

API Comments on EPA's Partial Second Draft of the NO₂ NAAQS Review REA: Part 1

(Not Including the Exposure Assessment and Health Risk Characterization)

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Introduction

On behalf of the American Petroleum Institute (API), Mr. Robert Paine of ENSR provided public comments to CASAC on September 10, 2008 on the first and second drafts of the *Risk and Exposure Assessment to Support the Review of the NO₂ Primary NAAQS (REA)* and the accompanying *Technical Support Document (TSD)*. ENSR's review focused on the modeling and statistical methods to estimate ambient concentrations, as well as unresolved dispersion modeling implementation issues for addressing short-term NO₂ concentrations. The REA applied a simple roll-up technique to estimate short-term (1-hour) average ambient concentrations for a hypothetical future where the highest measured annual average ambient NO₂ concentration just meets the current 53 ppb (100 µg/m³) annual air quality standard.

The second draft REA document, released for public review on September 2, 2008 (Docket ID No. EPA-HQ-OAR-2006-0922), also introduced the possibility of statistical short-term standards based on 98th and 99th percentiles of daily maximum 1-hour concentrations. The second draft document did not include Chapter 8 "Exposure Assessment and Health Risk Characterization" and an appendix containing supporting analyses. Therefore, these comments do address that essential chapter of the REA.s, but provides general comments on the limitations of EPA-approved models for short-term NO₂ predictions. Part 2 of these comments will follow after the missing Chapter 8 and the appendix is released by EPA.

To evaluate the degree to which an annual average air quality standard is protective of short-term concentrations, EPA has applied a simple roll-up technique. In this technique, it is assumed that the monitored proportional relation between the annual average concentration and peak 1-hour concentrations is retained when the annual concentrations is hypothetically increased to match the annual standard. By analyzing the data in the context of the atmospheric chemistry that results in the formation of NO₂ from emissions of NO, it is clear that using the simple roll-up technique to extrapolate compliance with an annual average standard to a short-term standard is inappropriate for pollutants such as NO₂, which are largely the products of atmospheric reactions. The simple roll-up technique used by EPA incorrectly assumes that the monitored peak to mean ratios (PMR, defined here as the peak 1-hour NO₂ concentration per year divided by the annual average concentration) is invariant. This assumption is shown to be invalid as the measured PMR decreases with higher annual average concentrations. The implication is that when evaluating the stringency of the annual NO₂ NAAQS for short-term exposure, the REA overestimates peak short-term concentrations and the frequency that they exceed health benchmarks. Because of this important finding, ENSR has developed a

more realistic statistical method to estimate peak 1-hour average ambient NO₂ concentrations that accounts for the variation of the PMR with annual NO₂.

Why Simple Roll-up is Not Appropriate for NO₂

The REA uses simple roll-up for both the ambient air quality analysis and the exposure analysis to extrapolate monitored or modeled conditions to hypothetical future conditions where the annual average NAAQS for NO₂ is just met. The simple roll-up method assumes that an increase in annual NO₂ concentrations needed to match the NAAQS will be proportionately reflected in all hourly concentrations. For the exposure assessment, an equivalent to the roll-up method is applied by adjusting the acute health effects benchmarks by the ratio of modeled ambient annual concentration to the annual NAAQS. Both applications of the roll-up method inherently rely on three assumptions, none of which are valid:

- 1) *The same mixture of sources will affect the NO₂ air quality now when ambient concentrations are generally well below the NAAQS, and at some point in time when the annual NAAQS is barely attained.* The present NO₂ air quality is the result of myriad sources throughout the surrounding area. For an inert pollutant, the PMR is highly dependent on source-receptor relationships, such as release height, distance and direction. Ambient NO₂ concentrations are generally a small fraction of the NAAQS. A substantial increase in annual average concentration would in reality need to be associated with changes in the source configuration (e.g., new roadways or industries) as it would be impossible for existing sources to emit at the levels necessary to increase concentrations to that extent.
- 2) *There is a proportional increase in emissions from all of these sources over all averaging periods.* Even if existing sources could account for the increase in emissions needed to just meet the NAAQS, it is highly unlikely that the all source emissions for all times of the day would change by the same percentage. For example, vehicular traffic, which is an important source of NO_x (NO + NO₂) emissions, has a strong diurnal cycle.
- 3) *Ambient concentrations over all averaging times will increase in direct proportion to emissions.* This assumption does not hold for NO₂ or other secondary pollutants. Only a small percentage ambient NO₂ is comprised of NO₂ directly emitted from sources, and most of NO₂ in the ambient air is created through chemical reactions with oxidants in the atmosphere, such as ozone. The issue is further complicated because the concentration of ambient ozone is in turn associated with complex photochemical reactions involving NO, NO₂ and hydrocarbon ubiquitous in the urban environment and, therefore, varies widely with time of day. If, at a particular hour the concentration of NO from a source is lower than the ambient ozone concentration, then nearly all NO emitted during that hour is converted to NO₂. If the NO concentration is greater than the ambient ozone concentration, then only a portion of the NO emitted is converted to NO₂ due to the limited amount of available ozone. Because the relative NO and ozone concentrations vary widely with time of day and time of year, the effect of ozone is that the highest hourly NO₂ concentrations are more likely to be limited than average NO₂ concentrations. Thus, an increase of the annual NO₂ concentration from existing levels to the NAAQS will result in a less-than-proportional increase in peak 1-hour NO₂ concentrations. The chemistry of NO₂ formation also has implications on the limitations of dispersion models, such as AERMOD, to accurately simulate peak 1-hour concentrations, which is discussed further in a separate section below.

Analysis of Ambient Measurement Data

ENSR downloaded ambient NO₂ concentration summaries from the EPA AirData for all U.S. monitors for the year 2007 (http://www.epa.gov/aqspubl1/annual_summary.html). For comparison purposes, monitor summary data for two primary pollutants, CO and SO₂, were also downloaded. Plots of the PMRs for second-high concentration per year are shown in Figures 1, 2 and 3, for NO₂, CO and SO₂, respectively. For the simple roll-up technique to be applicable, there would need to be no correlation between the PMR and the annual average concentration. The plots indicate that for the relatively non-reactive pollutants CO and SO₂, there is indeed virtually no correlation between the PMRs and annual average concentrations, but that for NO₂, there is a strong negative correlation. The plot shows that for NO₂ as the monitored annual average increases, the PMR decreases. Thus, applying the simple roll-up technique to NO₂ would substantially overestimate the PMR and the resultant projection of peak concentrations.

Figure 1 Scatter Plot: PMR versus Annual NO₂ Concentrations for 2007 Monitoring Data

