.072	0.019	0.000	
1995	0.038	3.73	1.15	20.50	5.60	0.27	0.064	0.017	0.000	
1996	0.040	3.96	1.22	21.74	5.94	0.28	0.068	0.018	0.000	
1997	0.046	4.50	1.39	24.68	6.75	0.32	0.077	0.020	0.000	
1998	0.034	3.37	1.04	18.52	5.06	0.24	0.058	0.015	0.000	
1999	0.026	2.58	0.79	14.15	3.87	0.19	0.044	0.012	0.000	
2000	0.025	2.46	0.76	13.53	3.70	0.18	0.042	0.011	0.000	
2001	0.023	2.26	0.70	12.41	3.39	0.16	0.039	0.010	0.000	
2002	0.035	3.46	1.07	18.98	5.19	0.25	0.059	0.015	0.000	
2003	0.050	4.92	1.52	27.02	7.38	0.35	0.084	0.022	0.000	

* “Year” corresponds to June 1 of the listed year to May 31 of the following year, for example ‘1974’ refers to the time period June 1, 1974 – May 31, 1975.

86 PCDD is expressed as TEQ.

Appendix B: Plaintiff Hours

Student Plaintiffs

Plaintiff	Year*	School Year		Summer School	
		Main Campus	Athletic Field	Main Campus	Athletic Field
Gary Davidson	1981	963.25	961.75	0	0
Janet Lee Day	1977	0	8	0	0
	1980	1581	538	0	0
	1981	1640	444	0	0
	1982	1595	489	0	0
	1983	1644	498	0	0
Jeffrey Frankel	1985	1260	180	0	0
	1986	1267	181	0	0
	1987	1260	180	120	0
	1988	1260	180	120	0
Richard Gordon	1978	1202.67	461.33	0	0
	1979	1202.67	461.33	0	0
	1980	1216.33	464.67	0	0
	1981	1195.83	459.67	0	0
Melissa Gross	1984	1080	540	0	100
	1985	1044	600	120	100
	1986	1049	604	0	50
	1987	999	240	0	50
Karen Lee	1961	1056	496	0	0
	1962	1050	494	0	0
	1963	1068	500	0	0
	1964	1050	494	0	0
Monica Revel	1989	1116	150	120	0
	1990	1116	150	0	0
	1991	1122.2	150.83	120	0
	1992	1116	150	0	0
	1994	0	125	0	0
	2001	0	92	0	0
Jaimie Shapiro	1973	1080	179	0	0
	1974	1068	177	120	0
	1975	1062	176	120	0
	1976	1062	176	120	0
Linnea Shore	1975	1192	216	0	0
	1976	1192	216	120	0
	1977	1224	216	120	0
	1978	1232	540	0	0
Stace Tackaberry	1951	0	45	0	0
	1952	0	45	0	0
	1953	0	45	0	0
	1954	0	45	0	0
	1955	1183	500	0	120
	1956	1183	500	0	120
	1957	1246	401	0	0

* For “School Year”, the number of hours given for a listed year corresponds to those during the school year beginning in the fall of that year, for example the hours listed for “1984” correspond to those during the 1984-1985 school year. For “Summer School”, the number of hours given for a listed year corresponds to those during the summer school session for that calendar year.

Christine Busch

Year*	Hospital Indoor	Hospital Outdoor
1994	600	37.5
Total	600	37.5

* “Year” corresponds to calendar year 1994. The entries for columns to right correspond to hours Ms. Busch spent indoor and outdoor at the hospital during this year.

John Laurie

Year*	Exposure Hours
1973	780
1974	780
1975	780
1976	1040
1977	1040
1978	1040
1979	0
1980	1040
1981	1040
1982	1040
1983	1040

* The number of hours given for a listed year corresponds to those during the period beginning on June 1 of that year, for example the hours listed for “1974” correspond to those during the period June 1, 1974 – May 31, 1975.

Busch, Christine

Year	Term	Hospital Indoor	Notes	Comments	Hospital Outdoor	Notes	Comments
1994	Work (includes break)	562.5	(20 hours/week-(2.5 shifts * 0.5 hr)) * 30 weeks	See Summary #4, 6 and Assumptions #2 and 3			
	Lunch	18.75	[(2.5 shifts/week) * (30weeks)]/2 * (1/2 hrs)	See Summary #8 and Assumptions 1-3	18.75	[(2.5 shifts/week) * (30weeks)]/2 * (1/2 hrs)	See Summary #8 and Assumptions 1-3
	Parking	18.75	[(2.5 shifts/week) * (30weeks)]/2 * (30 min/shift)	See Summary #7 and Assumptions #4 -7	18.75	[(2.5 shifts/week) * (30weeks)]/2 * (30 min/shift)	See Summary #7 and Assumptions #4 -7
		600	**Sum Total Hospital Indoor Hours**		**37.5**	**Sum Total Hospital Outdoor Hours**	

Summary
1. Not claiming residence exposure
2. Never been on BHHS campus
3. Claim exposure during employment at Century City Hospital
4. According to ***Busch QR: p. 6-7, #9(a)*** , she worked at the hospital from 2/94 - 9/94 approximately 20 hrs/wk
5. Worked at Century City Hospital end of January/beginning of February until end of August 1994 ***(Busch Depo., Vol. 1 (7/26/04) at p. 59:9-25)***
6. Worked ~ 20 hrs/week, generally 8-hour shifts and no night shift ***Busch Depo., Vol. 1 (7/26/04) at pp. 64:9 - 65:16***
7. Parked underneath the hospital at times and underground parking across the streets as well ***Busch Depo., Vol.1 (7/26/04) at p. 65:21-25***
8. Had two 15 min. indoor breaks and 30 min. indoor and outdoor lunch ***Busch Depo., Vol.1 (7/26/04) pp. 69:9-70:23***

Assumptions
1. No record of how many times she ate lunch indoors or outdoors, so divided those up in half
2. Since she usually had 8 hr shifts, assumed that she has 2.5 shifts by doing 20/8 = 2.5 shifts
3. Used Summary #5 to calculate total number of weeks = feb(28) + mar(31) + apr(30) + may(31) + jun(30) + jul(31) aug(31)/7days = 30.2857 weeks so will apply 30 weeks here
4. Parking assumed to take 15 min before work and leaving work = 30 min/shift wherever they parked
5. Parking under hospital considered hospital indoor
6. Parking underground parking across the street considered outdoor due to time needed to walk across
7. Half and half division between parking under the hospital and across the street

Exposure Hour calculation differs from Dr. Clark's total hours of 1528 hours in his spreadsheet for Christine Busch.
Sawyer indicated during deposition that Busch's seven months of exposure near BHHS would equal approximately 28 weeks.
Sawyer also calculates that her total hours equal to about 560 hrs using 20 hrs/week * 28 weeks = 560 hrs.
Although Clark indicated in his spreadsheet that he'll be using 5 hrs/day and 5 days/week although Busch said 20 hrs/week (extra 5 five hours), he ended up using 8 hrs/day * 191 days.

Davidson, Gary

Year	Term	Main Campus Hours	Notes	Comments
1981-1982	1st Semester	413.25	(11 hours - 6.25 hours) * 87 days	#5, 6, 11
	2nd Semester	550	(11 hours - 4.75 hours) * 88 days	#5, 6, 11
		963.25	*Total School Year Hours on MC (81 - 82)*	
		0	*Total Summer School Hours on MC (1981)*	
		963.25	**Total Hours**	
		963.25	**Sum Total Main Campus Hours**	

Calculation Assumptions/Comments:

