



Technical Support Document for the Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements:

Air Quality Modeling Analyses

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I. Introduction

This document describes the procedures and results of the air quality modeling analyses used to support the Heavy Duty Engine and Vehicle Standards and Highway Diesel Fuel (HDE) final rulemaking. The air quality modeling was conducted to support several components of the rulemaking including:

- (a) an assessment of the need for the HDE program,
- (b) an assessment of the costs and benefits associated with the rulemaking, and
- (c) an assessment of the expected impact of the program on ozone and PM levels.

The air quality model applications include episodic regional scale ozone modeling for the eastern and western U.S. and annual particulate matter (PM) modeling on a continental scale covering the 48 contiguous States. For both ozone and PM, 1996 base year simulations were made to examine the ability of the modeling systems to replicate observed concentrations of these pollutants.¹ This was followed by simulations for several future-year “base case” scenarios (i.e., 2007, 2020, and 2030)². The results of the future base case model runs were used to support the need for the HDE emissions reductions to help mitigate unhealthy concentrations of ozone and PM. In this regard, the predictions from these model runs were used to determine the extent of future 1-hour ozone exceedances (i.e., 1-hour daily maximum ozone concentrations ≥ 125 ppb) and the magnitude of “exposures”³ to unhealthy concentrations of ozone and PM_{2.5} (i.e., particulates with a diameter ≤ 2.5 $\mu\text{g}/\text{m}^3$). For 2020 and 2030 additional simulations were made to examine the impacts of the HDE controls on air quality in these years. In addition, the outputs of the 2030 base and control case model runs were used to calculate portions of the monetized benefits of the rule as part of the cost-benefits analysis.

The air quality model simulations, associated input and output data sets, and model performance statistics used to support the above analyses are described in this document. The procedures for calculating the monetized benefits of the rule are described in Chapter VII of the Regulatory Impact Assessment (RIA) document (EPA, 2000a). Also, in Chapter II of the RIA are discussions of (1) how the projected future-year exposures to ozone and PM_{2.5} were calculated along with the results of these analyses and (2) the impacts of the rule on future 1-hour ozone exceedances.

The remainder of this report includes a description of the overall magnitude of emissions

¹As described in Section III, base year ozone predictions from the western model simulations seriously underestimated observed concentrations to the extent that the results were not used for the HDE rulemaking.

²PM modeling was performed for the 2020 and 2030 scenarios and ozone modeling was performed for all three scenarios. The rationale for selecting these time periods is described in the preamble for this rule.

³For this analysis the term exposure is used to describe the number of people living in areas with concentrations above various cut-points.

for each of the scenarios modeled, the ozone and PM modeling systems, the time periods modeled, the base year model performance evaluations, and procedures for generating the results of the modeling for subsequent use in various HDE analyses. All of the air quality modeling input and output data sets can be obtained from the following ftp site:

ftp.epa.gov/modelingcenter/Heavy_Duty_Diesel

II. Emissions Inventory Estimates

In order to complete the requisite ozone and PM modeling, it was necessary to first develop a national mass emissions inventory. This mass emissions inventory was then used as the basis for developing component input files for the modeling. The development and details of these inventories for each of the scenarios (i.e., 1996 base, 2007 base, 2020 base, 2020 control, 2030 base, and 2030 control) are more fully described elsewhere (EPA, 2000b, 2000c).

The mass inventories are prepared at the county-level for on-highway mobile, electric generating unit (EGU), non-EGU point, stationary area, and nonroad sources. The inventories contain annual and typical summer season day (SSD) emissions for the following pollutants: oxides of nitrogen (NO_x), volatile organic compounds (VOC), carbon monoxide (CO), oxides of sulfur (SO_x), primary particulate matter with an aerodynamic diameter less than or equal to 10 micrometers and 2.5 micrometers (PM₁₀ and PM_{2.5}), ammonia (NH₃), and secondary organic aerosols (SOA). The 2007, 2020, and 2030 Base Case inventories are prepared by applying growth and control assumptions to the 1996 Base Year inventory. The 2007, 2020, and 2030 Control Case inventories are developed from the 2007, 2020, and 2030 Base Case inventories, respectively, by applying HDE control and fuel measures to the on-highway vehicle and nonroad emission source sectors. Section II.A. and II.B. below provide summaries of the emissions for a summer season day and on an annual basis, respectively. The summer day emissions are provided to give a general sense of the magnitude of emissions used in the ozone modeling. Similarly, the annual emissions give a general sense of what was used for modeling concentrations of primary and secondary PM. The procedures for developing the model-ready emissions inputs are described in Section III for ozone modeling and Section IV for PM modeling.

A. Ozone Precursor Emissions (Summer Season Day)

Table II-1 displays the typical summer season day 1996 base year emissions for those States within the Eastern U.S. ozone modeling domain (see Section III). Emissions are provided for volatile organic compounds (VOC), nitrogen oxides (NO_x), and carbon monoxide (CO) which are the anthropogenic precursor emissions for ozone.

Table II-2 shows the total summer day emissions for all States in the East combined along with the percent change between various emissions scenarios.

Table II-1. Summer season daily State-level emissions (tons) for the 1996 Base.

State	VOC	NO _x	CO	State	VOC	NO _x	CO
Alabama	1,254	1,971	5,866	Nebraska ¹	612	875	2,750
Arkansas	709	935	3,092	New Hampshire	240	267	1,011
Connecticut	476	603	2,335	New Jersey	1,330	1,333	4,785
Delaware	167	243	663	New York	2,385	2,054	9,589
DC	61	60	223	North Carolina	2,089	2,292	8,140
Florida ¹	2,791	3,443	16,065	North Dakota ¹	350	857	1,096
Georgia	1,715	2,255	9,615	Ohio	2,364	3,758	11,977
Illinois	2,428	3,187	8,498	Oklahoma ¹	1,149	1,495	6,510
Indiana	1,536	2,652	7,177	Pennsylvania	2,068	2,924	10,112
Iowa	785	1,216	2,893	Rhode Island	159	103	635
Kansas ¹	782	1,661	3,212	South Carolina	996	1,230	4,412
Kentucky	998	2,276	3,857	South Dakota ¹	270	460	1,069
Louisiana	1,274	2,562	6,501	Tennessee	1,660	2,384	5,915
Maine ¹	323	273	1,379	Texas ¹	4,350	6,893	17,932
Maryland	601	1,078	3,641	Vermont	139	118	602
Massachusetts	901	958	3,669	Virginia	1,459	1,865	6,560
Michigan ¹	2,427	2,420	9,269	West Virginia	418	1,340	1,931
Minnesota ¹	1,263	1,511	4,214	Wisconsin	1,354	1,450	4,720
Mississippi	934	1,109	3,500				
Missouri	1,158	1,761	5,563	Total	45,975	63,872	200,978

1. State is partially outside the ozone modeling domain, but the emissions totals are provided for the entire State.

Table II-2. Total summer season daily emissions (tons) for the 37 States within the Eastern modeling domain for each of the six modeling scenarios.

	VOC	NO _x	CO	Scenario Diff (%)	VOC	NO _x	CO
1996 Base	45,975	63,872	200,978				
2007 Base	36,285	46,822	195,401	From 1996	-21.1	-26.7	-2.8
2020 Base	37,190	39,948	230,507	From 2007 Base	2.5	-14.7	18.0
2020 Control	36,801	36,086	228,481	From 2020 Base	-1.0	-9.7	-0.9
2030 Base	41,007	42,239	261,829	From 2020 Base	10.2	5.7	13.6
2030 Control	40,499	36,806	259,186	From 2030 Base	-1.2	-12.9	-1.0

B. Particulate Matter and Precursor Emissions (Annual)

Table II-3a shows the national annual emissions of primary PM and precursor species for secondary PM for the 1996 base year, 2030 base case, and 2030 control case scenarios. Table II-

3b shows the percent change in emissions between several of these scenarios.

Table II-3a. Total national annual emissions (tons) for the 48 States included in the PM modeling.

	Organic Carbon	Elemental Carbon	Gaseous Sulfate	Primary Nitrate	Other ¹ PM-2.5	Total PM-2.5
1996 Base	1,224,857	566,051	167,392	13,386	2,210,692	4,182,378
2030 Base	1,416,023	536,979	220,966	17,618	2,611,202	4,802,789
2030 Control	1,394,587	465,905	220,189	17,481	2,615,144	4,713,306

1. Other PM-2.5 contains primarily crustal material.

	VOC	NO _x	CO	SO ₂	NH ₃	SOA
1996 Base	18,522,037	26,117,335	98,637,147	18,789,382	4,762,317	202,517
2030 Base	15,676,964	18,717,720	120,491,650	16,436,874	5,400,554	163,196
2030 Control	15,430,241	16,157,296	119,211,301	16,285,231	5,400,554	157,884

Table II-3b. The percent change in total national annual emissions for selected scenarios.

	Organic Carbon	Elemental Carbon	Gaseous Sulfate	Primary Nitrate	Other PM-2.5	Total PM-2.5
2030 Base vs 1996 Base	15.6 %	- 5.1 %	32.0 %	31.6 %	18.1 %	14.8 %
2030 Control vs 2030 Base	- 1.5 %	- 13.2 %	- 0.4 %	- 0.8 %	0.1 %	- 1.9 %

	VOC	NO _x	CO	SO ₂	NH ₃	SOA
2030 Base vs 1996 Base	-15.4 %	-28.3 %	22.2 %	-12.5 %	13.4 %	-19.4 %
2030 Control vs 2030 Base	-1.6 %	-13.7 %	-1.1 %	-0.9 %	0.0 %	-3.3 %

III. Ozone Modeling over the Eastern United States

The Urban Airshed Model-Variable Grid (UAM-V), (SAI, 1996) was used as the tool for simulating base year and future concentrations of ozone in support of the HDE air quality assessments. UAM-V was designed for the expressed purpose of modeling regional ozone episodes. The model contains a subgrid-scale plume model, allows for nested finer resolution grids, and requires hourly meteorological fields. Model runs were made for the 1996 base year as well as for a 2007 base, and 2020 and 2030 base and control scenarios. As described below, each of these emissions scenarios was simulated for three meteorological datasets during the summer of 1995.