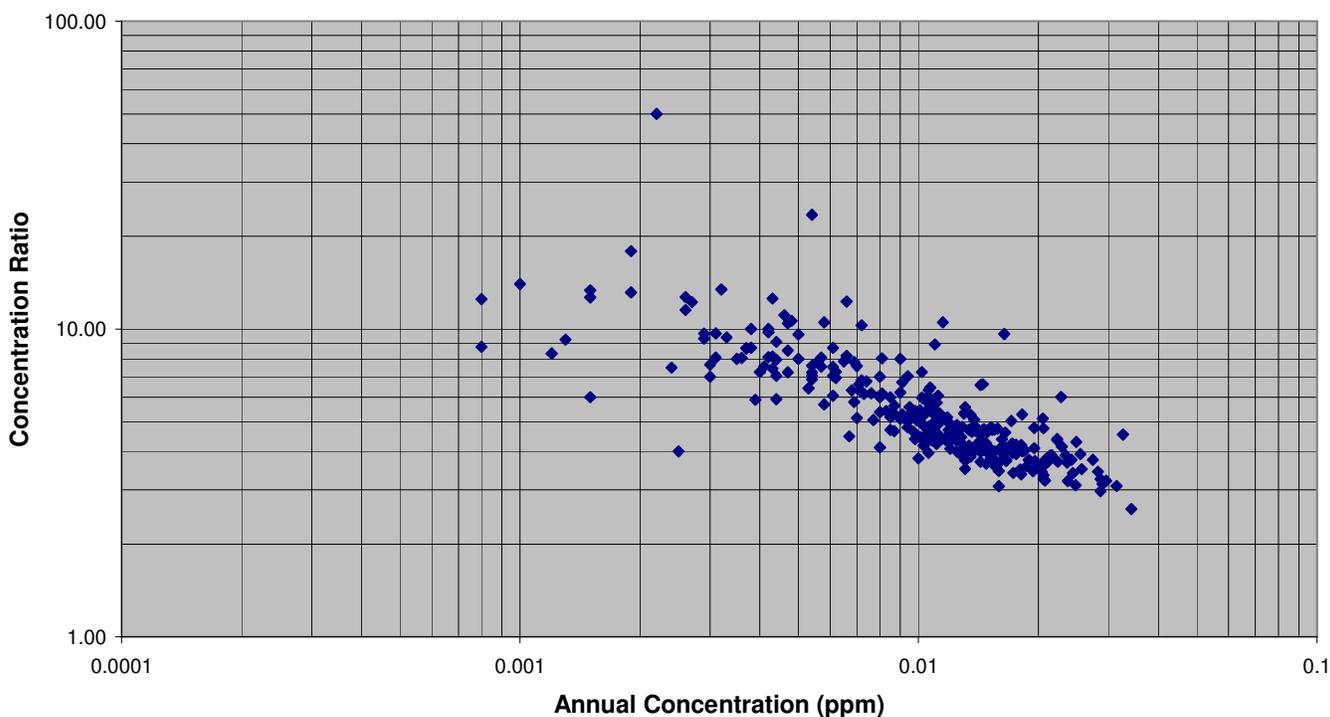


Figure 2 Scatter Plot: PMR versus Annual CO Concentrations for 2007 Monitoring Data

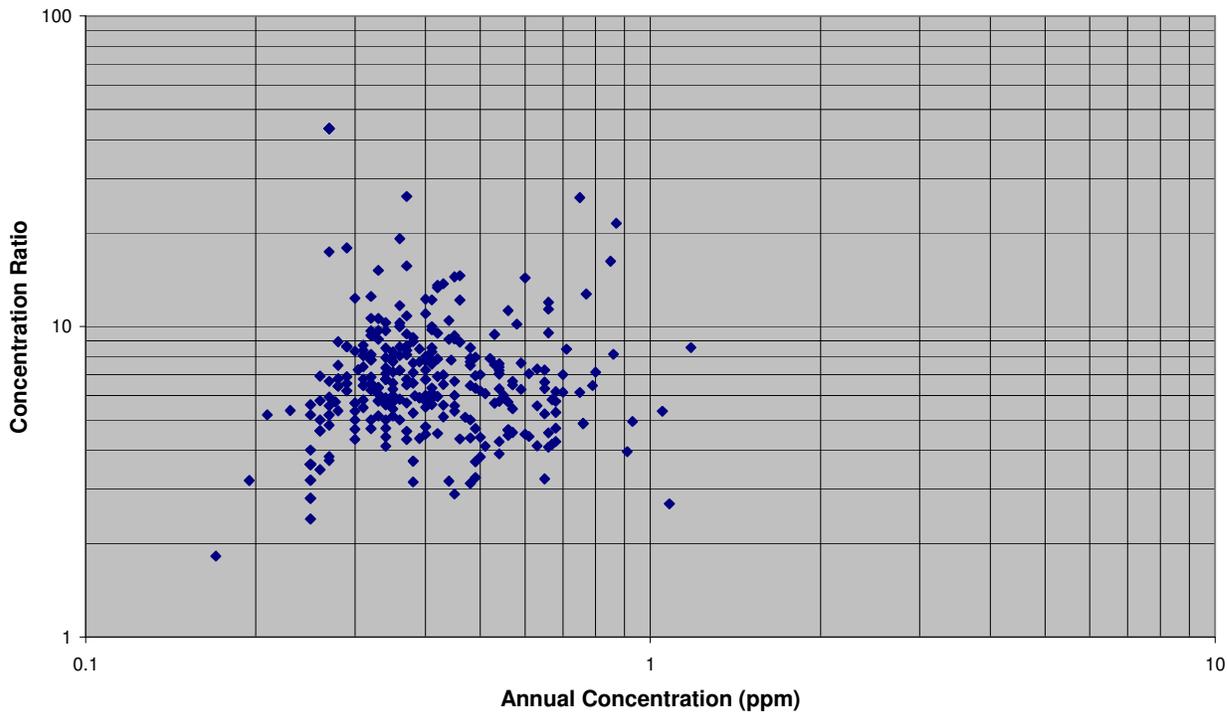
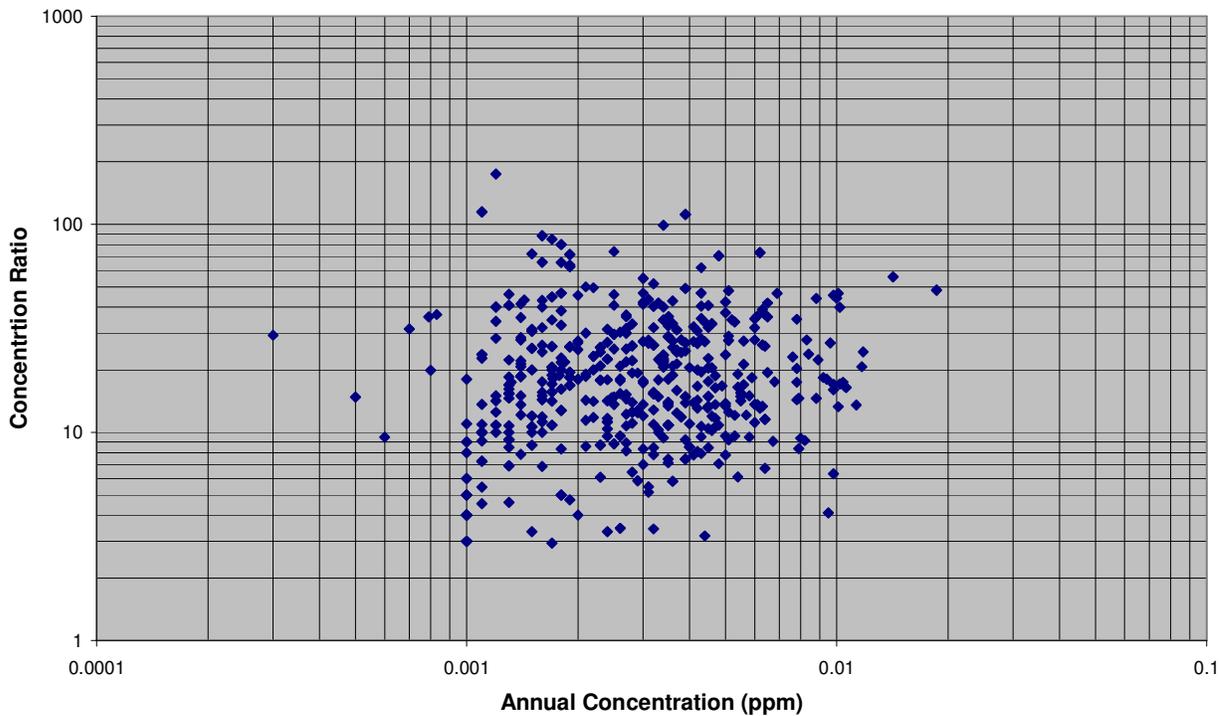


Figure 3 Scatter Plot: PMR versus Annual SO₂ Concentrations for 2007 Monitoring Data



Development of a PMR Model for NO₂

The PMR has been shown, based on the analysis of 2007 data, to vary strongly with annual NO₂ concentration. ENSR downloaded NO₂ data for the past three years (2005, 2006 and 2007) and compiled data for all monitoring site-years (1113) with greater than 75% data capture. Given the uncertainty in monitoring low concentrations as noted in the REA, a subset of 680 site-years for which the annual average NO₂ exceeded 0.01 ppm, less than 20% of the present NAAQS, were analyzed. Data values are available for the 99th percentile statistic, but not the 98th percentile value. The 99th percentile value was used as a conservative measure of a statistically-based standard in the analyses presented below, but we present some results for estimated 98th percentile values as well. In addition, the occurrence of hourly concentrations irrespective of how many times in one day they occur (rather than the maximum peak daily value) was analyzed as a conservative measure that would overstate the number of occurrences of peak hourly impacts vs. the maximum peak daily impacts.