1. He attended BHHS 9/1981 - 6/1982 although diploma was received in 8/82, not physically on campus after June ***(Depo. Vol. 1 p. 127:15 - 128:14)***
2. Did not attend summer school
3. PE assumed to be all on AF and 1.5 hr/day for fall semester for volleyball, football, and sports conditioning baseball each being 2.5 credit units ***(transcript)***. For spring, he says he had weight lifting in swim gym, which is not listed in the transcript ***(Questionnaire p. 17 #27)***, which is considered main campus, which is not listed in the transcript.
4. He was excused from PE according to doctor's note 3/13/-5/3 ***(Depo. Vol. 1 p. 129:11-131:17)*** and BHHS office record from 4/23 until end of semester (***Depo. Vol. 1 p. 131:19 - 133:3)***, but assumed he was still participating in sports since he says he participated in activities such as weight lifting and baseball ***(Depo.Vol. 1 p.132)***
5. 4 hours/day in addition to regular school hours for baseball and intermurals ***(Questionnaire page 16 #25)***
6. "Regular school hours" assumed to be 7 hours (8am - 3pm) due to insufficient information ***(Questionnaire p. 16 #25)***
7. In ***supplemental answers p. 6 #32***, he states that he ate lunch outside on "football bleachers and on a flight of steps by swim gym"
8. Lunch assumed to be 45 minutes and assumed all lunch near football bleachers, taking the most conservative approach
9. He states he spent "leisure time by socializing or participating in physical activity after school on the field and campus" ***(Supplemental answers p. 6 #32)*** but due to insufficient information, assumed this is part of the 4 additional hours after school
10. ***Transcript*** has PE exemption and SC-Wrestling for spring 1982
11. Total hours on campus = 7 hours of regular school hours + 4 hours of baseball and intermurals = 11 hours
12. He stated he had volleyball in fall of 1982 ***(Supplemental Answers p. 6 #28.a.3)***, but he got his diploma in August 1982 so 2.5 credit units are not added. Instead, volleyball was in fall of 1981 so this was added to fall 1981 ***(transcript)***
13. All general PE considered to be on athletic field to be conservative
14. School days based upon BHHS School Calendar

Athletic Field Hours	Notes	Comments
543.75	(4 hours/day * 87 days) + (1.5 hrs/day * 87 days) + (45 min/day * 87 days)	See #3, 5, 7, 8 (4 hours of baseball/intermurals + 1.5 hour of PE + 45 min lunch)
418	(4 hrs/day * 88 days) + (45 min/day * 88 days)	See #3, 5, 7, 8 (4 hours of baseball/intermurals + 45 min lunch)
961.75	*Total School Year Hours on AF (81 - 82)*	
0	*Total Summer School Hours on AF (1981)*	
961.75	**Total Hours**	

961.75 **Sum Total Athletic Field Hours**

Janet Lee Day

Year	Term	Main Campus Hours	Notes	Comments
1977-1978	tennis with sibling Janine	0	none	
		0	**total hours on MC 77-78**	
1980-1981 (Freshman)	1st Semester (Fall)	869	(8 hrs x 89 days) - (1 hr PE/day * 89 days) + (3 hrs X 8 boys b-ball home games) + (3 hrs X 89 days b-ball practice) - (2.5 hrs/wk * 18 wks of sports conditioning/fitness)	See Comments #2, 3, 7 and 16
	2nd Semester (Spring)	712	8 hours x 89 days	See #3
		1581	**total hours on MC 80-81**	
1981-1982 (Sophomore)	1st Semester (Fall)	936	(8 hours x 87 days) + (3 hrs X 8 boys b-ball home games) + (3 hrs X 87 days basketball practice) - (2.5 hrs/week * 18 weeks)	See #3, 7, and 16
	2nd Semester (Spring)	704	8 hours x 88 days	See #3
		1640	**total hours on MC 81-82**	
1982-1983 (Junior)	1st Semester (Fall)	936	(8 hours x 87 days) + (3 hrs X 8 boys b-ball home games) + (3 hrs X 87 days basketball practice) - (2.5 hrs/week * 18 weeks)	See #3, 7, and 16
	2nd Semester (Spring)	659	8 hours x 88 days - (2.5 hrs/week * 18 weeks)	See #3
		1595	**total hours on MC 82-83**	
1983-1984 (Senior)	1st Semester (Fall)	969	(8 hours x 90 days) + (3 hrs X 8 boys b-ball home games) + (3 hrs X 90 days basketball practice) - (2.5 hrs/week * 18 weeks)	See #3, 7, and 16
	2nd Semester (Spring)	675	8 hours x 90 days - (2.5 hrs/week * 18 weeks)	See #3
		1644	**total hours on MC 83-84**	
		6460	**Sum Total Main Campus Hours**	

Calculation Assumptions and remarks:

1. Any time frame (e.g. 1-2 hours) the max amount was used (e.g. 2 hours).
2. PE included during school hours for first year at BHHS (Took PE only fall) ***Questionnaire p. 17 #27*** assumed to be 50 min.
3. The regular school hours is not explicitly defined anywhere, depositions indicate 8am-3pm or 8am-4pm, max has been considered (8hours) for calculating main campus hours.
4. No summer school info was found in analysis, deposition and questionnaire.
5. Janine says Janet played basketball and did track all 4 years ***(Depo. Vol. 1 p. 140:24-141:24)***
6. Janine says in her deposition that she played tennis 3-4 times in 1977-1978 ***(Depo. Vol. 1 p. 166:22-167:1)*** so 4 times was used
7. All sport practices and game events included in the athletic field hours except basketball.
8. All sport practice and game events were outside the school hours.
9. Fall of 80-84 did track ~ 1 hr/day ***Questionnaire p. 19 #29***
10. Assumed 2 hours/time for tennis
11. Attended BHHS 9/1980 - 6/1984 ***(Questionnaire p. 7 #7 and p. 16 #23)***
12. According to ***Questionnaire p. 19 #29***, spent 3 hrs/day on athletic field 5 days/week when on track team during spring of 81-84 and during fall 1 hour/day
13. All games assumed to be 3 hours long (whether she was a spectator or playing)
14. All sport meets, used 8 home games by assuming 6-8 teams in league and equal number of home games ***(Janine Day Depo. Vol. 1 p. 154:16-155:25)***
15. Did not include hours she attended games to see siblings cheer (time frame and years unknown)
16. Girls basketball games assumed to be included during the practice hours (indoor)
17. Track meets assumed to be included during the practice hours
18. Both basketball and track practice are 3 hours/day following "3 hours/day 5 days/week for sports" in ***questionnaire p. 17 #25*** 2-3 hrs/day (3 hours is used) as seen on ***Janine Day Depo. Vol. 1 p.154:16-155:25***
19. Orchestra time after school performance not considered here due to insufficient information
20. Fitness and Conditioning (2.5 credit units) fall of 80 - 83, spring of 83 - 84 according to ***Supplemental Questionnaire p. 6 #32.***
21. Assuming fitness and conditioning on AF and given 2.5 hrs/week following item #20
22. School days based upon BHHS School Calendar

Athletic Field Hours	Notes	Comments
8	4 times * 2 hours/time	See #6 and 10
8	**total hours on AF 77-78**	
247	(1 hour track practice x 89 days) + (3 hrs x 8 football game event) + (1 hr PE * 89 days) + (2.5 hrs/week * 18 weeks)	See #2, 5, 7-9, 12-14, 17-18
291	(3 hour track practice x 89 days) + (3 hours X 8 home baseball games as spectator)	See #7-8, 12-14, and 17-18
538	**total hours on AF 80-81**	
156	(1 hour track practice x 87 days) + (3 hrs x 8 football game event) + (2.5 hrs/week * 18 weeks for sports cond)	See #5, 7-9, 12-14, 17-18
288	(3 hour track practice x 88 days) + (3 hours X 8 home baseball games as spectator)	See #7-8, 12-14, and 17-18
444	**total hours on AF 81-82**	
156	(1 hour track practice x 87 days) + (3 hrs x 8 football game event) + (2.5 hrs/week * 18 weeks for sports cond)	See #5, 7-9, 12-14, 17-18
333	(3 hour track practice x 88 days) + (3 hours X 8 home baseball games as spectator) + (2.5 hrs/week * 18 weeks of sports cond)	See #7-8, 12-14, and 17-18
489	**total hours on AF 82-83**	
159	(1 hour track practice x 90 days) + (3 hrs x 8 football game event) + (2.5 hrs/week * 18 weeks for sports cond)	See #5, 7-9, 12-14, 17-18
339	(3 hour track practice x 90 days) + (3 hours X 8 home baseball games as spectator) + (2.5 hrs/week * 18 weeks of sports cond)	See #7-8, 12-14, and 17-18
498	**total hours on AF 83-84**	
1977	**Sum Total Athletic Field Hours**	