A. Episode Selection

There are several considerations involved in selecting episodes for an ozone modeling analysis (EPA, 1999a). In general, the goal should be to model several differing sets of meteorological conditions leading to ambient ozone levels similar to an area's 1 -hour design

value⁴. Ideally, the modeling time periods would be supported by large amounts of ambient data that could be used in input development and model evaluation. The issue, in terms of regional modeling, is how to meet these episode selection goals over a large number of individual ozone non-attainment areas without having to model several entire ozone seasons (impossibly time consuming and resource-intensive). It is inevitable that the chosen episodes will feature observed ozone lower than the design value in some areas and greater than the design value in other areas. For the HDE analyses, we simulated the same episodes during the summer of 1995 as used for the Tier 2 rule. These periods were selected because 1995 is a recent time period for which we had model-ready meteorological inputs.

Based on a review of observed daily maximum ozone concentrations across the eastern U.S. during June through August, three episodes were selected for ozone modeling: June 12-24, July 5-15, and August 10-21. The start of each episode was chosen to correspond to days with no ozone exceedances. Thirty episode days were modeled in all, not including the three ramp-up days used in each episode to minimize the effects of initial conditions. The meteorological conditions and ozone levels during each episode are described below.

1. Episodic Meteorological Conditions and Ozone Levels

Warm temperatures, light winds, cloud-free skies, and stable boundary layers are some of the typical characteristics of ozone episodes. On a synoptic scale, these conditions usually result from a combination of high pressure aloft (500 millibars) and at the surface. At a smaller scale, the conditions that lead to local ozone exceedances can vary from location to location (based on factors such as wind direction, sea/lake breezes, etc.) The meteorological and resultant ozone patterns for the three 1995 modeling episodes are discussed in more detail below.

June 12-24, 1995

The initial stages of this episode were fairly typical from the standpoint of regional meteorology. A 500-millibar ridge propagated into the eastern U.S. from the west. The ridge was associated with a surface high that migrated south from Canada. A cold front passed completely through the region by June 13 (Wednesday) allowing the modeling to start with a clean set of initial conditions. Maximum temperatures during the June 15 - 17-period were generally in the 80s and little precipitation was measured. By June 17, a strong (1028 mb) surface high was anchored over the region.

The observed ozone fields in the early part of the episode were high (e.g., 125-130 ppb) only in locations such as Houston, Beaumont, and Lake Michigan. It was not until June 17 that concentrations exceeded 100 ppb over large parts of the domain (i.e., Midwest and Northeast

⁴Generally, the design value for a monitoring site is the 4th highest 1-hour daily maximum concentration over a 3 year period. The design value for an area is the highest design value among all sites in the area.

Corridor).

However, as the aloft pattern amplified, a cut off low developed over the southeastern U.S. On the 19th and 20th, cooler temperatures and occasional rain prevailed in the Southeast. This resulted in a temperature pattern that featured maximums of 90-100 degrees F over the northern tier of States and 75-85 degrees F in the south. Additionally, the strong cyclonic circulation around this low resulted in aloft flow from east to west over the mid-Atlantic and Ohio Valley States. Ozone continued to build throughout this period in the Northeast, peaking on the 19th and 20th with values greater than 125 ppb common from Washington, D.C. to Boston.

The last four days of the episode were relatively clean in the Northeast due to the combination of a “backdoor” cold front and the northward migration of the cut off low. Meanwhile ozone conducive conditions returned to the Texas Gulf Coast and Lake Michigan areas. The highest value over the entire summer of 1995 (210 ppb) was recorded near Houston on the 22nd. The episode came to an end on the 25th as a long-wave trough replaced the 500-mb ridge over the eastern U.S.

Table III-1 shows a State-by-State listing of daily exceedance counts during the June 1995 HDE episode. There were 85 exceedances of the ozone NAAQS during this period. The peak day of the episode was June 19. Texas had the most exceedances (28).

Table III-1. Summary of exceedance days, by State/day, for the June 1995 HDE episode. Dates in bold indicate episode days (i.e., non-ramp-up days).

	AL	AR	CT	DE	DC	FL	GA	IL	IN	KY	LA	ME	MD	MA	MI	M	NH	NJ	NY	NC	OH	OK	PA	RI	SC	TN	TX	VA	W	WI	TOT
6/12/95																															0
6/13/95																											1				1
6/14/95																											1				1
6/15/95									1																		1				2
6/16/95																											1		1		2
6/17/95			1												4														2	7	
6/18/95			2		1				1			1															1			6	
6/19/95			3	3	1							7	2				4	2		1		8	1							32	
6/20/95			2	2							2	1					3										3			13	
6/21/95																											7			7	
6/22/95																											7			7	
6/23/95											2																4			6	
6/24/95								4	2							2											3			11	

July 5-15, 1995

The mid-July episode, which covered most of the Ozone Transport Assessment Group (OTAG) July 1995 episode, is much easier to characterize from a meteorological perspective. A strong 500-mb ridge progressed from west to east across the eastern U.S. over the period. This feature was centered over Colorado on the 8th, over Kansas on the 11th, over Illinois on the 13th, and over Pennsylvania on the 15th. The ridge finally flattened out on the 16th allowing a surface cold front to clean out the northern portions of the domain and less stable conditions to prevail over the southern portions.

Excessively hot temperatures accompanied the core of this strong ridge. Temperatures in the 90s and 100s were common throughout the episode. Rainfall was confined primarily to the coastal regions in the south and southeast. Wind speeds were moderate and the mean transport direction was southwest to northeast, especially over the northern half of the domain.

From the 8th through the 10th, ozone levels in the airmass over the eastern U.S. were gradually increasing. Ozone hot spots occurred in urban areas like Houston, Dallas, and Atlanta. By the 11th, the area of regionally high ozone (roughly defined as the area where peak ozone was greater than 75 ppb) had expanded to encompass most of the domain. On top of that “background,” local contributions from urban emissions yielded ozone exceedances in places like Kansas City, St. Louis, Birmingham, Dallas, Memphis, Atlanta, Baton Rouge, Evansville, Louisville, Cincinnati, Chicago, Milwaukee, Columbus, and Baltimore/Washington on the 11th and 12th.

July 13 and 14 marked the highest regional ozone levels of the summer as most sites, with the exception of those in the Southeast, exceeded 100 ppb. Almost all major metropolitan areas in the northern two-thirds of the domain measured values greater than 125 ppb on this day. For the 14th and 15th, most of the ozone problem shifted east and south due to both transport and the location of the aloft core of warm air. The Northeast Corridor, Charlotte, Greensboro, Birmingham, and Atlanta all had exceedances of the standard on this day. The episode ended abruptly on the 16th (Sunday) for most of the domain, although elevated ozone lingered over the southern regions into the early part of the next week.

Table III-2 shows a State-by-State listing of daily exceedance counts during the July 1995 HDE episode. There were 199 exceedances of the ozone NAAQS during this period. The peak day of the episode, in terms of exceedance monitors was July 14. Texas had the most exceedances (26).

Table III-2. Summary of exceedance days, by State/day, for the July 1995 HDE episode. Dates in bold indicate episode days (i.e., non-ramp-up days).

	AL	AR	CT	DE	DC	FL	GA	IL	IN	KY	LA	ME	MD	MA	MI	M	NH	NJ	NY	NC	OH	OK	PA	RI	SC	TN	TX	VA	W	WI	TOT		
7/05/95																																0	
7/06/95																																	0
7/07/95																												2					2
7/08/95																											2						2
7/09/95								1																			4						5
7/10/95								4								1											1						6
7/11/95	1	1						3			1					3											1	5					15
7/12/95	1								1	1	1		5			4	1			3						1	5			7	30		
7/13/95		1	5					8	1			2	3	7	6			1		4						6			1			46	
7/14/95			7	3				2	2			1	4	2	6			7	5	3	3				3	3	1	1				53	
7/15/95	1		3	3				2	2				10		1			6	3										4			40	

August 7-21, 1995

A one-day ozone event occurred over New England on August 10, and a separate one-day event occurred in the Lake Michigan region on the 12th. By the 14th, high pressure aloft and at the surface dominated the eastern half of the U.S. Temperatures ranged from 90 to 100 degrees F over most of the domain throughout this period. Ozone was highest over Georgia, Tennessee, Kentucky, North Carolina, and Virginia during this period. Hurricane Felix brushed the East Coast from the 16th – 18th, but appeared to have little effect on ozone levels or ozone transport away from the immediate eastern seaboard.

A weak cold front, draped across the Great Lakes over most of the episode, moved slowly southward over the eastern half of the Appalachians during the August 18-21 period. This front initiated precipitation that helped keep ozone concentrations low in the upper Midwest. The 18th featured high ozone across the South in cities such as: Atlanta, Charlotte, Birmingham, Augusta, as well as St. Louis. On the 19th and 20th, as the front slid further south, ozone air quality improved over this region as well. Only sites in Texas and Louisiana remain above 125 ppb. The 21st marked the fourth day that the same airmass has resided over the Northeast.

Table III-3 shows a State-by-State listing of daily exceedance counts during the August 1995 HDE episode. There were 90 exceedances of the ozone NAAQS during this period. The peak day of the episode, in terms of exceedance monitors was August 21st.

Table III-3. Summary of exceedance days, by State/day, for the August 1995 HDE episode. Dates in bold indicate episode days (i.e., non-ramp-up days).