The plot of the NO₂ PMR for 2nd high value and the 99th percentile value are shown in Figures 4 and 5, respectively. These plots also provide the results of a power law regression, using a least-squares fitting technique, where:

$$PMR = a (AveNO_{2measured})^{-b} \tag{Equation 1}$$

For the 2nd High 1-hour concentration the regression equation a = 0.8115 and b = -0.4071.

For the 99th Percentile concentration the regression equation a = 0.5799 and b = -0.395.

Figure 4: PMR for Second-High 1-hour vs. Annual NO₂ Concentrations for 2005-2007 Monitoring Data

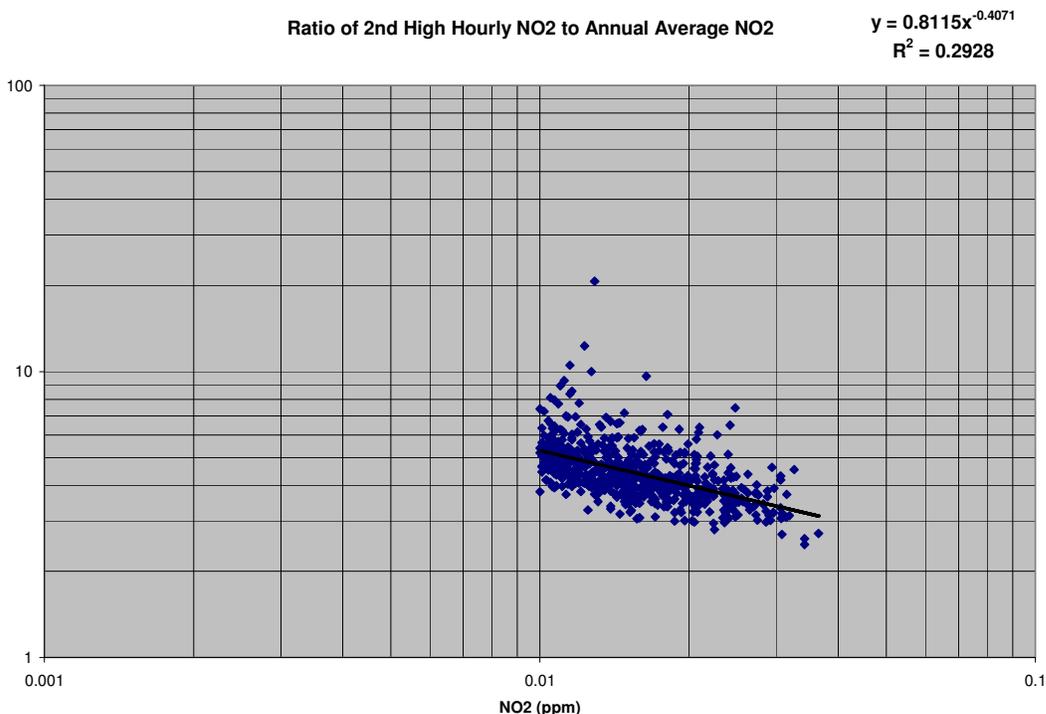
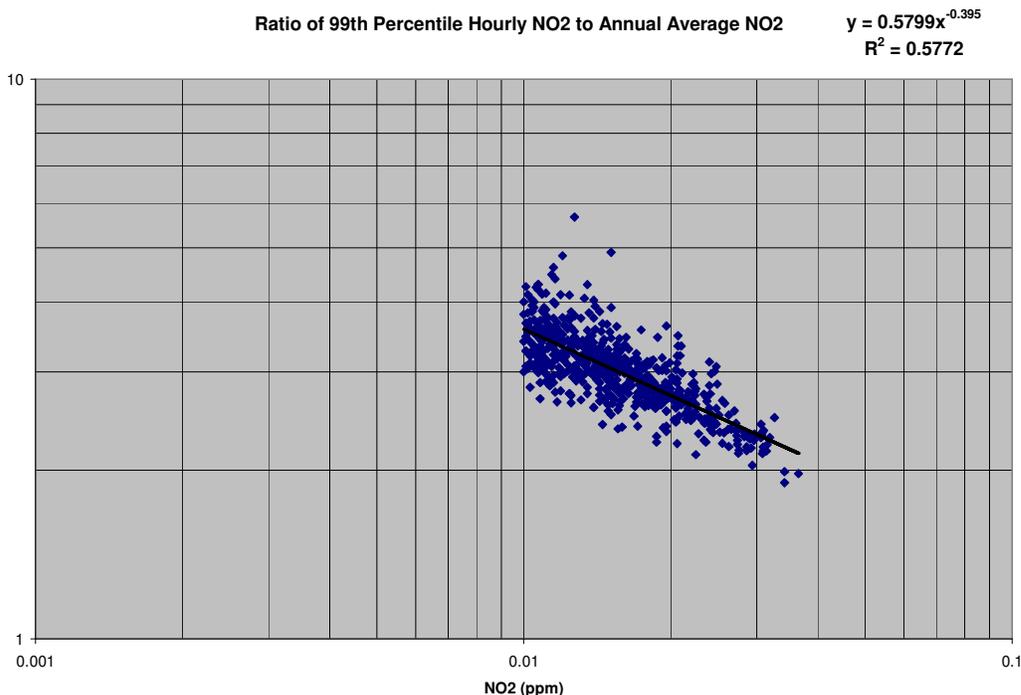


Figure 5: PMR for 99th Percentile 1-hour vs. Annual NO₂ Concentrations for 2005-2007 Monitoring Data



Applying the NO₂ PMR Model to Evaluate Peak 1-hour Concentrations

As can be seen from Figure 4 and Figure 5, there is variability in the PMR at a particular location and year, due to such factors as specific source-receptor-relationships, source types, intermittency and diurnal variation of emissions sources and meteorology. The statistical analysis of the PMR for the 2005-2007 nationwide data indicates that the measured PMR would be expected to decrease as the average NO₂ increases, according to average NO₂ raised to the power “b”.

The regression equation can be used instead of simple roll-up to estimate the second-high and 99th percentile value associated with an average concentration.

For each monitor-year the “a” defined by the measured PMR at the specific location, where, according to Equation 1:

$$a = PMR_{measured} (AveNO_{2measured})^{-b} \tag{Equation 2}$$

To then estimate the PMR for the monitor-year at an alternative Annual Limit (AL in ppm), such as the current NAAQS, the value for “a” is substituted into Equation 1:

$$PMR_{AL} = PMR_{measured} (AveNO_{2measured})^{-b} (AL)^b \tag{Equation 3}$$

To estimate the peak (e.g., 2nd highest or 99th percentile) concentration at AL:

$$\begin{aligned} \text{Peak NO}_{2AL} &= PMR_{AL}(AL) \\ &= [PMR_{measured} (AveNO_{2measured})^{-b} (AL)^b] (AL) \end{aligned}$$

$$\begin{aligned}
 &= (\text{Peak NO}_{2\text{measured}}) (\text{AveNO}_{2\text{measured}})^{-1} (\text{AveNO}_{2\text{measured}})^{-b} (\text{AL})^{1+b} \\
 &= (\text{Peak NO}_{2\text{measured}}) (\text{AveNO}_{2\text{measured}})^{-(1+b)} (\text{AL})^{1+b}
 \end{aligned}
 \tag{Equation 4}$$