Jeffrey Frankel

Year	Term	Main Campus Hours	Notes	Comments
1985-1986 (Freshman)	1st Semester	630	(8 - 1 hour/day) * 90 days	See #1, 3, and 7
	2nd Semester	630	(8 - 1 hour/day) * 90 days	See #1, 3, and 7
		1260	*Total School Year Hours on MC (85 - 86)*	
		0	*Total Summer School Hours on MC (1985)*	
		1260	**Total Hours**	
1986-1987 (Sophomore)	1st Semester	630	(8 - 1 hour/day) * 90 days	See #1, 3, and 7
	2nd Semester	637	(8 - 1 hour/day) * 91 days	See #1, 3, and 7
		1267	*Total School Year Hours on MC (86 - 87)*	
		0	*Total Summer School Hours on MC (1986)*	
		1267	**Total Hours**	
1987-1988 (Junior)	1st Semester	630	(8 - 1 hour/day) * 90 days	See #1, 3, and 7
	2nd Semester	630	(8 - 1 hour/day) * 90 days	See #1, 3, and 7
	summer school (1987)	120	30 days * (4 hours/day)	See #2 and 10
		1260	*Total School Year Hours on MC (87 - 88)*	
		120	*Total Summer School Hours on MC (1987)*	
		1380	**Total Hours**	
1988-1989 (Senior)	1st Semester	630	(8 - 1 hour/day) * 90 days	See #1, 3, and 7
	2nd Semester	630	(8 - 1 hour/day) * 90 days	See #1, 3, and 7
	summer school (1988)	120	30 days * (4 hours/day)	See #2 and 10
		1260	*Total School Year Hours on MC (88 - 89)*	
		120	*Total Summer School Hours on MC (1988)*	
		1380	**Total Hours**	
		5287	**Sum Total Main Campus Hours**	

Calculation Assumptions/Comments:

1. School days based upon BHHS School Caldendar
2. Took summer school 11th (1987) and 12th (1988) grade according to ***BHHS transcript***
3. Says he was at school 6.5 - 7 hours/day in ***Questionnaire p. 18 #25***
4. PE every semester from 85 - 89 with majority being 5 days/week (some 3 days/week) and half of them outdoor ***(Questionnaire p. 18 #27)***
5. Spent 50 - 60 min on athletic field 5 days/week ***(Questionnaire p. 20 #29)***
6. Assuming PE performed 5 days/week and 1 hour for PE for all 8 semesters since he had 5 units for each semester
7. According to ***Deposition Vol. 1 p. 97:18 - 98:16,*** he sometimes took 0 period classes, assume he attended school from 7:20 - 3:32 (8 hours) all 4 years
8. He attended open houses but that is not accounted here ***(Deposition Vol. 1 p. 100:3 - 20)***
9. Assumed all PE outdoor
10. Says summer school was 6 - 8 weeks, 5 days/week, 2.5 - 3 hr/day in ***questionnaire p. 18 #26***

Athletic Field Hours	Notes	Comments
90	1 hr/day * 90 days/semester	See #4 - 6, and 9
90	1 hr/day * 90 days/semester	See #4 - 6, and 9
180	*Total School Year Hours on AF (85 - 86)*	
0	*Total Summer School Hours on AF (1985)*	
180	**Total Hours**	
90	1 hr/day * 90 days/semester	See #4 - 6, and 9
91	1 hr/day * 91 days/semester	See #4 - 6, and 9
181	*Total School Year Hours on AF (86 - 87)*	
0	*Total Summer School Hours on AF (1986)*	
181	**Total Hours**	
90	1 hr/day * 90 days/semester	See #4 - 6, and 9
90	1 hr/day * 90 days/semester	See #4 - 6, and 9
180	*Total School Year Hours on AF (87 - 88)*	
0	*Total Summer School Hours on AF (1987)*	
180	**Total Hours**	
90	1 hr/day * 90 days/semester	See #4 - 6, and 9
90	1 hr/day * 90 days/semester	See #4 - 6, and 9
180	*Total School Year Hours on AF (88 - 89)*	
0	*Total Summer School Hours on AF (1988)*	
180	**Total Hours**	
721	**Sum Total Athletic Field Hours**	

Richard Gordon

Year	Term	Main Campus Hours	Notes	Comments
1978-1979 (Freshman)	1st Semester	601.3333333	(8.5-1 hr 40 min/day)*88days/semester	See #1, 4, and 6
	2nd Semester	601.3333333	(8.5 -1 hr 40 min/day)*88days/semester	See #1, 4, and 6
	tennis during school year			
		1202.666667	*Total School Year Hours on MC (78 - 79)*	
		0	*Total Summer School Hours on MC (1978)*	
		1202.666667	**Total Hours (78-79) on MC**	
1979-1980 (Sophomore)	1st Semester	601.3333333	(8.5-1 hr 40 min/day)*88days/semester	See #1, 4, and 6
	2nd Semester	601.3333333	(8.5 -1 hr 40 min/day)*88days/semester	See #1, 4, and 6
	tennis during school year			
		1202.666667	*Total School Year Hours on MC (79 - 80)*	
		0	*Total Summer School Hours on MC (1979)*	
		1202.666667	**Total Hours (79-80) on MC**	
1980-1981 (Junior)	1st Semester	608.1666667	(8.5-1 hr 40 min/day)*89days/semester	See #1, 4, and 6
	2nd Semester	608.1666667	(8.5 -1 hr 40 min/day)*89days/semester	See #1, 4, and 6
	tennis during school year			
		1216.333333	*Total School Year Hours on MC (80 - 81)*	
		0	*Total Summer School Hours on MC (1980)*	
		1216.333333	**Total Hours (80-81) on MC**	
1981-1982 (Senior)	1st Semester	594.5	(8.5-1 hr 40 min/day)*87days/semester	See #1, 4, and 6
	2nd Semester	601.3333333	(8.5 -1 hr 40 min/day)*88days/semester	See #1, 4, and 6
	tennis during school year			
		1195.833333	*Total School Year Hours on MC (81-82)*	
		0	*Total Summer School Hours on MC (1981)*	
		1195.833333	**Total Hours (81-82) on MC**	
		4817.5	**Sum Total Main Campus Hours**	

Calculation Assumptions/Comments:
1. Number of school days based upon BHHS School Calendar
2. Tennis (1-2 times/week intermittently on campus, ***questionnaire p. 22 #32***) and football, unspecified
3. PE every semester ***(questionnaire page 18 #27)***
4. He says he was on campus 5 days/week approximately 8 hrs/day in ***questionnaire page 17 #25***
5. No summer school
6. Was on campus between 7:30-7:45am until 3:30-4:00pm ***Depo. Vol.1 p. 188:11-189:3*** so gave maximum time (8.5 hrs/day) he could be there to be conservative
7. To be conservative, PE considered to be 1 hr and 40 min/day ***(Supplemental Questionnaire p. 5 #28)*** everyday due to no specification of # of days/week
8. Considered 8 home games for each year and 3 hours/game for football for 4 years while he was in school to be conservative (Assumed 8 teams in league and same # of homes games)
9. Assumed 2 hrs/time, 2 times/week only during school season given for tennis (in school for 36 weeks = 180 days/5 days) near AF
10. He says he and other students congregated on the campus after school hours and sporting events - ambiguous and need more specific information to add more hours
11. Says he ate lunch "outside in the quad area adjacent to the cafeteria", which is considered as part of main campus
12. All general PE considered to be on AF to be conservative

Athletic Field Hours	Notes	Comments
170.6666667	(1 hr and 40 min/day * 88 days/semester) + (8 home games *3 hrs/game)	See #7 and 8
146.6666667	1 hr and 40 min/day * 88 days/semester	See #7
144	(36 weeks) * (2 times/week) * (2 hrs/time)	See #2 and 9
461.3333333	*Total School Year Hours on AF (78 - 79)*	
0	*Total Summer School Hours on AF (1978)*	
461.3333333	**Total Hours (78-79) on AF**	
170.6666667	(1 hr and 40 min/day * 88 days/semester) + (8 home games *3 hrs/game)	See #7 and 8
146.6666667	1 hr and 40 min/day * 88 days/semester	See #7
144	(36 weeks) * (2 times/week) * (2 hrs/time)	See #2 and 9
461.3333333	*Total School Year Hours on AF (79 - 80)*	
0	*Total Summer School Hours on AF (1979)*	
461.3333333	**Total Hours (79-80) on AF**	
172.3333333	(1 hr and 40 min/day * 89 days/semester) + (8 home games *3 hrs/game)	See #7 and 8
148.3333333	1 hr and 40 min/day * 89 days/semester	See #7
144	(36 weeks) * (2 times/week) * (2 hrs/time)	See #2 and 9
464.6666667	*Total School Year Hours on AF (80 - 81)*	
0	*Total Summer School Hours on AF (1980)*	
464.6666667	**Total Hours (80-81) on AF**	
169	(1 hr and 40 min/day * 87 days/semester) + (8 home games *3 hrs/game)	See #7 and 8
146.6666667	1 hr and 40 min/day * 88 days/semester	See #7
144	(36 weeks) * (2 times/week) * (2 hrs/time)	See #2 and 9
459.6666667	*Total School Year Hours on AF (81 - 82)*	
0	*Total Summer School Hours on AF (1981)*	
459.6666667	**Total Hours (81-82) on AF**	
1847	**Sum Total Athletic Field Hours**	