	AL	AR	CT	DE	DC	FL	GA	IL	IN	KY	LA	ME	MD	MA	MI	M	NH	NJ	NY	NC	OH	OK	PA	RI	SC	TN	TX	VA	W	WI	TOT
8/07/95																															0
8/08/95																															0
8/09/95																															0
8/10/95	1											1		2			1													5	
8/11/95	1						1																				1			3	
8/12/95	1							4	1		1				1															8	
8/13/95															1															1	
8/14/95	1											3					1		1								1			7	
8/15/95	1						3		1													1					2			8	
8/16/95							2			3													1							5	
8/17/95							2			2										1						1	1			7	
8/18/95	4						5	1								1										1				12	
8/19/95							1				2																	6		9	
8/20/95																											6			6	
8/21/95			3	3							1		3	2				2	2				1	1			1			19	

2. General Representativeness of Episodic Ozone as Compared to Design Values

In order to examine the representativeness of ozone levels during the episodes selected for modeling, a comparison was made between the daily maximum observed values to recent design values. In this analysis, the magnitude of county-specific design values for 1996-1998 were compared to the highest through 5th highest concentrations measured in the county during the three episodes. Counties with design values (DV) >120 ppb were selected for analysis in order to focus on concentrations approaching and exceeding the NAAQS. As can be seen in Table III-4, 70 of the 110 counties examined have design values within 15 ppb of the highest observed ozone in the HDE episodes. Additionally, the second-high observed value yields more values below the design value than above it. The results indicate that the selected episodes contain measured ozone concentrations that are representative of design values over a large portion of the eastern U.S.

Table III-4. Summary of Comparing the Five Highest Daily Maxima to Recent Design Values.

Ranking of Observation within HDE Days	# of cases in which the observed was greater than the design value by 15 ppb	# of cases in which the observed was within 15 ppb of the design value	# of cases in which the observed was less than the design value by 15 ppb
Highest ozone	32	70	8
2 nd high ozone	10	80	20
3 rd high ozone	2	71	37
4 th high ozone	0	57	53
5 th high ozone	0	45	65

B. Domain and Grid Configuration

As with episode selection, there are also several considerations involved in selecting the domain and grid configuration to be used in the ozone modeling analysis. The modeling domain should encompass the area of intended analysis with an additional buffer of grid cells to minimize the effects of uncertain boundary condition inputs. Grid resolution should be equivalent to the resolution of the primary model inputs (emissions, winds, etc.) and equivalent to the scale of the air quality issue being addressed. The regional/national HDE ozone analyses used the previously established Tier 2 domain to model regional ozone over the eastern U.S.

The HDE UAM-V modeling was completed using two grids of varying extent (shown in Figure III-1) and resolution as described below.

Main Grid: Resolution: 1/2° longitude, 1/3° latitude (approximately 36 km)
East-West extent: -99 W to -67 W
North-South extent: 26 N to 47 N
Vertical extent: Surface to 4 km
Dimensions: 64 by 63 by 9

Nested Grid⁵: Resolution: 1/6° longitude, 1/9° latitude (approximately 12 km)
East-West extent: -92 W to -69.5 W
North-South extent: 32 N to 44 N
Vertical extent: Surface to 4 km
Dimensions: 137 by 110 by 9

⁵ Model concentrations are not calculated for the outer periphery of the nested grid. Two buffer rows and columns are needed to solve the advection portion of the mass balance equation.

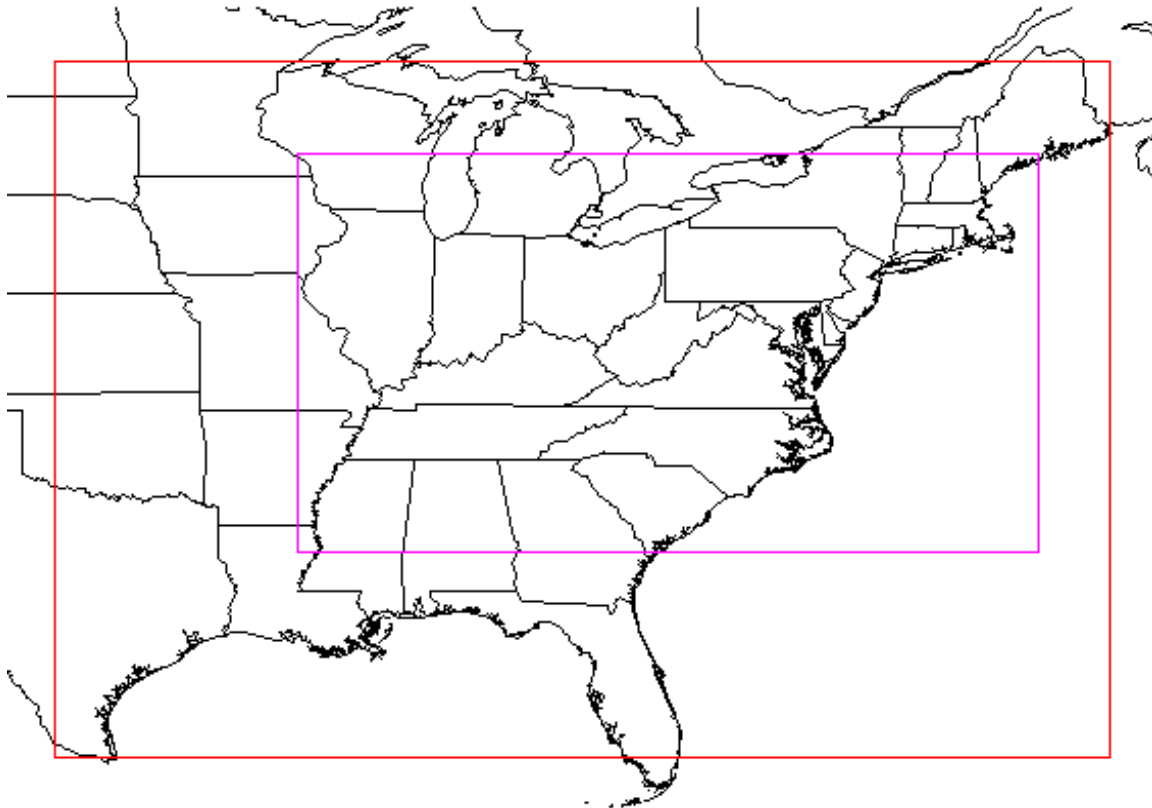


Figure III-1. Map of the HDE Eastern U.S. modeling domain. The outer box denotes the entire modeling domain (36 km) and the inner box indicates the fine grid location (12 km).

The vertical layers were consistent between the two grids: 0-50, 50-100, 100-300, 300-600, 600-1000, 1000-1500, 1500-2000, 2000-2500, 2500-4000. All model heights are in meters above ground level. The number of vertical layers is greater than past regional-scale modeling applications (e.g., OTAG) and was intended to better capture the depth of the planetary boundary layer.

This modeling domain allows for the calculation of residual future ozone exceedances and the effects of HDE emissions reductions over most major metropolitan areas in the eastern U.S. (The Dallas-Fort Worth area may be the exception given its proximity to the western boundary.)

C. Meteorological Modeling

In order to solve for the change in pollutant concentrations over time and space, the air quality model requires certain meteorological inputs that, in part, govern the formation, transport, and destruction of pollutant material. In particular, the UAM-V model used in the HDE analyses requires five meteorological input files: wind (u- and v-vector wind components), temperature,

water vapor mixing ratio, atmospheric air pressure, and vertical diffusion coefficient. Fine grid values of wind and vertical diffusivity are used; the other fine grid meteorological inputs are interpolated from the coarse grid files.

The gridded meteorological data for the three historical 1995 episodes were developed by the New York Department of Environment and Conservation (NYDEC) using the Regional Atmospheric Modeling System (RAMS), version 3b. RAMS (Pielke *et. al.*, 1992) is a numerical meteorological model that solves the full set of physical and thermodynamic equations which govern atmospheric motions. The output data from RAMS, which is run in a polar stereographic projection and a sigma-p coordinate system, are then mapped to the UAM-V grid. Two separate meteorological UAM-V inputs, cloud fractions and rainfall rates, were developed based on observed data.

RAMS was run in a nested-grid mode with three levels of resolution: 108 km, 36 km, and 12 km with 28-34⁶ vertical layers. The top of the surface layer was 16.7 m in the 36 and 12km grids. The two finer grids were at least as large as their UAM-V counterparts. In order to keep the model results in line with reality, the simulated fields were nudged to an European Center for Medium-Range Weather Forecasting (ECMWF) analysis field every six hours. This assimilation data set was bolstered by every four-hourly special soundings regularly collected as part of the North American Research Strategy on Tropospheric Ozone (NARSTO) field study in the northeast U.S.

A summary of the settings and assorted input files employed in this RAMS application are listed below in Table III-5. For more detail on the meteorological model configuration, see Lagouvardos *et al.* (1997).

⁶ The inner nests were modeled with 34 layers while the outer 108 km domain was modeled with 28 layers.

Table III-5. Summary of RAMS model settings and inputs.

Model Setting/Input File	Description
Input- Topography	30 arc-second data from EROS Data Center.
Input - Sea-surface temperature	Mean monthly climatological data from NCAR.
Input - Vegetation type	10 arc-minute data from NOAA/NGDC.
Input - Initial conditions	The model was initialized with gridded one-degree ECMWF data
Input - Soil moisture	Six layer soil model. Assumed deeper layers were more moist than
Setting	Non-hydrostatic
Setting - Lateral boundary conditions	Klemp-Wilhelmson
Setting - Horizontal diffusivity	Smagorinsky
Setting - Vertical diffusivity	Mellor and Yamada parameterization scheme
Setting - Shortwave/Longwave radiation	Mahrer and Pielke

A limited model performance evaluation (Sistla, 1999) was completed for a portion of the 1995 meteorological modeling (July 12-15). Observed data not used in the assimilation procedure were compared against modeled data at the surface and aloft. In general, there were no widespread biases in temperatures and winds. Furthermore, the meteorological fields were compared before and after being processed into UAM-V inputs. It was concluded that this preprocessing did not distort the meteorological fields.

D. Development of Other UAM-V Input Files

The hourly, gridded, model-ready anthropogenic emissions for the six modeling scenarios were created using EMS-95 (Alpine Geophysics, 1994). As part of this processing, emissions for stationary and nonroad sources were developed for typical summer weekday, Saturday, and Sunday emissions levels and then used for the corresponding day-types that occurred during the episodes. The exceptions to this are utility emissions which were adjusted to reflect differing emissions levels during June, July, and August (EPA, 2000b). Hourly mobile source emissions were developed using grid-specific temperature data. Biogenic emissions were developed using the BEIS-2 model (Pierce et al., 1998). In addition, the photochemical grid model requires several other types of input data. In general, most of these miscellaneous model files were taken from existing regional modeling applications. Clean conditions were used to initialize the model and as lateral and top boundary conditions as in Tier 2 (EPA, 1999b).