For the 99th percentile:

$$= (99\% \text{NO}_{2\text{measured}}) (\text{AveNO}_{2\text{measured}})^{-0.605} (\text{AL})^{0.605} \tag{Equation 5a}$$

For the 2nd High per year:

$$= (2\text{nd HighNO}_{2\text{measured}}) (\text{AveNO}_{2\text{measured}})^{-0.5929} (\text{AL})^{0.5929} \tag{Equation 5b}$$

For the case where AL = the present NAAQS of 0.053 ppm, this yields:

$$99\% \text{NO}_{2\text{NAAQS}} = 0.1691 (99\% \text{NO}_{2\text{measured}}) (\text{AveNO}_{2\text{measured}})^{-0.605} \tag{Equation 6a}$$

$$2\text{nd High NO}_{2\text{NAAQS}} = 0.1752 (2\text{nd HighNO}_{2\text{measured}}) (\text{AveNO}_{2\text{measured}})^{-0.5929} \tag{Equation 6b}$$

For the case of simple roll-up, b=0 and the equation simplifies to:

$$\text{Peak NO}_{2\text{AL}} = (\text{Peak NO}_{2\text{measured}}) (\text{AveNO}_{2\text{measured}})^{-1} (\text{AL}) \tag{Equation 7}$$

Current Air Quality in Terms of Peak NO₂ Concentrations

Figures 6 and 7 provide plots of the second-highest per year and 99th percentile NO₂ concentrations for 2005-2007 versus the annual average concentration for all site-years (948) with greater than 75% data capture and annual average concentration exceeding 10% of the NAAQS. Figure 6 indicates that with the exception of only three data points, the second-highest hourly concentrations are all below 0.2 ppm. For the 99th percentile, all values except one are less than 0.08 ppm. As can be seen from these figures, the 99th percentile value is more highly correlated to the annual average concentration than the second-high concentration.

The second draft REA indicates that EPA is also considering the 98th percentile value. Although AirData summaries do not include the 98th percentile concentrations, they include the 75th, 90th, 95th and 99th percentile values. By plotting the values for NO₂ monitors for 2007 on log-probability paper (upon which a straight line represents a log-normal distribution), ENSR estimated that the 98th percentile value for any monitor site year would be between 80% and 96% of the 99th percentile value, with a mean of 90% of the 99th percentile value.

The second draft REA also alludes to using the highest daily 1-hour NO₂ concentration as an air quality metric rather than hourly data directly. Given that peak NO₂ concentrations could persist for several hours in a given day, the 99th percentile concentration considering all hourly values will be a higher concentration than the 99th percentile of the daily maxima. Thus, the present analysis is consistent with second draft REA, which indicates that measurements of existing air quality show that 99th percentile hourly NO₂ values are all below 0.1 ppm, by a substantial margin.

Figure 6 Plot of Second High 1-Hour Concentration versus Annual Average (2005-2007)

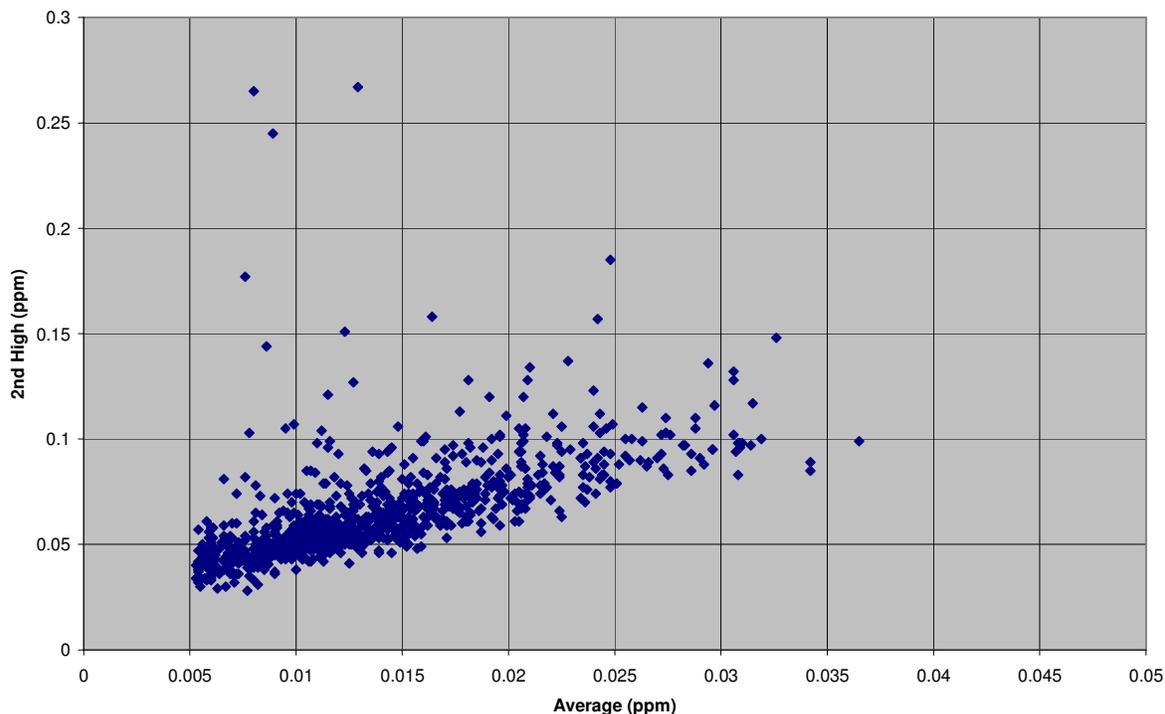
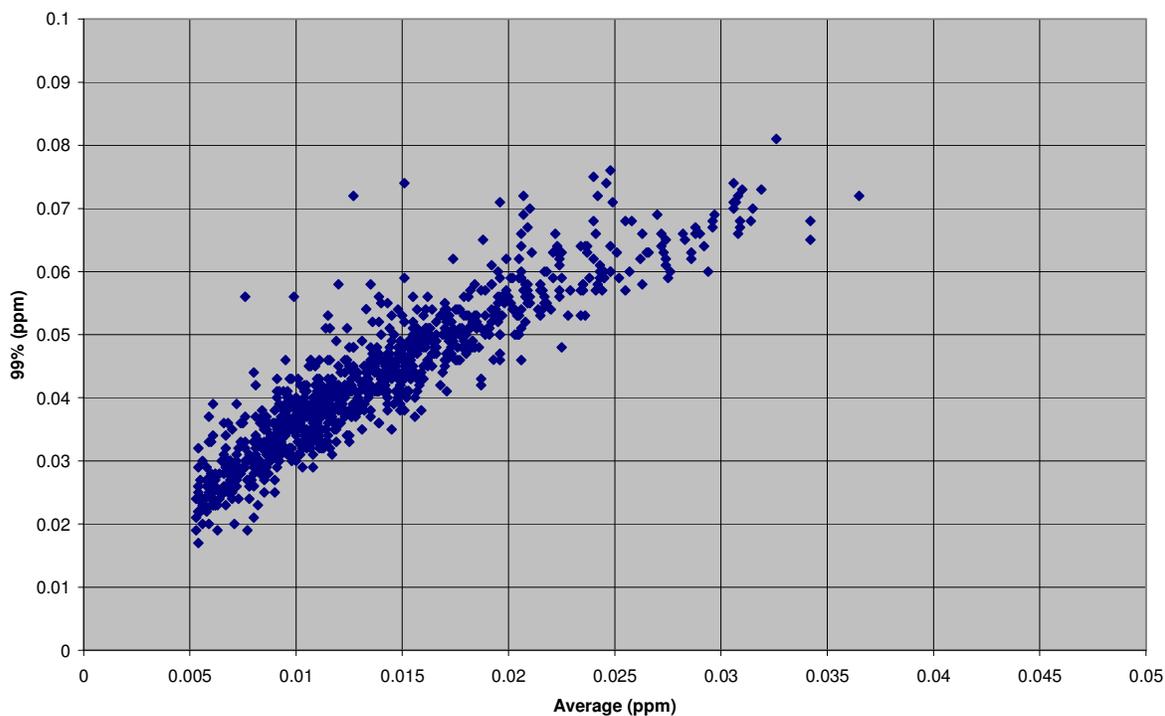