Melissa Gross

Year	Term	Main Campus Hours	Notes	Comments	Athletic Field Hours	Notes	Comments
1984-1985 (Freshman)	1st Semester (Fall)	630	(9 - 2 hours) x 90 days	See #3, #10 and #11	180	2 hours x 90 days	See #12, #13, and #14.
	2nd Semester (Spring)	450	(9 - 4 hours) x 90 days	See #3 and #10	360	4 hours x 90 days	See #8, #9, #13, #14, and #17
	Summer School (1984)	0	none		100	10 hours x 10 days	See #7 and #16
		1080	***Total School Year Hours (84-85) on MC***		540	***Total School Year Hours (84-85) on AF***	
		0	***Total Summer School Hours (84) on MC***		100	***Total Summer School Hours (84) on AF***	
		1080	**Total Hours**		**640**	**Total Hours**	
1985-1986 (Sophomore)	1st Semester (Fall)	594	(9 - 3 hours x 72 days) + (9 x 18 days)	See #3 and #10	240	(3 hours x 72 days) + (8 home games x 3 hours)	See #4, #9, and #12
	2nd Semester (Spring)	450	(9 - 4 hours) x 90 days	See #3 and #10	360	4 hours x 90 days	See #8, #9, #13, #19, and #20
	Summer School (1985)	120	(4 hours x 30 days)	See #6	100	10 hours x 10 days	See #7 and #16
		1044	***Total School Year Hours (85-86) on MC***		600	***Total School Year Hours (85-86) on AF***	
		120	***Total Summer School Hours (85) on MC***		100	***Total Summer School Hours (85) on AF***	
		1164	**Total Hours**		**700**	**Total Hours**	
1986-1987 (Junior)	1st Semester (Fall)	594	(9 - 3 hours x 72 days) + (9 x 18 days)	See #3 and #10	240	(3 hours x 72 days) + (8 home games x 3 hours)	See #4, #9, and #12
	2nd Semester (Spring)	455	(9 - 4 hours) x 91 days	See #3 and #10	364	4 hours x 91 days	See #8, #9, #13, and #18
	Summer School (1986)	0	none		50	5 hours x 10 days	See #7
		1049	***Total School Year Hours (86-87) on MC***		604	***Total School Year Hours (86-87) on AF***	
		0	***Total Summer School Hours (86) on MC***		50	***Total Summer School Hours (86) on AF***	
		1049	**Total Hours**		**654**	**Total Hours**	
1987-1988 (Senior)	1st Semester (Fall)	594	(9 - 3 hours x 72 days) + (9 x 18 days)	See #3 and #10	240	(3 hours x 72 days) + (8 home games x 3 hours)	See #4, #9, and #12
	2nd Semester (Spring)	405	4.5 hours x 90 days	See #5 and #10	0	none	See #5
	Summer School (1987)	0	none		50	5 hours x 10 days	See #7
		999	***Total School Year Hours (87-88) on MC***		240	***Total School Year Hours (87-88) on AF***	
		0	***Total Summer School Hours (87) on MC***		50	***Total Summer School Hours (87) on AF***	
		999	**Total Hours**		**290**	**Total Hours**	
		4172	**Main Campus School Year Hours**		**1984**	**Athletic Field School Year Hours**	
		120	**Main Campus Summer School Hours**		**300**	**Athletic Field Summer School Hours**	
		4292	**Sum Total Main Campus Hours**		**2284**	**Sum Total Athletic Field Hours**	

Calculation Assumptions:

1. Need more information to include small flags time period during 1986-1987, ambiguous and doesn't fit into 8am-5pm time period. ***Supplemental Answers p. 9 #31a.6.***
2. No transcript information available for 1987-1988 Senior year. Assumed cheerleading/spirit only happened in Fall of 1987. ***See #5.***
3. Time on campus of 8am-5pm contains 9 hours (all classes and activities must fit within this period). ***Questionnaire p. 15 #25.***
4. Assumed 8 home football games per year each during cheerleading lasting 3 hours. ***No references can be given for this assumption.***
5. Senior year, spring semester (1988) = 8am-12:30pm contains 4.5 hours (Golf Manager off campus). ***Gross Depo., Vol.1 at p.97:13-17 and Supplemental Answers p. 9 #31a.7.***
6. Summer school session assumed to be 4 hrs/day. 30 days based on BHHS School Calendar
7. Cheerleading clinics are 5 hours x 10 days during summer. ***Gross Depo. Vol. 1 at p. 98:24-99:5.*** Assumed AF to be conservative.
8. PE classes took place in the Spring semesters 1984-1988. ***Supplemental Answers p. 8 #27.***
9. Assumed cheerleading in the fall (during football season) and spirit group in the spring (during tryouts, other sports seasons).
Had to make this assumption to keep 8am-5pm time frame with academic classes. No references can be given for this assumption.
10. Time allotted for Main Campus hours includes lunch time spent on front lawn through 1987. ***Supplemental Answers p. 9 #32.***
11. Time allotted for Main Campus hours includes swimming PE class, fall 1984. ***Supplemental Answers p. 9 #31a.3.***
12. Cheerleading is for 3 hours/day, 4 days/week (72 days/semester) 1985-1987 (cannot cheer spring 1988 due to #5). ***Supplemental Answers p. 8 #31a.1.***
13. Spirit group is for 3 hours/day (Spring 1985 can only be 2 hours, if using 8am-5pm time frame and including drill team) 5 days/week 1985-1987. ***Supplemental Answers p.9 #31a.8.***
14. Drill team is fall 1984 and spring 1985 (didn't attend BHHS during spring 1984, she was in junior high) for 2 hour (fall, 1984) and 1 hour
(spring, 1985 in conjunction with spirit group to keep within 8am-5pm time frame), 5 days/week. Supplemental Answers p.8 #31a.2 and transcript.
15. PE includes PE classes and after school activities that occurred until 5 PM. ***Supplemental Answers p. 8 #28a.1.***
16. Drill team summer clinics are 5 hours x 10 days during 1984 and 1985 summer. ***See #7 and Supplemental Answers p. 8 #31a.2. Assumed AF to be conservative.***
17. Weight Training "Fitness" PE class is for 1 hour/day 5 days/week, Spring 1985. ***Transcript and Supplemental Answers p. 8 #28a.2.***
18. Sports conditioning PE class is for 1 hour/day 5 days/week, Spring 1987. ***Transcript and Supplemental Answers p. 8 #28a.3.***
19. Volleyball PE class is for 0.5 hours/day 5 days/week, Spring 1986. ***Transcript and Supplemental Answers p. 9 #31a.4.***
20. Field Sports PE class is for 0.5 hours/day, 5 days/week, Spring 1986. ***Transcript and Supplemental Answers p. 9 #31a.5.***
21. Number of school days based upon BHHS School Calendar

John Laurie

Year	Term	Max Campus Hours	Notes	Comments
1973-1974 (7th)	YMCA	780	(3 hours/day) * (5 days/week) * 52 weeks/yr * 1 yr	See # 10
		780	**Maximum hours at BHHS (73 - 74)**	
1974-1975 (8th)	YMCA	780	(3 hours/day) * (5 days/week) * 52 weeks/yr * 1 yr	See # 10
		780	**Maximum hours at BHHS (74 - 75)**	
1975-1976 (9th)	YMCA	780	(3 hours/day) * (5 days/week) * 52 weeks/yr * 1 yr	See # 10
		780	**Maximum hours at BHHS (75 - 76)**	
1976-1977 (10th)	YMCA	1040	(20 hours/week) * 52 weeks/year * 1 year	maximum of 20 hours/week used for the entire year
		1040	**Maximum hours at BHHS (76 - 77)**	
1977-1978 (11th)	YMCA	1040	(20 hours/week) * 52 weeks/year * 1 year	maximum of 20 hours/week used for the entire year
		1040	**Maximum hours at BHHS (77 - 78)**	
1978-1979 (12th)	YMCA	1040	(20 hours/week) * 52 weeks/year * 1 year	maximum of 20 hours/week used for the entire year
		1040	**Maximum hours at BHHS (78 - 79)**	
1979-1980 (1st yr at Univ of Redlands)				
		0	**Maximum hours at BHHS (79 - 80)**	
1980-1981 (Soph at USC)	YMCA	1040	(20 hours/week) * 52 weeks/year * 1 year	maximum of 20 hours/week used for the entire year
		1040	**Maximum hours at BHHS (80 - 81)**	
1981-1982 (Jr at USC)	YMCA	1040	(20 hours/week) * 52 weeks/year * 1 year	maximum of 20 hours/week used for the entire year
		1040	**Maximum hours at BHHS (81 - 82)**	
1982-1983 (Sr at USC)	YMCA	1040	(20 hours/week) * 52 weeks/year * 1 year	maximum of 20 hours/week used for the entire year
		1040	**Maximum hours at BHHS (82 - 83)**	
1983-1984 (1st yr at Law)	YMCA	1040	(20 hours/week) * 52 weeks/year * 1 year	maximum of 20 hours/week used for the entire year
		1040	**Maximum hours at BHHS (83 - 84)**	
		9620	**Sum Total Maximum Campus Hours**	