The model requires information regarding land use type and surface albedo for all Layer 1 grid cells in the domain. Existing Tier 2/OTAG data were used for these non-day-specific files. Photolysis rates were developed using the JCALC portion of the UAM-V modeling system (SAI,

1996). Turbidity values were set equal to a constant thought to be representative of regional conditions.

E. Model Performance Evaluation

The goal of the base year modeling was to reproduce the atmospheric processes resulting in high ozone concentrations over the eastern United States during the three 1995 episodes selected for modeling. Note that the base year of the emissions was 1996 while the episodes are in 1995. The effects on model performance of using 1996 base year emissions for the 1995 episodes are unknown.

An operational model performance evaluation for surface ozone for the 1995 episodes was performed in order to estimate the ability of the modeling system to replicate base year ozone concentrations. This evaluation is comprised principally of statistical assessments of model versus observed pairs. The robustness of an operational evaluation is directly proportional to the amount and quality of the ambient data available for comparison.

1. Statistical Definitions

Below are the definitions of those statistics used for the evaluation. The format of all the statistics is such that negative values indicate model ozone predictions that were less than their observed counterparts. Positively-valued statistics indicate model overestimation of surface ozone. Statistics were not generated for the first three days of an episode to avoid the initialization period. The operational statistics were principally generated on a regional basis in accordance with the primary purpose of the modeling which is to assess the need for, and impacts of, a national mobile source emissions control program. However, a local assessment of model performance was also completed to ensure that the model did not significantly overestimate the need for controls in individual areas. The statistics were calculated for (a) the entire HDE domain, (b) four quadrants (Midwest, Northeast, Southeast, Southwest), and (c) 47 local areas. The statistics that were calculated for each of these sets of areas are described below.

Domainwide unpaired peak prediction accuracy: This metric simply compares the peak concentration modeled anywhere in the selected area against the peak ambient concentration anywhere in the same area. The difference of the peaks (model - observed) is then normalized by the peak observed concentration.

Peak prediction accuracy: This metric averages the paired peak prediction accuracy calculated for each monitor in the subregion. It characterizes the capacity of the model to replicate peak (afternoon) ozone over a subregion. The daily peak model versus daily peak observed residuals are paired in space but not in time.

Mean normalized bias: This performance statistic averages the normalized (by observation) difference (model - observed) over all pairs in which the observed values were greater than 60 ppb. A value of zero would indicate that the model over predictions and model under predictions exactly cancel each other out.

Mean normalized gross error: The last metric used to assess the performance of the HDE base cases is similar to the above statistic, except in this case it is the absolute value of the residual which is normalized by the observation, and then averaged over all sites. A zero gross error value would indicate that all model concentrations (in which their observed counterpart was greater than 60 ppb) exactly matched the ambient values.

2. Domainwide and Regional Model Performance

As with previous regional photochemical modeling studies, the HDE base year simulations are accurate representations of the historical ozone patterns at certain times and locations and poor representations at other times and locations over this large modeling domain. From a qualitative standpoint, there appears to be considerable similarity on most days between the observed and simulated ozone patterns. Additionally, where possible to discern, the model appears to follow the day-to-day variations in synoptic-scale ozone fairly closely. Other relevant observations, in terms of model performance, are listed below.

- Mean normalized bias and mean normalized gross error values are similar to the Tier 2 model performance statistics for the entire domain and the four quadrants as summarized in Table III-6. In turn, the Tier 2 model performance was very similar to what was observed in OTAG, as summarized in the Tier 2/Low Sulfur Technical Support Document (TSD) (EPA, 1999b).

Table III-6. Tier 2 and HDE Base Year model performance for the entire grid and by quadrant.

Mean Normalized Bias	Tier 2 June 95	Tier 2 July 95	Tier 2 August 95	HDE June 95	HDE July 95	HDE August 95
Domain	-10	-6	+2	-13	-11	+5
Midwest	-11	-13	+7	-15	-16	+10
Northeast	-17	-9	-9	-20	-11	-15
Southeast	-4	+4	+7	-7	-3	+12
Southwest	+2	+8	+6	+1	+3	+11

Mean Normalized Gross Error	Tier 2 June 95	Tier 2 July 95	Tier 2 August 95	HDE June 95	HDE July 95	HDE August 95
Domain	24	24	23	22	23	24
Midwest	24	26	22	22	24	22
Northeast	27	22	24	27	23	24
Southeast	20	24	22	18	21	25
Southwest	24	27	24	22	24	27

- In general, the model under predicts ozone for the June and July episodes (-13 and -11 percent, respectively). This underestimation bias generally occurs over the first half of an episode. The latter portions of these episodes are generally unbiased.
- Mean normalized gross error ranges from 18 to 27 percent. Bias and errors are generally lowest in the Southeast region.
- The model typically underestimates the peaks as well as the mean ozone, but not as severely.
- Although the overall tendency (June/July episodes) is to underestimate the observed ozone, there are several instances in which large overestimations occurred.
- The model is slightly biased toward overestimation in the August episode (5 percent). Only the Northeast quadrant is underestimated (-15 percent) in this episode.
- While there are no established statistical criteria for evaluating the adequacy of regional modeling applications, the relatively low values of bias and error plus the OTAG and Tier 2 equivalent performance indicate the modeling is sufficient for a national assessment of the need for (and impact of) HDE controls.

3. Local-scale Model Performance

The HDE modeling results were also evaluated at a “local” level. The purpose of this analysis was to ensure that areas determined to need the HDE emissions reductions based on 1-hour exceedances of the ozone standard were not unduly influenced by local overestimation of ozone in the model base year. For this analysis, the modeling domain was broken up into 47 local subregions as shown in Figure III-2. The primary statistics for each of the 47 subregions is shown in Table III-7.

If one were to compare the performance of the 1995 eastern base year modeling against the performance criteria recommended in EPA's ozone modeling guidance (EPA, 1996) for accuracy (within +/- 20 percent), bias (within +/- 15 percent), and error (less than 35 percent), the results indicate that 57% of the regions would meet these criteria for the June episode, 45% of the regions would for the July episodes, and 55% of the regions would for the August episode. Most of the areas that did not meet the local-scale criteria exhibited an under prediction bias of 15 percent or more.

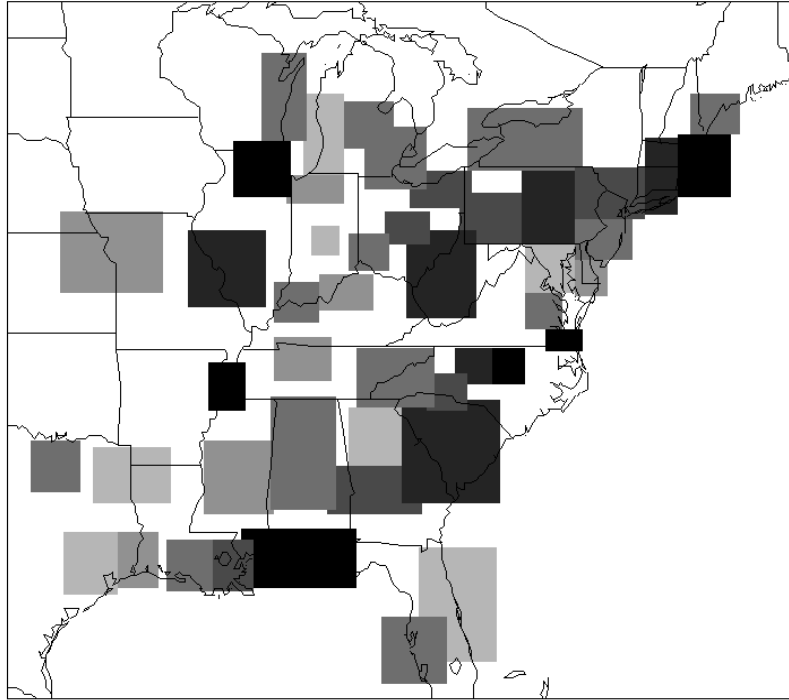


Figure III-2. Map of the 47 HDE local-scale evaluation zones.

The general tendency of the model, as discussed above, is to underestimate observed ozone concentrations. Given that one of the primary uses of the model is to calculate potential exceedance areas in the future that may require additional ozone precursor control, this model tendency should lead to a conservative estimate of future-year air quality need. When the model is used in a relative sense to assess potential impacts from the rulemaking, any model bias will be in both the base and control simulations and should be canceled out as comparisons are made.

Table III-7. HDE Base Year model performance for the 47 local regions.