Figure 7 Plot of 99th Percentile 1-Hour Concentration versus Annual Average (2005-2007)



Projected Peak 1-Hour NO₂ Concentrations Based Upon the Annual Average NAAQS

The PMR model and the direct roll-up method were both applied to the 2005-2007 NO₂ measurement database for all monitor years with greater than 75% data capture and annual average concentrations exceeding 0.01 ppm. Figure 8 shows provides the results of the projected 99th percentile values using the simple roll-up method and Figure 9 provides the results for the more appropriate PMR model. Figures 10 and 11 provide similar information for estimates of the 98% percentile values (they range from 80 to 96% of the 99th percentile values, with individual data values determined on a randomized statistical basis within this range). Projections of peak 1-hour NO₂ values for three different annual average levels were assessed: 0.03, 0.04 and 0.053 ppm (the current NAAQS). The columns in Figures 8 and 9 represent the percent of the 680 monitor-years for which the 99th percentile (and 98th percentile in Figures 10 and 11) 1-hour concentration would exceed levels of 0.1, 0.15 and 0.2 ppm. The simple roll-up method indicates that if all monitors just barely complied with the current annual NAAQS, then 100% of the 99th percentile 1-hour concentrations would exceed 0.1 ppm and that more than 20% would exceed 0.2 ppm. In stark contrast, the more appropriate PMR model indicates for the same compliance situation that less than 40% of the monitor years would exceed 0.1 ppm, less than 0.5 % would exceed 0.15 ppm, and that no monitors would exceed 0.2 ppm. For that reason, we did not report results for 1-hour concentrations greater than 0.2 ppm. These results indicate that the present NAAQS is protective of the 99th percentile threshold of 0.15 ppm for almost all locations and is always protective of the 0.2 ppm threshold. The present NAAQS is also protective of the 98th percentile for 1-hour concentrations of at least 0.1 ppm for over 90% of the data values.

Direct comparisons of the PMR Model and the Roll-up Method are provided in Figure 12 (a through d) corresponding to annual average air quality objectives of 0.053, 0.05, 0.04 and 0.03 ppm. The fraction of points exceeding benchmark thresholds such as 0.2 ppm can be seen for both the simple roll-up and PMR methods, which correspond to the bar graphs in Figures 8 and 9. The figures show that the degree of overestimation of the simple roll-up method increases with the annual average objective. This is because the closer the objective is to the current annual average, the more representative the observed PMR.

Figure 8 Application of the Direct Roll-up Method to Estimate Percentage of Monitor-years Where 99th Percentile Concentrations Exceed Threshold Levels of 0.1, 0.15 and 0.2 ppm Corresponding to Annual Average Concentrations of 0.03, 0.04, 0.05 and 0.053 0.03 to 0.053 ppm

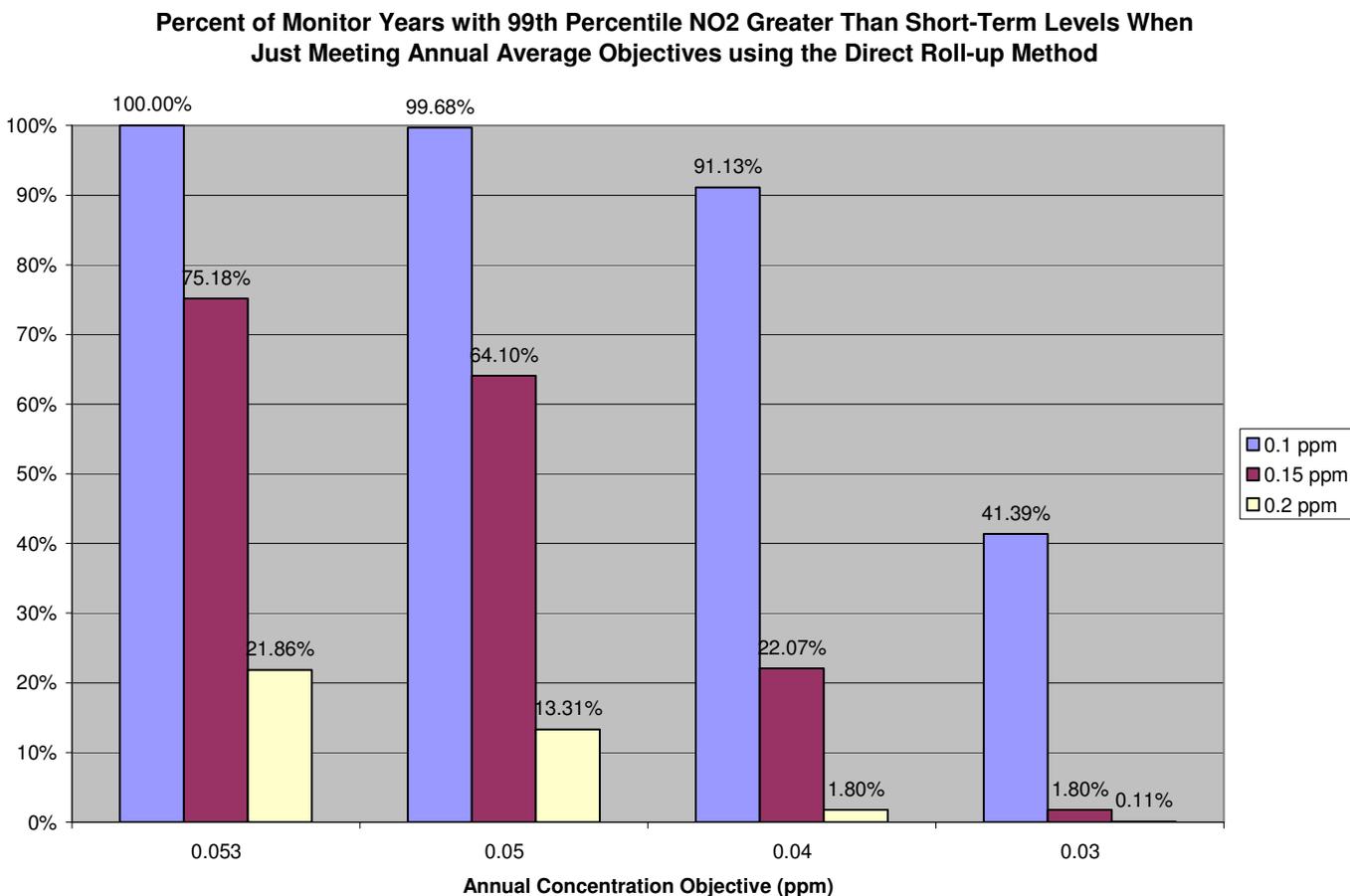


Figure 9 Application of the PMR Model to Estimate Percentage of Monitor-years Where 99th Percentile Concentrations Exceed Threshold Levels of 0.1, 0.15 and 0.2 ppm Corresponding to Annual Average Concentrations of 0.03, 0.04, 0.05 and 0.053 0.03 to 0.053 ppm

Percent of Monitor Years with 99th Percentile NO2 Greater Than Short-Term Levels When Just Meeting Annual Average Objectives using the PMR Model