Calculation Assumptions/Comments:

1. For simplification, consider everything on campus
2. Although he doesn't say whether he was on campus during the whole year, considering all 52 weeks for 73-84 to be conservative
3. Calculated maximum since he gives such wide range of hours on campus (14 - 20 hours/week) between 1976 - 1984 except for freshman year at Univ. of Redlands (79-80) ***Depo. Vol. 2 p. 451:24-452:11***
4. Years during law school (especially 1st year) was negligible according to Laurie although he was there some times ***Depo. Vol. 2 p. 455:15-456:23***
5. Sporadic exposure from 1984 - 1987 (assume 3 yrs of law school) when he was in law school ***Depo. Vol. 2 p. 455:15 - 456:23***
6. Not enough information given on other years although he might have gone to BHHS sporadically/intermittently
7. Unsure how long he attended law school, but assumed 3 years and gave recreational tennis throughout the year for 3 years
8. Laurie says the time period of 1984-1988 was negligible ***(Depo. Vol. 2. p. 456:18-23)***
9. He mentions that he was on campus "much less" during 1st year at Univ. of Redlands since it wasn't "local"
10. ***In Depo. Vol. 1 p.111:22 - 112:1***, Laurie says that he started swimming at YMCA at age 14 (8th grade) and because he was in the older group he swam at BHHS from 6 - 8 pm. Also, he says he probably went to school around 5:30 pm or 5:45 pm and ended around 8:30 pm or 9 pm. Therefore, gave him 3 hours/day to be conservative although the practice was only 2 hours 5 days/week and entire year due to unknown duration (73 - 76)
11. In ***Questionnaire p. 20 #32***, he says "from approximately 1976 - 1982" he worked and participated with local YMCA in close proximity to BHHS ***Questionnaire p. 8 #9b***, he says "intermittently 1974 - 2003", and in ***Supplemental Questionnaire p. 7 #32***, it says "from approximately 1973 - 1984", so going with the most recent information and maximum exposure to be conservative
12. Although he says his time near BHHS decreased "substantially" during time of law school, since he states he was there till 1984 participating, included 1983 - 1984 time frame

Karen Lee

Year	Term	Main Campus Hours	Notes	Comments	Athletic Field Hours	Notes	Comments
1961-1962 (Freshman)	1st Semester	528	(8-2 hrs/day)*88days/semester	See #4	176	2 hrs/day * 88 days/semester	See #6
	2nd Semester	528	(8-2 hrs/day)*88days/semester	See #4	176	2 hrs/day * 88 days/semester	See #6
	Tennis during school year				144	(36 weeks) * (2 times/week) * (2 hrs/time)	See #7
		1056	*Total School Year Hours (61-62) on MC*		496	*Total School Year Hours (61-62) on AF*	
		0	*Total Summer School Hours (1961)*		0	*Total Summer School Hours (1961)*	
		1056	**Total Hours**		**496**	**Total Hours**	
1962-1963 (Sophomore)	1st Semester	522	(8-2 hrs/day)*87days/semester	See #4	174	2 hrs/day * 87 days/semester	See #6
	2nd Semester	528	(8-2 hrs/day)*88days/semester	See #4	176	2 hrs/day * 88 days/semester	See #6
	Tennis during school year				144	(36 weeks) * (2 times/week) * (2 hrs/time)	See #7
		1050	*Total School Year Hours (62-63) on MC*		494	*Total School Year Hours (62-63) on AF*	
		0	*Total Summer School Hours (1962)*		0	*Total Summer School Hours (1962)*	
		1050	**Total Hours**		**494**	**Total Hours**	
1963-1964 (Junior)	1st Semester	534	(8-2 hrs/day)*89days/semester	See #4	178	2 hrs/day * 89 days/semester	See #6
	2nd Semester	534	(8-2 hrs/day)*89days/semester	See #4	178	2 hrs/day * 89 days/semester	See #6
	Tennis during school year				144	(36 weeks) * (2 times/week) * (2 hrs/time)	See #7
		1068	*Total School Year Hours (63-64) on MC*		500	*Total School Year Hours (63-64) on AF*	
		0	*Total Summer School Hours (1963)*		0	*Total Summer School Hours (1963)*	
		1068	**Total Hours**		**500**	**Total Hours**	
1964-1965 (Senior)	1st Semester	522	(8-2 hrs/day)*87days/semester	See #4	174	2 hrs/day * 87 days/semester	See #6
	2nd Semester	528	(8-2 hrs/day)*88days/semester	See #4	176	2 hrs/day * 88 days/semester	See #6
	Tennis during school year				144	(36 weeks) * (2 times/week) * (2 hrs/time)	See #7
		1050	*Total School Year Hours (64-65) on MC*		494	*Total School Year Hours (64-65) on AF*	
		0	*Total Summer School Hours (1964)*		0	*Total Summer School Hours (1964)*	
		1050	**Total Hours**		**494**	**Total Hours**	
		4224	**Sum Total Main Campus Hours**		**1984**	**Sum Total Athletic Field Hours**	

Calculation Assumptions/Comments:

1. Number of school days based upon BHHS School Calendar
2. Sporting events, and (Jan & Dean) events mentioned in questionnaire not included due to insufficient information
3. PE every semester ***(questionnaire page 18 #27)***
4. She says she was on campus 5 days/week for 8 hrs/day in ***questionnaire page 16 #25***
5. No summer school record
6. Due to cheer and drill team, gave 2 hrs spent on field everyday, which includes 1 hr/day for PE
7. Tennis given 2 times/week (weekend) and 2 hrs/time during school year (36 weeks) due to insufficient information, she only mentions playing tennis on the weekends in ***questionnaire p. 20 #32***

Monica Revel

Year	Term	Main Campus Hours	Notes	Comments
1989-1990 (Freshman)	1st Semester (Fall)	558	((40 min + 332 min)/60min) * 90	See #4 and 5
	2nd Semester (Spring)	558	((40 min + 332 min)/60min) * 90	See #4 and 5
	Summer School (1989)	120	4 hours x 30 days	See #2, 3, and 7
		1116	**Total Hours on MC during school year 89-90**	
		120	**Total Hours on MC during summer school 89**	
1990-1991 (Sophomore)	1st Semester (Fall)	558	((40 min + 332 min)/60min) * 90	See #4 and 5
	2nd Semester (Spring)	558	((40 min + 332 min)/60min) * 90	See #4 and 5
		1116	**Total Hours on MC during school year 90-91**	
1991-1992 (Junior)	1st Semester (Fall)	558	((40 min + 332 min)/60min) * 90	See #4 and 5
	2nd Semester (Spring)	564.2	((40 min + 332 min)/60min) * 91	See #4 and 5
	Summer School (1991)	120	4 hours x 30 days	See #2, 3, and 7
		1122.2	**Total Hours on MC during school year 91-92**	
		120	**Total Hours on MC during summer 91**	
1992-1993 (Senior)	1st Semester (Fall)	558	((40 min + 332 min)/60min) * 90	See #4 and 5
	2nd Semester (Spring)	558	((40 min + 332 min)/60min) * 90	See #4 and 5
		1116	**Total Hours on MC during school year 92-93**	
1994				
2001 - 2002				
		4470.2	**Main Campus School Year Hours**	
		240	**Main Campus Summer School Hours**	
		4710.2	**Sum Total Main Campus Hours**	

Comment/Assumptions:

1. Number of school/summer school days based upon BHHS
2. Assumed 4 hours/day for summer session due to insufficient information
3. Summer school taken during summer 1989-1990 and 1991-1992 according to ***BHHS Student Transcript and Deposition Vol. 1 p. 160:2 - 161:25***
4. Used Sawyer's summary table that Clark used for calculating exposure hours (40 min for lunch, 50 min of PE, and 332 min spent indoor in classrooms)
5. Lunch and classroom considered main campus and PE location is AF after comparing the receptor points.
6. Used hours Dr. Clark gave for 1994
7. Dr. Clark does not account for summer school hours; therefore, we added summer school exposure hours to 89 and 91 using assumptions mentioned in #2
8. Used Sawyer's summary table for calculation exposures hours for 06/01 - 01/02 = 30 + 31 + 31 + 30 + 31 + 30 + 31 + 31 = 245 days/ (7days/week) = 35 weeks using 157.5 hrs/week
9. ((35 weeks) * (157.5 hrs/week)) = 91.875 hrs rounded to get 92 hrs

Athletic Field Hours	Notes	Comments
75	(50min/60min) * 90 days	See #4 and 5
75	(50min/60min) * 90 days	See #4 and 5
0	none	
150	**Total Hours on AF during school year 89-90**	
0	**Total Hours on AF during summer school 89**	
75	(50min/60min) * 90 days	See #4 and 5
75	(50min/60min) * 90 days	See #4 and 5
150	**Total Hours on AF during school year 90-91**	
75	(50min/60min) * 90 days	See #4 and 5
75.83333333	(50min/60min) * 91 days	See #4 and 5
0	none	
150.8333333	**Total Hours on AF during school year 91-92**	
0	**Total Hours on AF during summer school 91**	
75	(50min/60min) * 90 days	See #4 and 5
75	(50min/60min) * 90 days	See #4 and 5
150	**Total Hours on AF during school year 92-93**	
125	(50min/60min) * 150 days	See #6
125	**Total Hours on AF in 1994**	
92	((157.5 min/week) * 35 weeks)/60min	See #8 and 9
92	**Total Hours on AF 2001 - 2002**	
817.8333333	**Athletic Field School Year Hours**	
0	**Athletic Field Summer School Hours**	
817.8333333	**Sum Total Athletic Field Hours**	

Jaimie Shapiro

Year	Term	Main Campus Hours	Notes	Comment	Athletic Field Hours	Notes	Comment
1973-1974 (Freshman)	1st Semester (Fall)	537	(7 - 1) hours x 89 days + (1 production * 3 hrs)	See #3, 11	89	1 hr/day * 89 days	See #6, 8, 9
	2nd Semester (Spring)	543	(7 - 1) hours x 90 days + (1 production * 3 hrs)	See #3, 11	90	1 hr/day * 90 days	See #6, 8, 9
	Summer School (1973)	0			0		
		1080	*Total School Year Hours (73-74) on MC*		179	*Total School Year Hours (73-74) on AF*	
		0	*Total Summer School Hours (1973) on MC*		0	*Total Summer School Hours (1973) on AF*	
		1080	**Total Hours**		**179**	**Total Hours**	
1974-1975 (Sophomore)	1st Semester (Fall)	531	(7 - 1) hours x 88 days + (1 production * 3 hrs)	See #3, 11	88	1 hr/day * 88 days	See #6, 8, 9
	2nd Semester (Spring)	537	(7 - 1) hours x 89 days + (1 production * 3 hrs)	See #3, 11	89	1 hr/day * 89 days	See #6, 8, 9
	Summer School (1974)	120	4 hours x 30 days	See #4	0	none	
		1068	*Total School Year Hours (74-75) on MC*		177	*Total School Year Hours (74-75) on AF*	
		120	*Total Summer School Hours (1974) on MC*		0	*Total Summer School Hours (1974) on AF*	
		1188	**Total Hours**		**177**	**Total Hours**	
1975-1976 (Junior)	1st Semester (Fall)	531	(7 - 1) hours x 88 days + (1 production * 3 hrs)	See #3, 11	88	1 hr/day * 88 days	See #6, 8, 9
	2nd Semester (Spring)	531	(7 - 1) hours x 88 days + (1 production * 3 hrs)	See #3, 11	88	1 hr/day * 88 days	See #6, 8, 9
	Summer School (1975)	120	4 hours x 30 days	See #4	0	none	
		1062	*Total School Year Hours (75-76) on MC*		176	*Total School Year Hours (75-76) on AF*	
		120	*Total Summer School Hours (1975) on MC*		0	*Total Summer School Hours (1975) on AF*	
		1182	**Total Hours**		**176**	**Total Hours**	
1976-1977 (Senior)	1st Semester (Fall)	531	(7 - 1) hours x 88 days + (1 production * 3 hrs)	See #3, 11	88	1 hr/day * 88 days	See #6, 8, 9
	2nd Semester (Spring)	531	(7 - 1) hours x 88 days + (1 production * 3 hrs)	See #3, 11	88	1 hr/day * 88 days	See #6, 8, 9
	Summer School (1976)	120	4 hours x 30 days	See #4	0	none	
		1062	*Total School Year Hours (76-77) on MC*		176	*Total School Year Hours (76-77) on AF*	
		120	*Total Summer School Hours (1976) on MC*		0	*Total Summer School Hours (1976) on AF*	
		1182	**Total Hours**		**176**	**Total Hours**	
		4272	**Main Campus School Year Hours**		**708**	**Athletic Field School Year Hours**	
		360	**Main Campus Summer School Hours**		**0**	**Athletic Field Summer School Hours**	
		4632	**Sum Total Main Campus Hours**		**708**	**Sum Total Athletic Field Hours**	

Calculation Assumptions:

1. Any time frame (e.g. 1-2 hours) the max amount was used (e.g. 2 hours).
2. Any time length (e.g. 1-2 weeks) the max amount was used (e.g. 2 weeks).
3. Time spent on campus on average is 7 hours per day as stated in ***question #25 (page 16) of questionnair*** e.
4. Summer school session assumed as 4 hours per day due to no clear description by plaintiff
5. PE for Junior/Senior year did include an off campus bowling class
6. According to ***questionnaire p. 16 #27*** , had PE 3 days/week and about 4 hours/week. 4 hours/week * (90days/5 days) = (4 * 18 weeks) = 72 hours/semester for PE on athletic field
7. All general PE counted as athletic field hours to be conservative (even bowling)
8. According to ***transcript*** , she had 2 PE classes every semester, each worth 2.5 credit units, so giving 5 hrs/week of PE on AF to be conservative (1 hr/day)
9. ***Supplemental Questionnaire*** states she had PE classes for less than 4 hrs/week, but following transcript in this calculation to be conservative
10. Ate lunch in and around cafeteria according ***Supplemental Questionnaire p. 7 #32*** , but this is considered part of school hrs and main campus
11. Says she attended theatrical productions 1973 - 1977 ***(Supplemental Questionnaire p. 7 #32)*** ,
so assumed 2 productions/year (1 production/semester) and 3 hrs/production due to insufficient information
12. Number of school days based upon BHHS School Calendar

Linnea Shore

Year	Term	Main Campus Hours	Notes	Comments	Athletic Field Hours	Notes	Comments
1975-1976 (Freshman)	1st Semester (Fall)	596	((8 hrs/day) * 88 days) - (18 weeks * 6 hrs/wk)	See #5	108	3 days/week * 18 weeks * 2 hours/day	See #6 and 9
	2nd Semester (Spring)	596	((8 hrs/day) * 88 days) - (18 weeks * 6 hrs/wk)	See #5	108	3 days/week * 18 weeks * 2 hours/day	See #6 and 9
						none	
		1192	**Total Hours on MC 75-76**		**216**	**Total Hours on AF 75-76**	
		0	**Total Hours on MC during Summer 75**		**0**	**Total Hours on AF during Summer 75**	
1976-1977 (Sophomore)	1st Semester (Fall)	596	((8 hrs/day) * 88 days) - (18 weeks * 6 hrs/wk)	See #5	108	3 days/week * 18 weeks * 2 hours/day	See #6 and 9
	2nd Semester (Spring)	596	((8 hrs/day) * 88 days) - (18 weeks * 6 hrs/wk)	See #5	108	3 days/week * 18 weeks * 2 hours/day	See #6 and 9
	Summer School (1976)	120	4 hours/day * 30 days	See #2			
		1192	**Total Hours on MC 76-77**		**216**	**Total Hours on AF 76-77**	
		120	**Total Hours on MC during Summer 76**		**0**	**Total Hours on AF during Summer 76**	
1977-1978 (Junior)	1st Semester (Fall)	612	((8 hrs/day) * 90 days) - (18 weeks * 6 hrs/wk)	See #5	108	3 days/week * 18 weeks * 2 hours/day	See #6 and 9
	2nd Semester (Spring)	612	((8 hrs/day) * 90 days) - (18 weeks * 6 hrs/wk)	See #5	108	3 days/week * 18 weeks * 2 hours/day	See #6 and 9
	Summer School (1977)	120	4 hours/day * 30 days	See #2	0	none	
		1224	**Total Hours on MC 77-78**		**216**	**Total Hours on AF 77-78**	
		120	**Total Hours on MC during Summer 77**		**0**	**Total Hours on AF during Summer 77**	
1978-1979 (Senior)	1st Semester (Fall)	616	(10 - 3 hours/day) * 88 days	See #5 and 10	270	3 hours/day * 5 days/week * 18 weeks	See #7 and 8
	2nd Semester (Spring)	616	(10 - 3 hours/day) * 88 days	See #5 and 10	270	3 hours/day * 5 days/week * 18 weeks	See #7 and 8
		1232	**Total Hours on MC 78-79**		**540**	**Total Hours on AF 78-79**	
		4840	**Total MC School Year Hours**		**1188**	**Total AF School Year Hours**	
		240	**Total MC Summer School Hours**		**0**	**Total AF Summer School Hours**	
		5080	**Sum Total Main Campus Hours**		**1188**	**Sum Total Athletic Field Hours**	