Region	Domainwide Unpaired Accuracy	Average Accuracy of the Peak	Mean Normalized Bias	Mean Normalized Gross Error
Dallas	-0.155	-0.079	-0.102	0.216
Houston-Galveston	-0.128	0.043	0.032	0.267
Beaumont-Port Arthur	0.078	0.151	0.167	0.251
Baton Rouge	0.055	0.212	0.254	0.308
New Orleans	0.266	0.198	0.212	0.264
St. Louis	0.002	-0.015	-0.007	0.205
Memphis	0.102	-0.090	-0.078	0.200
Alabama	0.052	0.024	0.047	0.201
Atlanta	0.235	0.079	0.079	0.244
Nashville	0.172	0.078	0.071	0.265
Eastern TN	-0.005	-0.159	-0.195	0.257
Charlotte	0.198	0.039	0.061	0.182
Greensboro	0.137	0.031	0.021	0.177
Raleigh-Durham	0.093	-0.026	-0.036	0.179
Evansville-Owensboro	0.097	-0.025	0.002	0.236
Indianapolis	-0.045	-0.104	-0.115	0.217
Louisville	0.159	0.104	0.094	0.265
Cincinnati-Dayton	-0.038	-0.077	-0.057	0.230
Columbus OH	-0.039	-0.117	-0.109	0.204
West Virginia	0.150	0.043	0.048	0.225
Chicago	0.048	-0.156	-0.228	0.291
Milwaukee	0.141	-0.148	-0.190	0.239
Muskegon-Grand Rapids	0.057	-0.126	-0.153	0.226
Gary-South Bend	-0.097	-0.173	-0.212	0.271
Detroit	0.058	-0.119	-0.196	0.275
Pittsburgh	-0.027	-0.059	-0.073	0.218
Central PA	0.120	-0.040	-0.069	0.213
Norfolk	0.236	-0.015	-0.075	0.246
Richmond	0.203	0.032	0.040	0.192
Baltimore-Washington	0.029	-0.045	-0.074	0.213
Delaware	0.083	-0.074	-0.047	0.156
Philadelphia	-0.021	-0.114	-0.191	0.269
New York City	0.125	-0.108	-0.207	0.294
Hartford	-0.008	-0.134	-0.144	0.243
Boston	0.122	-0.103	-0.177	0.270
Maine	0.116	-0.135	-0.187	0.262
Longview-Shreveport	0.014	-0.049	-0.088	0.251
Kansas City	-0.113	-0.178	-0.197	0.238
Western NY	0.106	-0.136	-0.178	0.229
Northeast OH	0.014	-0.060	-0.081	0.209
South Carolina	0.161	0.060	0.053	0.188
Gulf Coast	0.239	0.167	0.216	0.279
FL West Coast	0.424	0.337	0.299	0.382
FL East Coast	0.248	0.137	0.133	0.250
Jackson, MS	0.347	0.084	0.084	0.198
Central MI	-0.016	-0.102	-0.161	0.227
Macon-Columbus AL	0.273	0.012	0.033	0.187

Because one of the primary uses of the model is to determine areas at risk of having exceedances in the future, it is important to determine how well the model is doing at estimating peak ozone concentrations in the base year. Particularly, it is important to ensure that the highest model ozone concentrations are not overestimated, which could lead to an exaggerated assessment of potential future exceedance areas. As such, the domainwide peak prediction accuracy was calculated for each day and area for which a model exceedance was predicted in the future. If the model peak was more than 20 percent overestimated, then that day/area was flagged as a possible performance issue. Of the 37 areas⁷ determined to need additional controls in the future based on HDE modeling projections of exceedances, 11 areas have an overprediction of the peak on some exceedance days in the base year modeling: Charlotte, Huntington KY, Macon, Nashville, Richmond, Charleston WV, Cincinnati, Cleveland, Norfolk, Orlando, and Tampa-St. Petersburg. However, for Cincinnati and Richmond there were also days with observed exceedances on which the modeling underpredicted ozone and therefore did not identify any exceedances.

4. Model Performance over the Western U.S. Domain

UAM-V modeling was also performed for the western U.S. using the domain and all of the inputs, except anthropogenic emissions, which were used in the western modeling for Tier 2 (EPA, 1999b). Anthropogenic emissions developed for the HDE rule (EPA, 2000b) were used for this modeling. An operational evaluation was performed for the western modeling using the same procedures and statistics discussed in section III-E-1. Model performance measures were calculated over the entire modeling domain, the 12 km fine grid, and 10 individual areas (Albuquerque, Denver, El Paso, Phoenix, Portland, Salt Lake City, the San Joaquin Valley, Seattle, San Francisco, and Southern California). Table III-8 contains the operational evaluation statistics. Observations on the evaluation results are listed below.

- Mean normalized bias and mean gross error values indicate that the model almost exclusively underestimates the amounts of ozone actually measured (where observed ozone is greater than 60 ppb). The average under prediction bias is about 40 percent.
- This large negative bias exists over both 1996 episodes (-0.423 for the 1st episode, -0.406 for the 2nd episode). There is a slight tendency for the underestimation bias to be worst in the early stages of the episodes. As seen in the table, model performance is poorest in southern California where there are a high number of monitors.
- There is a deterioration in the performance of the western U.S. HDE base case simulations relative to the same simulations completed as part of the Tier 2 air quality modeling exercise. Overall, the HDE base case exhibits even more underprediction (about 2-3 percent), mostly due to model-observed pairs in southern California.

⁷ These 37 areas are listed in Appendix A, as described in Section III.F..

Table III-8. Model performance statistics for individual local areas in the western U.S.

Region	Unpaired Peak Prediction Accuracy	Average Peak Prediction Accuracy	Mean Normalized Bias	Mean Normalized Gross Error
Albuquerque	-0.205	-0.340	-0.354	0.354
Denver	-0.182	-0.327	-0.351	0.352
El Paso	-0.279	-0.408	-0.437	0.437
Phoenix	-0.245	-0.398	-0.456	0.459
Portland	0.021	-0.145	-0.209	0.251
Salt Lake City	-0.199	-0.311	-0.347	0.353
San Joaquin Valley	-0.236	-0.372	-0.396	0.403
Seattle	0.144	-0.155	-0.252	0.359
San Francisco	-0.287	-0.361	-0.373	0.375
Southern California	-0.320	-0.571	-0.585	0.591

While model performance for ozone in the western U.S. for the HDE 1996 base is roughly similar to the performance found in the Tier 2 modeling for this same region, it is the different scope of the HDE rule that calls into question the use of these data in the HDE rulemaking. One of the primary differences relative to California between Tier 2 and HDE is that the HDE rule will provide additional emissions reductions in California⁸. Also, the HDE analysis has given more consideration to longer term ozone exposure analyses, which will certainly be compromised by inadequate model performance of this magnitude. The magnitude of the underpredictions, especially for areas of California, calls into question the credibility of the directional response of the model to controls. Also, considering the performance in the West relative to the performance of the model for the eastern U.S. (biases within plus/minus 10 percent) and what is typically expected out of such regional modeling applications, it was determined that this application of the model should not be used to support the air quality assessments in this rule.

F. Ozone Modeling Results For Future-Year Scenarios

The HDE modeling output for the East was analyzed to provide information to (a) support the determination of the need for HDE, and (b) examine the air quality impacts of the rulemaking. The procedures and results of each of these analyses are described below.

1. Future-Year Model-Predicted Exceedances

To support the determination of the need for HDE, the modeling results were examined to identify those CMSA and MSAs that have predicted exceedances of the 1-hour NAAQS in the 2007, 2020, and/or 2030 base scenarios. This determination was limited to those areas which

⁸This is in contrast to the Tier 2 assessment which included emissions reductions from the California Low Emissions Vehicle Program in the future-year baseline scenarios.

had ambient 1-hour design values above the standard (i.e., ≥ 125 ppb) or within 10 percent of the standard (i.e., ≥ 113 ppb). A CMSA/MSA is determined to contain a predicted exceedance if at least one of the grid cells assigned to the area has at least one exceedance during the episodes modeled. The procedures for assigning grid cells to areas are defined below. The CMSA/MSAs with predicted 2007, 2020, and/or 2030 base case exceedances are listed in Appendix A.

2. Impacts of the HDE Rule on 1-Hour Ozone

a. Definition of Areas for Analysis

In order to analyze the impacts of the HDE emissions reductions, it was necessary to "link" or assign the model's grid cells to individual CMSA/MSAs. The rules for assigning grid cells to CMSA/MSAs (i.e., areas) is as follows. The first step was to assign grid cells to States based on the fraction of the grid cells' area in a State. A grid cell was assigned to the State which contains most of the cells' area. Next, grid cells were assigned to an individual CMSA/MSAs if (1) the grid is wholly contained within the CMSA/MSA or (2) partially within (i.e., overlapping) the area, but *not* also partially within another CMSA/MSA. Grid cells that partially overlap two or more CMSA/MSAs are assigned to the county, and thereby the corresponding CMSA/MSA, which contains the largest portion of the grid cell. Each grid cell in the "coarse" or 36 km grid portion of the domain was divided into nine 12 km grids before applying the preceding methodology. The number of grid cells assigned to each metric area is listed in Appendix B.

b. Description of Ozone Metrics

The impacts of HDE on ozone were quantified using a number of metrics (i.e., measures of ozone concentrations). These metrics include:

- (1) the peak 1-hour ozone concentrations,
- (2) the number of exceedances,
- (3) the total amount of ozone ≥ 125 ppb,
- (4) the decrease in ozone, on average, and
- (5) the increase in ozone, on average.

(1) The peak 1-hour ozone represents the highest ozone prediction within the area (i.e., CMSA or MSA) across all episodes modeled.

(2) The number of exceedances is the total number of grid cells with predicted exceedances in the area across all days. This exceedance metric counts each grid cell every day there is a predicted exceedance in that grid. Thus, an individual grid cell can be counted more than once if there are multiple days with predicted exceedances in that grid.

(3) The total amount of ozone above 125 ppb in an area is determined by taking the difference between the predicted daily maximum ozone concentration and 125 ppb (i.e., daily maximum - 125 ppb) in each grid cell and then summing this amount across all grid cells in the area and days modeled. This metric is referred to as the "amount of nonattainment".

(4) The decrease, on average is determined by first summing all the reductions predicted in those grid cells with daily maximum ozone ≥ 125 ppb in the base case (i.e., base case exceedances). This total reduction is then divided by the number of base case exceedances in the area to yield the "ppb" decrease that occurs, on average, for the exceedances predicted in the area.

(5) The increase, on average is determined by summing any increases in ozone that occur in values already ≥ 125 ppb in the base case together with any increases that cause a value below 125 ppb in the base case to go above 125 ppb in the control case. This total increase is then divided by the number of exceedances in the base case.

The impacts of HDE on 1-hour ozone exceedances were examined for the individual CMSA/MSAs as well as by aggregating the metrics across all areas to obtain the overall impact expected from the program. The values of the metrics are provided in Appendix C for 2007, 2020 and 2030.