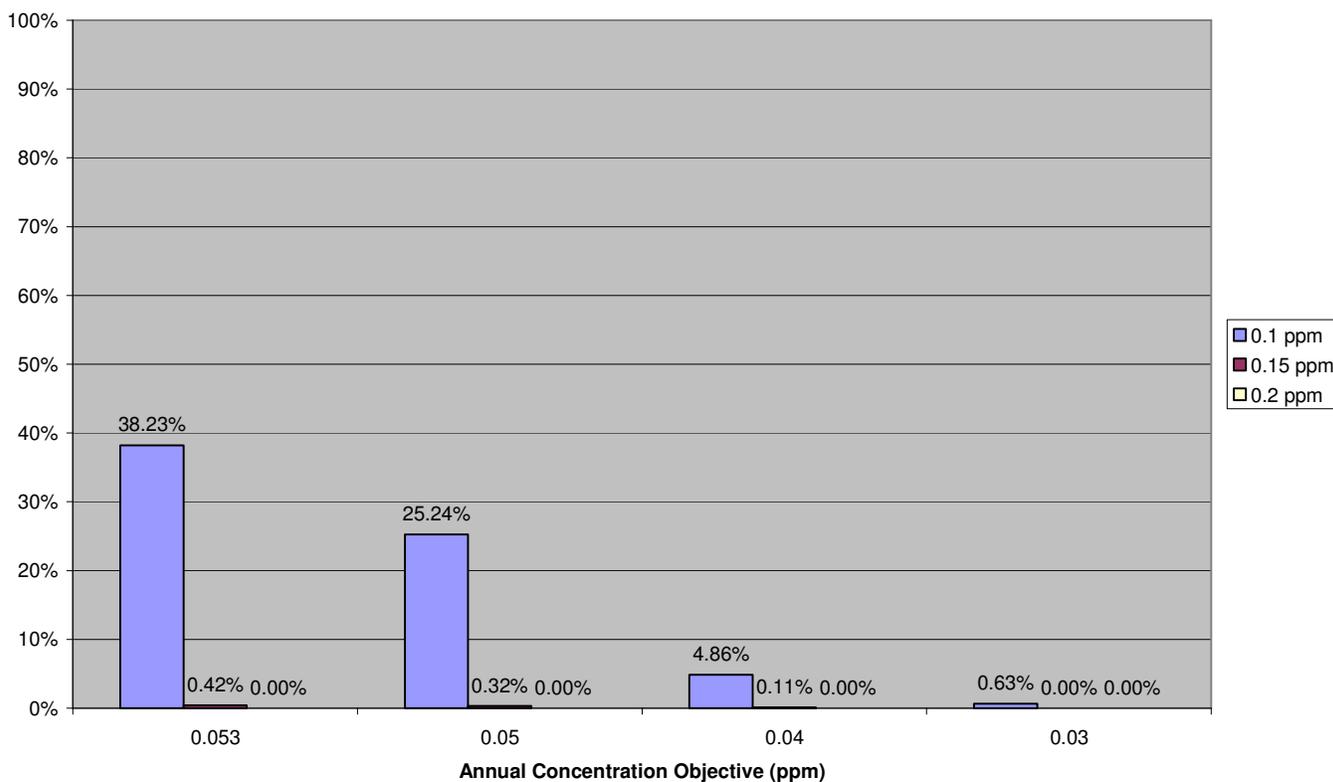


Figure 10 Application of the Direct Roll-up Method to Estimate Percentage of Monitor-years Where 98th Percentile Concentrations Exceed Threshold Levels of 0.1, 0.15 and 0.2 ppm Corresponding to Annual Average Concentrations of 0.03, 0.04, 0.05 and 0.053 0.03 to 0.053 ppm

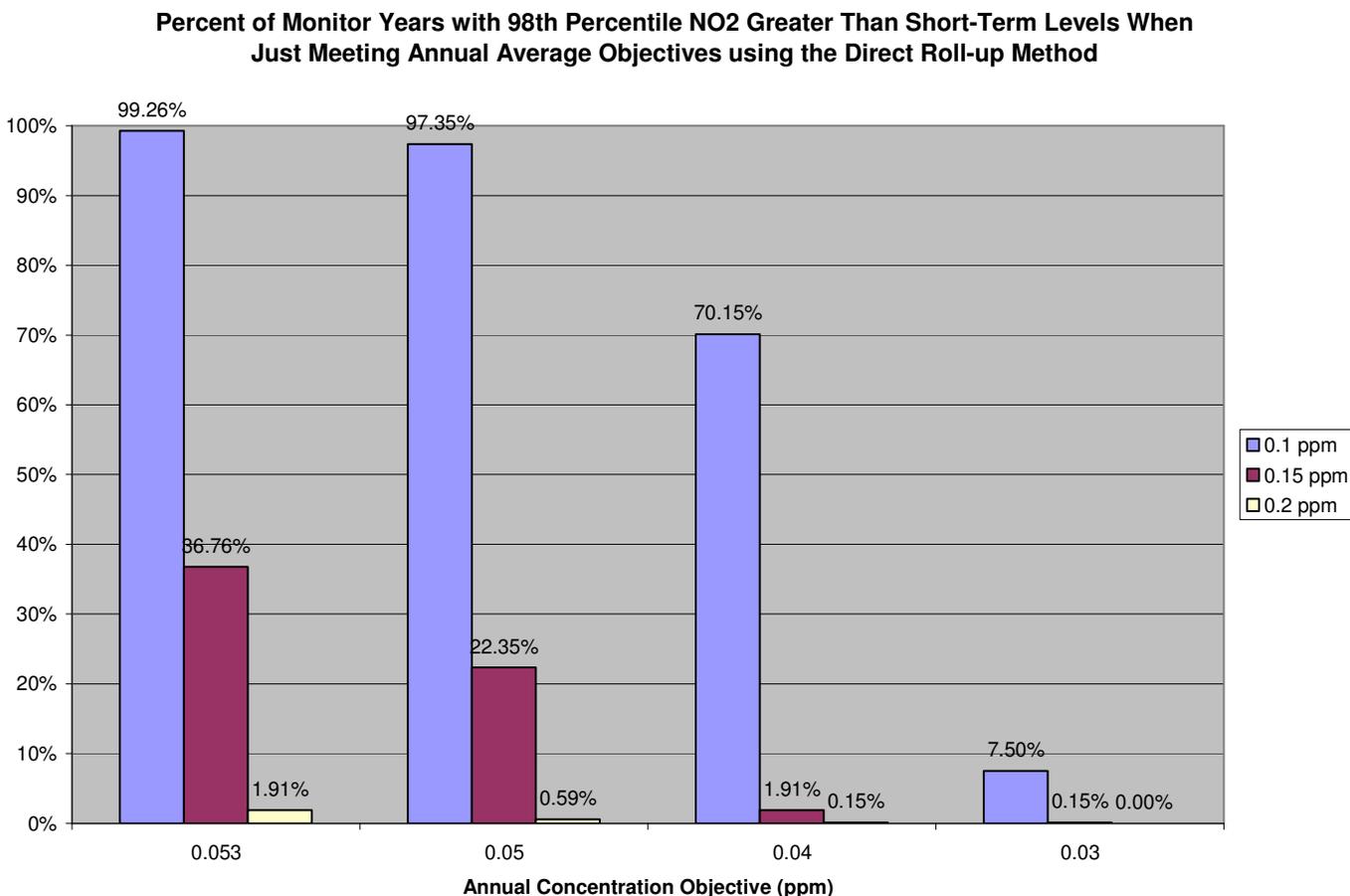


Figure 11 Application of the PMR Model to Estimate Percentage of Monitor-years Where 98th Percentile Concentrations Exceed Threshold Levels of 0.1, 0.15 and 0.2 ppm Corresponding to Annual Average Concentrations of 0.03, 0.04, 0.05 and 0.053 0.03 to 0.053 ppm

Percent of Monitor Years with 98th Percentile NO₂ Greater Than Short-Term Levels When Just Meeting Annual Average Objectives using the PMR Model