Calculation Assumptions:

1. Any time frame (e.g. 1-2 hours) the max amount was used (e.g. 2 hours).
2. Summer school days and hours information is inconsistent, assumed 4 hours/day and used BHHS School Calendar for number of days
3. All sport practices and game events included in the athletic field hours including bowling to be conservative
4. According to transcript, took 2 summer sessions (one in 76 and one in 77)
5. According to ***questionnaire p. 17 #25***, attended school 8 hours/day 75-78 and 10 hours/day from 78-79
6. PE every semester except during track in 78-79 according to ***questionnaire p. 17 #27***
7. Track 78-79 5 days/week 3-4 hours in questionnaire p. 20 #31(1) but in ***Depo. Vol. 1 p. 193:2-25***, she says 2-3 hours/day so will use deposition information max amount 3 hours/day and 5 days/week since this is latest information
8. Since she does not say when track began, assuming all of school year in 78-79
9. Participated in PE 3 days/week 2 hours/day according to ***Depo. Vol. 1 p. 155:4-9*** so 88 days/5days ~ 18 weeks or 90days/5day = 18 weeks/semester
10. For senior year, she specifically stated she was on campus 10 hr/day as stated in #6 above and did not participate in PE during the time of track; therefore, 10 hrs/day was used and 3 hrs/day on the athletic field
11. Inconsistency between PE classes listed in ***Supplemental Answers*** and ***transcript***. Following transcript, she had 5 units for PE every semester except senior year, meaning 5 hrs/week. Will keep 3 days/week and 2 hrs/day as listed in item #9 to be more conservative
12. She says she "congregated on campus after school hours", but this is too ambiguous to add any hours ***(Supplemental Answers p. 9 #32)***
13. She says she ate lunch in the "atrium outside cafeteria", but this is considered MC so doesn't affect calculations and also part of school hours ***(Supplemental Answers p. 9 #32)***
14. Stayed after school to watch football team practice ***(Supplemental Answers p. 9 #32)***, but her answers are too unclear to add any hours
15. Number of hours based upon BHHS School calendar

Stace Tackaberry

Year	Term	Main Campus Hours	Notes	Comment
1952	Spring	0		
		0	Total School Year Hours on MC (1952)	
1953	Spring	0		
		0	Total School Year Hours on MC (1953)	
1954	Spring	0		
		0	Total School Year Hours on MC (1954)	
1955	Spring	0		
		0	Total School Year Hours on MC (1955)	
1955-1956 (Freshman)	1st Semester (Fall)	546	(9 - 3 hours) x 91 days	See #3 (9 hour school day)
	2nd Semester (Spring)	637	(9 - 2 hours) x 91 days	See #3
	Summer School (1955)	0	none	
		1183	*Total School Year Hours on MC (55 - 56)*	
		0	*Total Summer School Hours on MC(1955)*	
		1183	**Total Hours**	
1956-1957 (Sophomore)	1st Semester (Fall)	546	(9 - 3 hours) x 91 days	See #3
	2nd Semester (Spring)	637	(9 - 2 hours) x 91 days	See #3
	Summer School (1956)	0	none	
		1183	*Total School Year Hours on MC(56 - 57)*	
		0	*Total Summer School Hours on MC(1956)*	
		1183	**Total Hours**	
1957-1958 (Junior)	1st Semester (Fall)	623	(9 - 2 hours) x 89 days	See #3
	2nd Semester (Spring)	623	(9 - 2 hours) x 89 days	See #3
	Summer School (1957)	0	none	
		1246	*Total School Year Hours on MC (57 - 58)*	
		0	*Total Summer School Hours on MC (1957)*	
		1246	**Total Hours**	
1958-1959 (Senior)	1st Semester (Fall)		Did not attend	
	2nd Semester (Spring)		Did not attend	
	Summer School (1958)		none	
		0	*Total School Year Hours on MC (58 - 59)*	
		0	*Total Summer School Hours (1958)*	
		0	**Total Hours**	
		3612	**Main Campus School Year Hours**	
		0	**Main Campus Summer School Hours**	
		3612	**Sum Total Main Campus Hours**	

Calculation Assumptions:

1. Any time frame (e.g. 1-2 hours) the max amount was used (e.g. 2 hours).
2. Any time length (e.g. 1-2 weeks) the max amount was used (e.g. 2 weeks).
3. Time spent on campus on average is 9 hours per day as stated in ***question #25 (page 16) of questionnaire*** .
4. Summer football sessions would take place during summer school session and assumed to be for half days or 4 hours/30 days.
5. States 1 hour for PE and 2 hours for Football, 5 days/week. Football is only 1955-1956. Swimming was from 1955-1957 (1 hour/day but not on field). ***Questionnaire questions 28 and 31*** .
6. If not playing football then time on athletic field is 2 hours per day. ***Questionnaire question 29*** .
7. Stopped attending BHHS in 11/1958 according to ***questionnaire p. 16 #23*** , but in ***depo. Vol. 1 p. 82:12-23*** he says he attended BHHS 2 1/2 to 3 yrs
8. ***Supplemental answers on p. 50 of questionnaire*** gives residence at Laurel Canyon Blvd. during part of senior year and this is assumed to be residence after returning from Texas for 6 - 8 months ***(Depo. Vol. 1 p.81:21 - 82:23)*** , so assuming BHHS attendance for 3 yrs (freshman to junior yr)
9. Little League Baseball approximately 1952 - 1955 and baseball approximately 1955 - 1958 according to ***Supplemental Answers p. 6 #32***
10. Assumed 2.5 hrs/game, 1 game/week, and 18 weeks (spring semester time) for years 52 - 58 due to insufficient information for baseball
11. He says he had "track-50 yard dash" from 55 - 56 ***(Supplemental Questionnaire p. 6 #32)*** , but insufficient information to add any hours
12. Although Dr. Clark applies 3.5 yrs to Tackaberry's high school years, our evaulation led us to believe that he attended BHHS for 3 school yrs at maximum.
13. Number of school days based upon BHHS School Calendar

Athletic Field Hours	Notes	Comment
45	2.5 hours/week * 18 weeks	See #9 - 10
45	Total School Year Hours on AF (1952)	
45	2.5 hours/week * 18 weeks	See #9 - 10
45	Total School Year Hours on AF (1953)	
45	2.5 hours/week * 18 weeks	See #9 - 10
45	Total School Year Hours on AF (1954)	
45	2.5 hours/week * 18 weeks	See #9 - 10
45	Total School Year Hours on AF (1955)	
273	3 hours x 91 days	See #5
227	2 hours x 91 days + (2.5 hrs/week * 18 weeks)	See #5 - 6, 9 - 10
120	4 hours x 30 days	See #4
500	*Total School Year Hours on AF (55 - 56)*	
120	*Total Summer School Hours on AF(1955)*	
620	**Total Hours**	
273	3 hours x 91 days	See #5
227	2 hours x 91 days + (2.5 hrs/week * 18 weeks)	See #5 - 6, 9 - 10
120	4 hours x 30 days	See #4
500	*Total School Year Hours on AF (56 - 57)*	
120	*Total Summer School Hours on AF(1956)*	
620	**Total Hours**	
178	2 hours x 89 days	See #5 and 6
223	2 hours x 89 days + (2.5 hrs/week * 18 weeks)	See #5 - 6, 9 - 10
0	none	
401	*Total School Year Hours on AF (57 - 58)*	
0	*Total Summer School Hours on AF(1957)*	
401	**Total Hours**	
	Did not attend	
	Did not attend	
	none	
0	*Total School Year Hours on AF (58 - 59)*	
0	*Total Summer School Hours on AF(1958)*	
0	**Total Hours**	
1581	**Athletic Field School Year Hours**	
240	**Athletic Field Summer School Hours**	
1821	**Sum Total Athletic Field Hours**	

Appendix C: References and Notes on Figure 6-5

CARB ATN represents the average of the measurements taken by CARB ATN Sites Downtown Los Angeles, Burbank, North Long Beach, and Azusa. CARB collects on average 20 to 30 samples yearly and reports annual averages for each monitoring site on its web site. These data are also available on a CD that can be ordered from CARB.