3. Need for HDE Rule Based on Unhealthy 8-Hour Ozone Concentrations

One component of the analysis to support the need for this rule was the calculation of the number of people living in metropolitan counties that experience 8-hour ozone concentrations above certain concentration levels for different lengths of time. This "exposure" type analysis was based on current 1997-1999 ambient 8-hour concentrations and projected future 8-hour concentrations, based on modeling of the HDE emissions scenarios. To provide the future-year estimates of 8-hour concentrations, 8-hour relative reduction factors (RRFs) were calculated then applied to ambient 8-hour daily maximum concentrations. The procedures for determining the RRFs are similar to those in EPA's draft guidance for modeling for an 8-hour ozone standard (EPA, 1999a). Hourly model predictions were processed to determine daily maximum 8-hour concentrations for each grid cell for each non-ramp-up day modeled. The RRF for a monitoring site was determined by first calculating the multi-day mean of the 8-hour daily maximum predictions in the nine grid cells surrounding the site using only those predictions ≥ 70 ppb, as recommended in the guidance. This calculations was performed for the base year scenario and each future-year scenario. The RRF for a site is the ratio of the mean 8-hour prediction in the future-year scenario to the mean 8-hour prediction in the base year scenario. This value was then multiplied by the ambient 8-hour concentrations to provide estimates of future 8-hour concentrations. These future concentrations were then used in the "exposure" analysis as described in the HDE docket (Docket A-99-06, item IV-B-09). The 8-hour RRFs are provided for each monitoring site in Appendix D.

4. One-Hour Ozone Relative Reduction Factors

EPA received comments that recommended using relative reduction factors applied to ambient design values as an approach to estimate which areas are expected to have a future problem attaining the 1-hour ozone standard. Specifically, the commenters recommended that EPA follow draft guidance for demonstrating attainment of the 8-hour NAAQS for such an analysis (EPA, 1999a). In response, we calculated relative reduction factors for the 2007, 2020, and 2030 base case and control scenarios using the general methodology in this guidance. The exceptions to this guidance is that we used a cut-off of 80 ppb as appropriate for considering 1-

hour model predictions as opposed to 70 ppb recommended in the guidance for 8-hour concentrations (see the Tier 2 Air Quality Modeling TSD, 1999). The 1-hour monitor-specific RRFs were applied to the ambient 1-hour design value (i.e., 4th highest 1-hour daily maximum concentration at the monitor from 1997-1999) at each site with valid data. The resulting future-year 1-hour design values were examined for all monitors in an area to select the highest value for the area. These data can be found in Docket A-99-06; item IV-B-06.. Information on the use of these data for this rule can be found in the Response to Comments Document.

IV. Particulate Matter Modeling over the Continental U.S.

A. REMSAD Model Description

The REgulatory Modeling System for Aerosols and Deposition (REMSAD), (ICF Kaiser, 1998) model was used as the tool for simulating base year and future concentrations of PM in support of the HDE air quality assessments. Model runs were made for the 1996 base year as well as for the 2020 and 2030 base and control scenarios. As described below, each of these emissions scenarios was simulated using 1996 meteorological data in order to provide the annual mean PM concentrations and estimates of visibility needed for the PM “exposure” analysis and benefits calculations.

REMSAD was designed to calculate the concentrations of both inert and chemically reactive pollutants by simulating the physical and chemical processes in the atmosphere that affect pollutant concentrations. Version 4.1 of REMSAD was used for the HDE modeling. The framework of this model is taken from version 1.23 of the UAM-V regional-scale photochemical model, without Plume-in-Grid and with a modified Carbon Bond IV routine, as described below. The UAM-V framework has been extended vertically to treat the entire troposphere and converted to a sigma (terrain following) vertical coordinate. REMSAD includes a cumulus convective parameterization scheme and a stratiform cloud parameterization scheme for the distribution and removal of pollutant species.

The basis for REMSAD is the atmospheric diffusion equation (also called the species continuity or advection/diffusion equation). This equation represents a mass balance in which all of the relevant emissions, transport, diffusion, chemical reactions, and removal processes are expressed in mathematical terms. REMSAD employs finite-difference numerical techniques for the solution of the advection/diffusion equation.

REMSAD uses a latitude/longitude horizontal grid structure in which the horizontal grids are generally divided into areas of equal latitude and longitude. The vertical layer structure of REMSAD is defined in terms of sigma-pressure coordinates. The top and bottom of the domain are defined as 0 and 1 respectively. The vertical layers are defined as a percent of the atmospheric pressure between the top and bottom of the domain. For example, a vertical layer of 0.50 sigma is exactly halfway between the top and bottom of the domain as defined by the local atmospheric pressure. Usually, the vertical layers are defined to match the vertical layer structure

of the meteorological model used to generate the REMSAD meteorological inputs.

1. Gas Phase Chemistry

REMSAD simulates gas phase chemistry using a reduced-form version of CB4 termed “micro-CB4” (mCB4) which treats fewer VOC species compared to the full CB4 mechanism. The inorganic and radical parts of the reduced mechanism are identical to CB4. In this version of mCB4 the organic portion is based on one primary species (VOC) and one primary and secondary carbonyl species (CARB). The VOC species was incorporated with kinetics representing an average anthropogenic hydrocarbon species. A second primary VOC species representing biogenic emissions is also included with kinetic characteristics representing isoprene. The intent of the mCB4 mechanism is to (a) provide a physically faithful representation of the linkages between emissions of ozone precursor species and secondary PM precursors species, (b) treat the oxidizing capacity of the troposphere, represented primarily by the concentrations of radicals and hydrogen peroxide, and (c) simulate the rate of oxidation of the nitrogen oxide (NO_x) and sulfur dioxide (SO_2) PM precursors. Box model testing of mCB4 has found that it performs very closely to the full CBM4 that is contained in UAM-V (Whitten, 1999).

2. PM Chemistry

Primary PM emissions in REMSAD are treated as inert species. They are advected and deposited without any chemical interaction with other species. Secondary PM species, such as sulfate and nitrate are formed through chemical reactions within the model. SO_2 is the gas phase precursor for particulate sulfate, while nitric acid is the gas phase precursor for particulate nitrate. Several other gas phase species are also involved in the secondary reactions.

There are two pathways for sulfate formation; gas phase and aqueous phase. Aqueous phase reactions take place within clouds, rain, and/or fog. In-cloud processes can account for the majority of atmospheric sulfate formation in many areas. In REMSAD, aqueous SO_2 reacts with hydrogen peroxide (H_2O_2) to form sulfate⁹. This reaction also occurs in the gas phase although the gas phase reaction is much slower. SO_2 also reacts with OH radicals in the gas phase to form sulfate.

Particulate nitrate is calculated in an equilibrium reaction between nitric acid, sulfuric acid, and ammonia. Nitric acid is a product of gas phase chemistry and is formed through the mCB4 reactions. The acids are neutralized by ammonia with sulfuric acid reacting more quickly than nitric acid. An equilibrium is established among ammonium sulfate and ammonium nitrate which strongly favors ammonium sulfate unless the available ammonia exceeds twice the available sulfate. Nitrate is then partitioned between particulate nitrate and gas phase nitric acid. The partitioning of nitrate depends on the availability of ammonia as well meteorological factors such as temperature and relative humidity.

⁹Hydrogen peroxide is formed from photochemical reactions within the mCB4 mechanism.

B. REMSAD Modeling Domain

The modeling domain used for the HDE modeling was designed to provide air quality predictions for the lower 48 States, as shown in Figure IV-1. The geographic characteristics of the domain are as follows:

120 (E-W) X 84 (N-S) grid cells

Cell size (~36 km)

1/2 degree longitude (0.5)

1/3 degree latitude (0.3333)

E-W range: 66 degrees W - 126 degrees W

N-S range: 24 degrees N - 52 degrees N

Vertical extent: Ground to 16,200 meters (100mb) with 8 layers

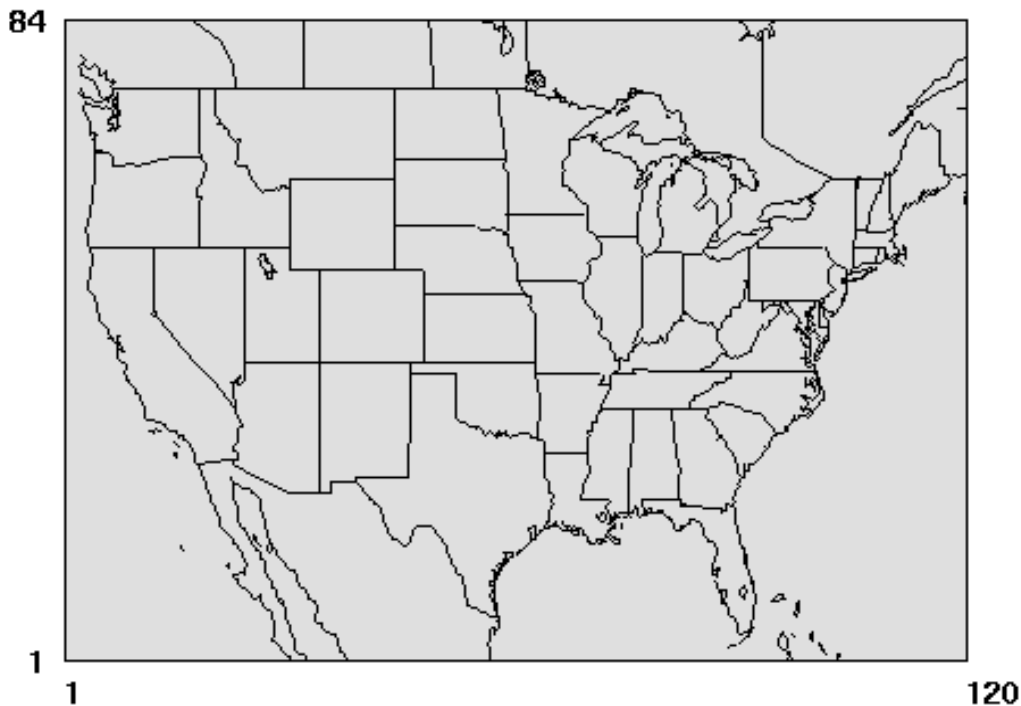


Figure IV-1. REMSAD Modeling Domain.