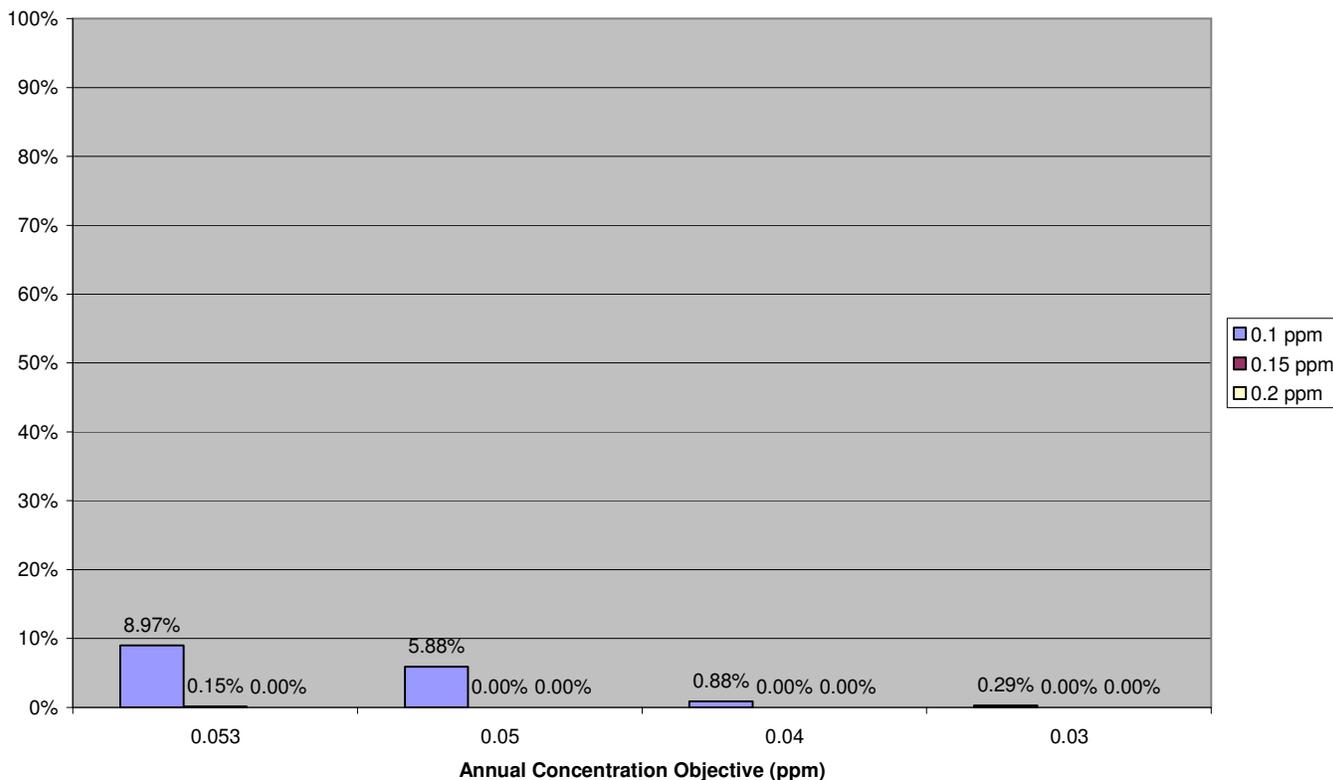


Figure 12 a) Scatter Plot of PMR Model and Roll-up Projection of the 99th Percentile NO₂ when the Annual Average for all Monitor-years is the Current NAAQS (0.053 ppm)

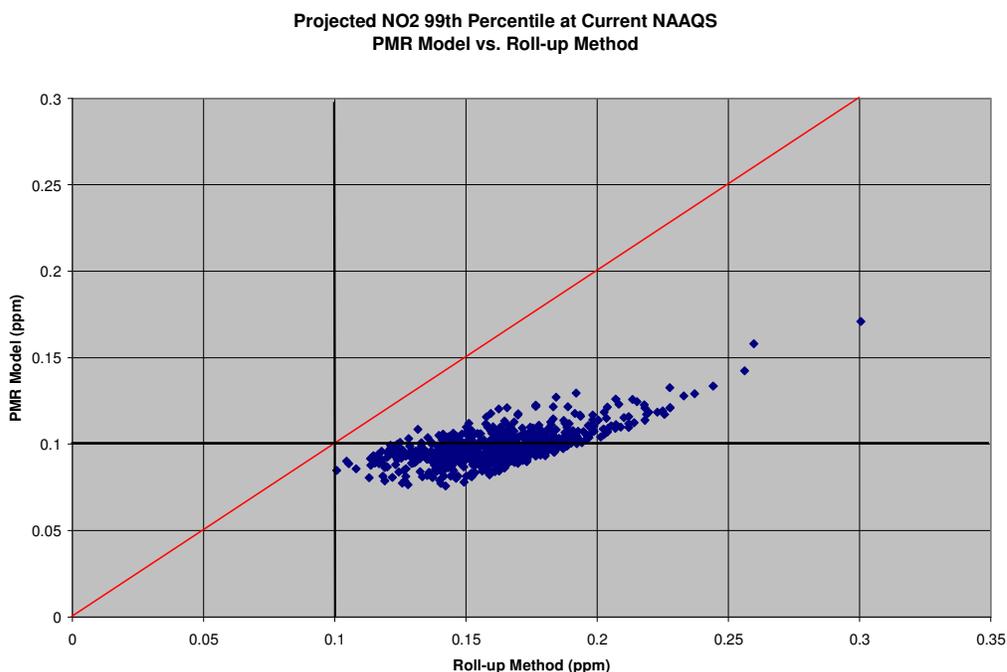


Figure 12 b) Scatter Plot of PMR Model and Roll-up Projection of the 99th Percentile NO₂ when the Annual Average for all Monitor-years is 0.05 ppm

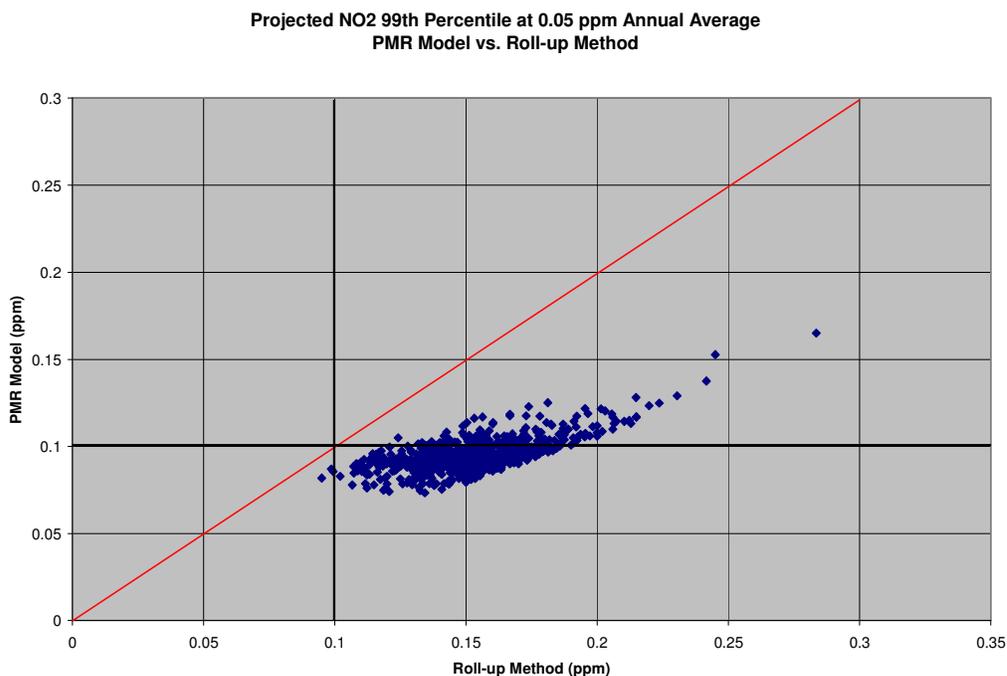


Figure 12 c) Scatter Plot of PMR Model and Roll-up Projection of the 99th Percentile NO₂ when the Annual Average for all Monitor-years is 0.04 ppm