The CARB87 data point is taken from the publication “Residential Population Exposure to Ambient Benzene in California” (P.D. Allen, CARB Technical Support Division, 1987). The point is taken from the 1984 population-weighted annual average benzene concentration of 4.3 ppb for the South Coast Air Quality Management District reported in this publication.

The TEAM data points are taken from the paper “Results from the Total Exposure Assessment Methodology (TEAM) Study in Selected Communities in Northern and Southern California” (Hartwell et al., *Atmos. Environ.*, 1987). Four weighted medians of fixed-site outdoor air measurements taken during February-March and May-June of 1984 in various communities the South Los Angeles area were reported in Table 6 and Figure 3 of this paper.

CARB84 data points are taken from the publication “Report to the Scientific Review Panel on Benzene” (CARB; November 27, 1984). Measurements were made at several locations in the Los Angeles area from mid-September 193 through March 1984. Average values reported for the following stations are plotted in the figure: Downtown LA (6.4 ppb, 30 samples), El Monte (6.1 ppb, 123 samples), and Dominguez (5.5 ppb, 23 samples).

CARB76 shows measurements reported in the publication “Atmospheric Hydrocarbon Concentrations, June through September, 1976” (Mayrsohn, H., CARB, 1977). Thirty-five samples were taken from 0600-0900 LST in Downtown LA. The value and above reported information is taken from Seinfeld, J. H., *Atmospheric Chemistry and Physics of Air Pollution*, J. Wiley and Sons, 1986.

LAAPCD comprises points taken from “Effects of the Motor Vehicle Control Program on Hydrocarbon Concentrations in the Central Los Angeles Atmosphere” (Leonard et al., *J. Air*

Pollution Control Assoc., 1976). The three plotted data points are averages from three measurement campaigns in Downtown LA: 1963-1965 April November (0600-0800 LST, 33 samples), 1971 August-October (0700-0900 LST, 23 samples), and 1973 July-August (0700-0800 LST, 23 samples).

Appendix D: References and Notes on Figure 5-1 and Figure 5-2

The reference emission rates plotted in Figure 5-1 and Figure 5-2 were obtained in the following manner.

1. Emission rates for half mile by half-mile area of LA area background (circles): These were calculated by us using the MATES-II estimates for benzene emission rates plotted in Figure 4-7 of the MATES-II report and from the formaldehyde emission rates reported in Table 4-2 of the MATES-II report[87]. From the plotted values in Figure 4-7 of the MATES-II report, we estimated the benzene emission rates for 1998 in the central Los Angeles area to be 25 kg/day over a 4-km^2 area. We then rescaled the value to that over a half-mile by half-mile square by multiplying it by 0.16, and converted the units to milligrams per second. The projection of these benzene emission rates forward and backward in time (dashed line, Figure 5-1) was obtained by multiplying the above computed value for 1998 (circle in Figure 5-1) by the ratio of the average measured benzene concentration in the Los Angeles area for a given year by its value for 1998. We obtain the average benzene concentrations in the Los Angeles area by averaging the annual average benzene concentrations for the following four sites in California Air Resources Board Air-Toxics Network (CARB-ATN): Burbank, Downtown Los Angeles, Azusa, and North Long Beach[88].

   The plotted value for formaldehyde (circle, Figure 5-2) is based on the value 31,458.8 lbs/day over the South Coast Air Basin taken from Table 4-2 of the MATES-II report. We approximated the area of these formaldehyde emissions to be 2,500 km^2, which is roughly the size of the non-rural area of the South Coast Air Basin. The value was then rescaled to that over a half-mile by half-mile square and converted to milligrams per second.

[87] The MATES-II report can be viewed and downloaded at http://www.aqmd.gov/matesiidf/matestoc.htm.
[88] These CARB-ATN measurements can be found at http://www.arb.ca.gov/adam/toxics/toxics.html.

2. Benzene emission rates for a half mile of Santa Monica Blvd. (solid-plus line): These emission rates were obtained by multiplying the emissions of total organic gases (TOG) from road traffic along a half-mile section of Santa Monica Blvd. in Beverly Hills by the percent benzene emission per TOG emission.

   The TOG emissions from the road traffic were estimated as

   $$\text{TOG} = \text{Emission Factor} \times \text{Average Vehicle Traffic} \times \text{Road Length}$$

   The emission factor is the grams TOG per mile driven. The average vehicle traffic is expressed in cars per day. The road length is specified as a half mile[89]. This multiplication gives TOG in grams per day. This is then multiplied by the % benzene per TOG and converted to milligrams per second in Figure 5-1. We did these calculations for each of six years: 1975, 1980, 1985, 1990, 1995, and 2000.

   The emission factors were estimated by us by running the California Air Resources Board mobile source emission-estimating algorithm EMFAC2002(v2) – which we will refer to as EMFAC[90]. The emission factors were computed by dividing the annual averaged daily emissions of TOG (tons per day) in Los Angeles County by the annual average daily road traffic (vehicle miles traveled per day), each of which estimated by EMFAC for Los Angeles County for the above six years. This division yields emission factors for each of the six years in tons TOG per mile, which are then converted to grams TOG per mile.

   The average vehicle traffic along the considered half-mile section of Santa Monica Blvd. was obtained from traffic counts along Santa Monica Blvd. that are regularly monitored by the California Department of Transportation[91]. We averaged the

89 Road length has units miles per car in the equation, since we are assuming each car passes through the entire specified length of road.

90 Details and download of EMFAC are found at http://www.arb.ca.gov/msei/on-road/on-road.htm.

91 These traffic counts are listed in the California Department of Transportation publications, “Traffic Volumes on California State Highways – Annual Report”. These reports are published annually by DOT back to the year 1934.

annually averaged daily counts reported for mileposts 5.16 (Santa Monica Blvd. at Beverly Glen), 5.58 (at Avenue of the Stars) and 6.20 (at Wilshire) to obtain an estimate of the road traffic along a half mile section centered roughly on the one mile section spanned by these mileposts.

The percentage of benzene emission per TOG emission was obtained from figures reported in Kirchetetter et al. (1999)[92]. We divided the grams per liter consumed fuel of non-methane organic compound (NMOC) emissions reported in Figure 4 of this paper by the grams per liter consumed fuel of benzene emissions reported in Figure 5 of this report. Since NMOC is approximately TOG minus methane, and since methane is not a major component of vehicle emissions, NMOC and TOG are approximately equal for this application[93]. From this analysis, we estimate a value of 6.25% benzene per TOG emission in years prior to 1995 and a value of 3% benzene per TOG emission in 1995 and after.

3. Benzene and formaldehyde emission rates from construction events (hexagon symbols in the figures): The emission rates of benzene and formaldehyde associated with two construction events in Century City were computed by Ms. Wilson. These rates were supplied to us by Ms. Wilson in pounds per year benzene and formaldehyde[94]. We converted these to milligrams per second and plotted their values in Figure 5-1 and Figure 5-2.

[92] Kirchetetter, T. W., B. C. Singer, R. A. Harley, G. R. Kendall, and M. Traverse, 1999: "Impact of California Reformulated Gasoline on Motor Vehicle Emissions, 1. Mass Emission Rates", *Environ. Sci. Technol.*, Vol. 33, 318-328.

[93] See http://www.arb.ca.gov/ei/speciate/ORGTERMS_NMHC_THC_TOGSummary.pdf and www.arb.ca.gov/ei/speciate/FACTSHEETS_ MODEL_EI_Speciation_TOG_8_00.doc for official definitions of TOG and NMOC.

[94] These were supplied to in the document "Draft Construction Emissions for 2029 Century Park E. and 1800 Century Park E.".