C. REMSAD Inputs

Input data for REMSAD can be classified into six categories: (1) simulation control, (2) emissions, (3) initial and boundary concentrations, (4) meteorological, (5) surface characteristics, and (6) chemical rates. The REMSAD predictions of pollutant concentrations are calculated from the emissions, advection, and dispersion processes coupled with the formation and

deposition of secondary PM species within every grid cell of the modeling domain. To adequately replicate the full three-dimensional structure of the atmosphere, the REMSAD program requires hourly (or 3-hour average) input data for a number of variables. Table IV-1 lists the required REMSAD input files.

Table IV-1. List of REMSAD input files.

Data type	Files	Description
Control	CONTROL	Simulation control information
Emissions	PTSOURCE EMISSIONS	Elevated source emissions Surface emissions
Initial and boundary concentrations	AIRQUALITY BOUNDARY	Initial concentrations Lateral boundary concentrations
Meteorological	WIND TEMPERATURE PSURF H2O VDIFFUSION RAIN	X,Y-components of winds 3D array of temperature 2D array of surface pressure 3D array of water vapor 3D array of vertical turbulent diffusivity coefficients 2D array of rainfall rates
Surface characteristics	SURFACE TERRAIN	Gridded land use Terrain heights
Chemical rates	CHEMPARAM RATES	Chemical reaction rates Photolysis rates file

1. Meteorological Data

REMSAD requires input of winds (u- and v-vector wind components), temperatures, surface pressure, specific humidity, vertical diffusion coefficients, and rainfall rates. The meteorological input files were developed from a 1996 annual MM5 model run that was developed for previous projects. MM5 is the Fifth-Generation NCAR / Penn State Mesoscale Model. MM5 (Grell *et. al.*, 1994) is a numerical meteorological model that solves the full set of physical and thermodynamic equations which govern atmospheric motions. MM5 was run in a nested-grid mode with 2 levels of resolution: 108 km, and 36km with 23 vertical layers sigma

layers extending from the surface to the 100 mb pressure level. The model was simulated in five day segments with an eight hour ramp-up period. The MM5 runs were started at 0Z, which is 7PM EST. The first eight hours of each five day period were removed before being input into REMSAD. Figure IV-2 shows the MM5 and REMSAD 36km domain superimposed on each other. Table IV-2 lists the vertical grid structures for the MM5 and REMSAD domains. Further detailed information concerning the development of the 1996 MM5 datasets can be found in (Olerud, 2000)

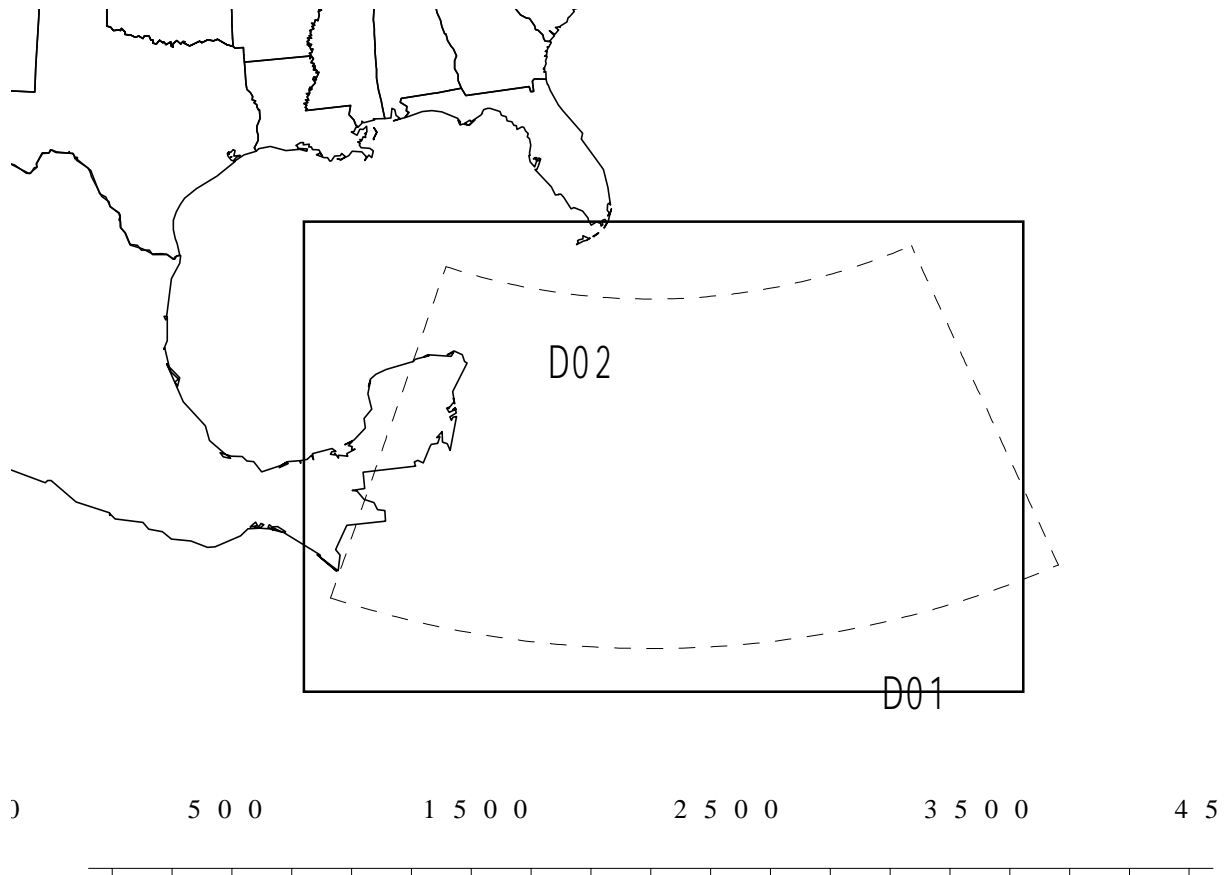


Figure IV-2. MM5 36km Domain (solid box) and REMSAD Domain (dashed lines).

Table IV-2. Vertical Grid Structure for 1996 MM5 and HDE REMSAD Domains. Layer heights represent the top of each layer. The first layer is from the ground up to 153 meters.

REMSAD Layer	MM5 Layer	Sigma	Approximate Height(m)	Pressure(mb)
0	0	1.000	0.0	1000.0
	1	0.995	38.0	995.5
	2	0.988	91.5	989.2
1	3	0.980	152.9	982.0
	4	0.970	230.3	973.0

REMSAD Layer	MM5 Layer	Sigma	Approximate Height(m)	Pressure(mb)
	5	0.956	339.5	960.4
2	6	0.938	481.6	944.2
	7	0.916	658.1	924.4
	8	0.893	845.8	903.7
	9	0.868	1053.9	881.2
3	10	0.839	1300.7	855.1
	11	0.808	1571.4	827.2
	12	0.777	1849.6	799.3
	13	0.744	2154.5	769.6
4	14	0.702	2556.6	731.8
	15	0.648	3099.0	683.2
	16	0.582	3805.8	623.8
5	17	0.500	4763.7	550.0
	18	0.400	6082.5	460.0
6	19	0.300	7627.9	370.0
	20	0.200	9510.5	280.0
7	21	0.120	11465.1	208.0
	22	0.052	13750.2	146.0
8	23	0.000	16262.4	100.0

The physical options selected for this configuration of MM5 include the following:

1. One-way nested grids
2. Nonhydrostatic dynamics
3. Four-dimensional data assimilation (FDDA):
 - Analysis nudging of wind, temperature, and mixing ratios
 - Nudging coefficients range from $1.0 \times 10^{-5} \text{ s}^{-1}$ to $3.0 \times 10^{-4} \text{ s}^{-1}$
4. Explicit moisture treatment:
 - 3-D predictions of cloud and precipitation fields
 - Simple ice microphysics
 - Cloud effects on surface radiation
 - Moist vertical diffusion in clouds
 - Normal evaporative cooling
5. Boundary conditions:
 - Time and inflow/outflow relaxation
6. Cumulus cloud parameterization schemes:
 - Anthes-Kuo (108-km grid)
 - Kain-Fritsch (36-km grid)

7. No shallow convection
8. Full 3-dimensional Coriolis force
9. Drag coefficients vary with stability
10. Vertical mixing of momentum in mixed layer
11. Virtual temperature effects
12. PBL process parameterization: MRF scheme
13. Surface layer parameterization:
 - Fluxes of momentum, sensible and latent heat
 - Ground temperature prediction using energy balance equation
 - 24 land use categories
14. Atmospheric radiation schemes:
 - Simple cooling
 - Long- and short-wave radiation scheme
15. Sea ice treatment:
 - Forced Great Lakes/Hudson Bay to permanent ice under very cold conditions
 - 36-km treatment keyed by observations of sea ice over the Great Lakes
16. Snow cover:
 - Assumed no snow cover for July and August
 - National Center for Environmental Prediction (NCEP) snow cover for January to June, and for September to December

The MM5 model output cannot be directly input into REMSAD due to differences in the grid coordinate systems and file formats. A postprocessor called MM5REMSAD was developed to convert the MM5 data into REMSAD format. This postprocessor was used to develop 3-hour average meteorological input files from the MM5 output. Documentation of the MM5REMSAD code and further details on the development of the input files is contained in (Mansell, 2000).

2. Initial and Boundary Conditions, and Surface Characteristics

Application of the REMSAD modeling system requires data files specifying the initial species concentration fields (AIRQUALITY) and lateral species concentrations (BOUNDARY). Due to the extent of the proposed modeling domains and the regional-scale nature of the REMSAD model, these inputs were developed based on “clean” background concentration values. The HDE modeling used temporally and spatially (horizontal) invariant data for both initial and boundary conditions. Species concentration values were allowed to decay vertically for most species. Table IV-3 summarizes the initial and boundary conditions used in the HDE REMSAD modeling.