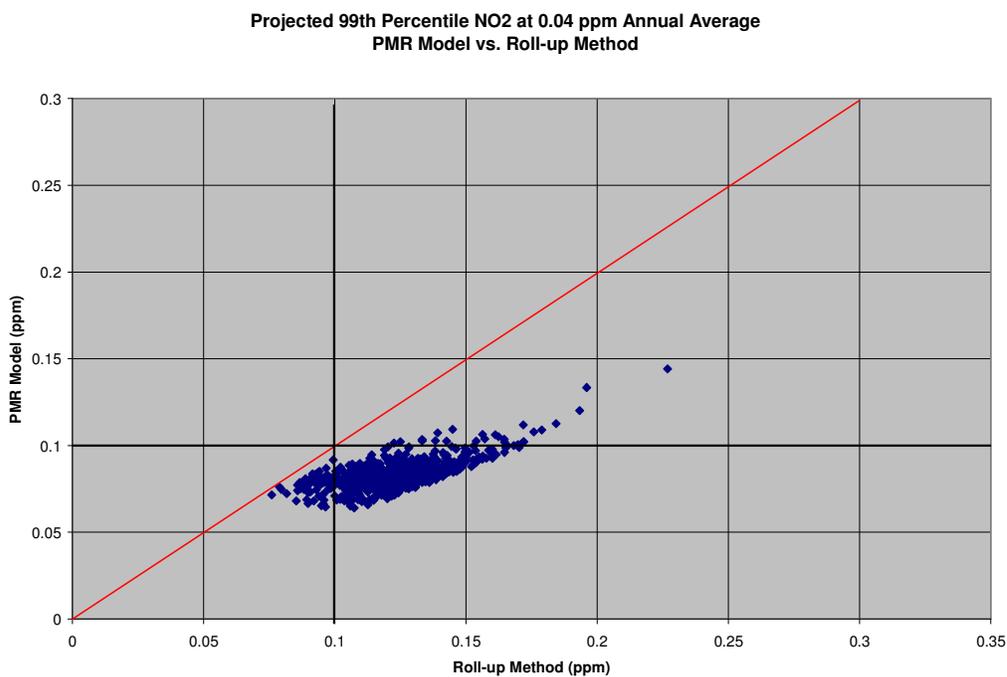
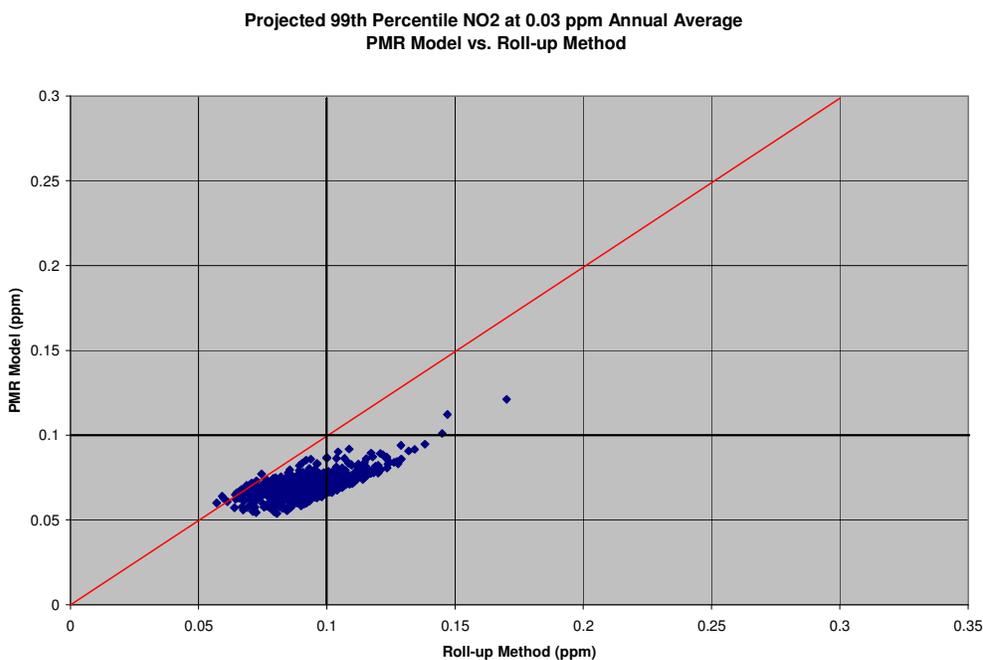


Figure 12 d) Scatter Plot of PMR Model and Roll-up Projection of the 99th Percentile NO₂ when the Annual Average for all Monitor-years is 0.03 ppm



Modeling Issues for Short-Term NO₂ Concentrations

EPA modeling staff members made a presentation to CASAC on September 9, 2008 regarding their progress in conducting a modeled exposure assessment for cities such as Atlanta. EPA has noted that the highest ambient air NO₂ impacts from emission sources are expected to be caused by roadway emissions (mobile sources). There are significant complications with modeling this type of source for specific 1-hour periods.

- The accurate depiction of each hour's NO₂ emission rate as well as the hourly ozone background concentration is very challenging. The ozone concentration is an essential input for accurate depiction of short-term NO₂ concentrations.
- Certain aspects of the roadway emissions, including the wake turbulence caused by the traffic as well as typical vehicle sizes have significant diurnal patterns. The traffic speed is also highly diurnal, with slower speeds during rush hour.
- Minimum wind speeds affecting peak 1-hour predictions would be affected by the wake caused by the traffic itself.
- The geometry of the roadway and the direction of the wind will highly influence the predicted concentrations near the roadway on an hour-to-hour basis.

Most of these problems are minimized when the depiction of emissions and how they are modeled are averaged on an annual basis. It is therefore much more feasible to model annual averages of NO₂ than 1-hour peak values due to the critical dependence of the predicted short-term averages on the complicating factors noted above.

Conclusions

It is evident from the existing NO₂ monitoring data that there are no monitors that exceed the 0.1 ppm 1-hour benchmark. With the likelihood that NO₂ emissions will, if anything, be decreasing over time in the future, the monitoring data does not support a need to change the current NO₂ NAAQS. This document also discusses significant model implementation difficulties for predicting 1-hour average NO₂ concentrations, especially given the type of sources (roadway emissions) that are involved. Given these difficulties, we note that U.S. EPA Guideline models such as AERMOD are much more amenable for simulating annual NO₂ concentrations than peak 1-hour NO₂ concentrations.

The first and second draft REAs for NO₂ evaluated the peak 1-hour NO₂ concentrations when the annual average concentration marginally attains the annual average NAAQS by applying a simple roll-up method. This document explains that the roll-up method is not applicable to reactive pollutants such as NO₂ and demonstrates that it results in a substantial overestimation of peak 1-hour NO₂ concentrations. To provide an unbiased estimate, this document describes the development and application of the PMR model, a more appropriate statistical model for the peak-to-mean ratio to estimate peak 1-hour NO₂ concentrations than the simple roll-up method. Current NO₂ monitoring data indicates that the 99th and 98th percentile 1-hour concentrations are less than 0.1 ppm at all locations. Applying the PMR model to the monitoring data indicates that the 0.053 ppm annual NAAQS is protective of the 0.2 ppm level (1-hour average) at all locations. It is also protective over 90% of the data values for a 1-hour level of 0.1 ppm level at a 98th percentile level, as compared to the highly inappropriate conclusion that the simple roll-up procedure results in nearly all data points exceeding this benchmark. The PMR model results also indicate that the current annual NAAQS is protective of the 0.15 ppm level (1-hour average) at nearly all locations for the 98th and 99th percentile statistics. In general, application of the unrealistically conservative roll-up method indicates that much higher concentrations of 1-hour NO₂ concentrations would occur if annual concentrations just met the NAAQS. We

urge EPA to replace the roll-up method with the PMR model presented here for extrapolating monitored annual averages to the current NAAQS.

Given that this analysis indicates that the present ambient air quality standard is protective of the 98th percentile concentrations on a 1-hour average basis of 0.1 ppm and greater, there is not a compelling case to change the current annual NO₂ NAAQS nor to establish a short-term term standard for NO₂.