Table IV-3. REMSAD Initial and Boundary Conditions (ppm)

	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8
Species								
NO	1.00E-12	1.00E-12	1.00E-12	1.00E-12	8.57E-13	5.71E-13	2.86E-13	7.14E-14
NO2	1.00E-04	1.00E-04	1.00E-04	1.00E-04	8.57E-05	5.71E-05	2.86E-05	7.14E-06
O3	4.00E-02	4.00E-02	4.00E-02	4.00E-02	4.00E-02	4.00E-02	4.00E-02	4.00E-02
SO2	7.00E-04	7.00E-04	7.00E-04	7.00E-04	6.00E-04	4.00E-04	2.00E-04	5.00E-05
NH3	5.00E-04	5.00E-04	5.00E-04	5.00E-04	3.67E-04	1.63E-04	4.08E-05	2.55E-06

	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8
VOC	2.00E-02	2.00E-02	2.00E-02	2.00E-02	1.71E-02	1.14E-02	5.71E-03	1.43E-03
CARB	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07
ISOP	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09
CO	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
HNO3	1.00E-05	1.00E-05	1.00E-05	1.00E-05	8.57E-06	5.71E-06	2.86E-06	7.14E-07
PNO3	1.00E-05	1.00E-05	1.00E-05	1.00E-05	7.35E-06	3.27E-06	8.16E-07	5.10E-08
GSO4	1.00E-04	1.00E-04	1.00E-04	1.00E-04	7.35E-05	3.27E-05	8.16E-06	5.10E-07
ASO4	1.00E-12	1.00E-12	1.00E-12	1.00E-12	8.57E-13	5.71E-13	2.86E-13	7.14E-14
NH4N	1.00E-05	1.00E-05	1.00E-05	1.00E-05	7.35E-06	3.27E-06	8.16E-07	5.10E-08
NH4S	1.00E-04	1.00E-04	1.00E-04	1.00E-04	7.35E-05	3.27E-05	8.16E-06	5.10E-07
SOA	1.00E-03	1.00E-03	1.00E-03	1.00E-03	7.35E-04	3.27E-04	8.16E-05	5.10E-06
POA	1.00E-03	1.00E-03	1.00E-03	1.00E-03	7.35E-04	3.27E-04	8.16E-05	5.10E-06
PEC	5.00E-03	5.00E-03	5.00E-03	5.00E-03	3.67E-03	1.63E-03	4.08E-04	2.55E-05
PMFINE	1.00E-03	1.00E-03	1.00E-03	1.00E-03	7.35E-04	3.27E-04	8.16E-05	5.10E-06
PMCOARS	1.00E-03	1.00E-03	1.00E-03	1.00E-03	6.30E-04	1.87E-04	2.33E-05	3.64E-07

Application of the REMSAD model requires specification of gridded terrain elevations (TERRAIN) and landuse characteristics (SURFACE). The SURFACE data files provides the fraction of the 11 landuse categories recognized by REMSAD in each grid cell. Landuse characteristics are used in the model for the calculation of deposition parameters. For this task, a landuse/terrain processor, PROC_LUTERR, was developed based on the MM5 TERRAIN preprocessor. Landuse data was obtained from the USGS Global 30 sec. vegetation database which is the same database used in the 1996 MM5 models runs. This dataset provides 24 landuse categories, including urban. For the REMSAD application, the 10 min. (1/6 deg.) datasets was utilized. The processor remapped the 24 USGS vegetation categories to those required for application of REMSAD. It also aggregated the 10 min resolution data to the ~36 km horizontal resolution used for this REMSAD application.

For the TERRAIN input data files, a similar global terrain elevation dataset is also available from NCAR and was used for this task. While it is possible to use the terrain elevations obtained from the MM5 model output data files, it was deemed more appropriate to begin with the USGS 10 min. resolution database due to the various map projections and interpolations involved in developing the required data files for the geodetic coordinates used in REMSAD. However, because proper application of REMSAD will require zero terrain elevations, “dummy” terrain files (with all zeroes) were developed and provided for input to REMSAD.

3. Emissions Inputs

The REMSAD emissions input files were generated using the EPS2.5 emissions preprocessing system. The annual county level HDE emissions inventory data was speciated, temporally allocated and gridded to the REMSAD domain. The individual species contained in these inventory files were oxides of nitrogen (NO_x), volatile organic compounds (VOC), carbon monoxide (CO), sulfur dioxide (SO₂), ammonia (NH₃), primary PM₁₀, and primary PM_{2.5}. The primary PM emissions were further speciated into primary elemental carbon (PEC), primary

organic aerosols¹⁰ (POA), primary sulfate (GSO₄), primary nitrate (PNO₃), crustal/fugitive (PMFINE), and primary coarse particles in the 2.5-10 um range (PMCOARS). Secondary organic aerosols (SOA) are estimated from the total anthropogenic VOC emissions. The yield of SOA is calculated from the raw county level VOC inventory and the SOA emissions were input into REMSAD in the same way as primary PM emissions (EPA, 2000b).

The annual emissions for stationary and nonroad sources were processed to generate separate sets of emissions representing typical weekday, Saturday, and Sunday emissions for each season. For mobile sources, monthly emissions were obtained from the mass emissions files and processed to create emissions for each day-type for each month. Hourly emissions for anthropogenic emissions were created by applying diurnal profile factors to the daily emissions. Hourly biogenic emissions were created by applying a typical diurnal pattern to monthly average biogenic VOC emissions developed using the BEIS2 model. Biogenic emissions were not altered for any of the scenarios modeled.

D. Model Performance Evaluation

The goal of the 1996 base year modeling was to reproduce the atmospheric processes resulting in formation and dispersion of fine particulate matter across the U.S. An operational model performance evaluation for PM_{2.5} and its related speciated components (e.g., sulfate, nitrate, elemental carbon etc.) for 1996 was performed in order to estimate the ability of the modeling system to replicate base year concentrations. All of the observational data used in this analysis can be found at the CAPITA website:

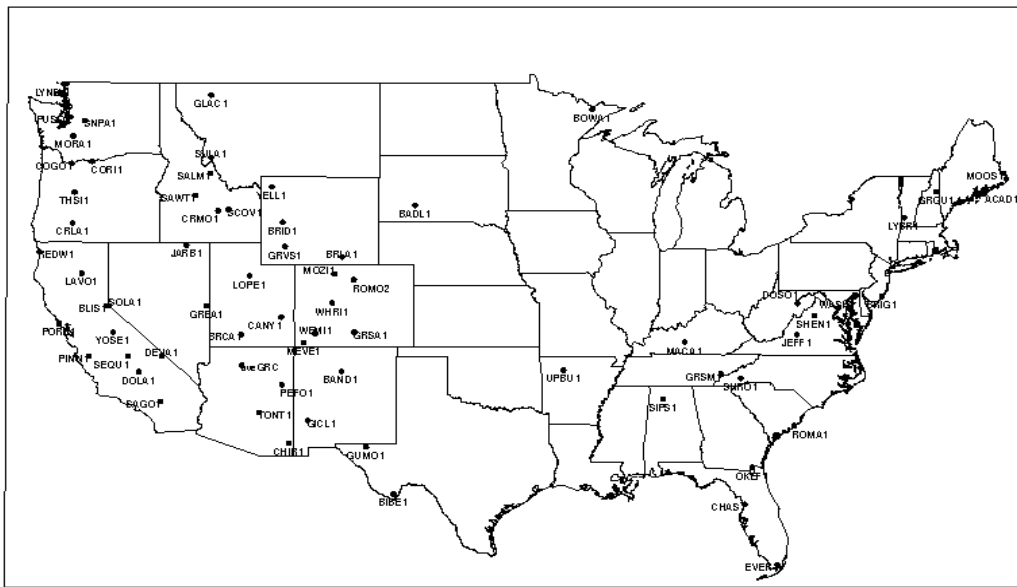
http://capita.wustl.edu/datawarehouse/Datasets/CAPITA/NAMPM_fine/Data/NAMPM_f.html

This evaluation is comprised principally of statistical assessments of model versus observed pairs. The robustness of any evaluation is directly proportional to the amount and quality of the ambient data available for comparison. Unfortunately, there are few PM_{2.5} monitoring networks with available data for evaluation of the HDE PM modeling. Critical limitations of the existing databases are a lack of urban monitoring sites with speciated measurements and poor geographic representation of ambient concentration in the East. PM_{2.5} monitoring networks were recently expanded in 1999 to include more than 1000 Federal Reference Method (FRM) monitoring sites. The purpose of this network is to monitor PM_{2.5} mass levels in urban areas. These monitors only measure total PM_{2.5} mass and do not measure PM species. In the next 1-2 years a new network of ~300 urban oriented speciation monitor sites will begin operation across the country. These monitors will collect a full range of PM_{2.5} species that are necessary to evaluate models and to develop PM_{2.5} control strategies.

¹⁰The primary organic carbon emissions were multiplied by a factor of 1.2 to account for the additional mass of oxygen and other compounds typically found attached to particulate organic carbon.

The largest available ambient database for 1996 comes from the **I**nteragency **M**onitoring of **P**ROtected **V**isual **E**nvironments (IMPROVE) network. IMPROVE is a cooperative visibility monitoring effort between EPA, federal land management agencies, and state air agencies. Data is collected at Class I areas across the United States mostly at National Parks, National Wilderness Areas, and other protected pristine areas (IMPROVE 2000). There were approximately 60 IMPROVE sites that had complete annual PM_{2.5} mass and/or PM_{2.5} species data for 1996. Forty two sites were in the West¹¹ and 18 sites were in the East. Figure IV-3 shows the locations of the IMPROVE monitoring sites used in this evaluation. IMPROVE data is collected twice weekly (Wednesday and Saturday). Thus, there is a total of 104 possible samples per year or 26 samples per season. For this analysis, a 50% completeness criteria was used. That is, in order to be counted in the statistics a site had to have > 50% complete data in all 4 seasons. If any season was missing, an annual average was not calculated for the site. See Appendix F for a list of the IMPROVE sites used in the evaluation.

1996 IMPROVE Monitoring Sites



12DEC00

Figure IV-3. Map of 1996 IMPROVE monitoring sites used in the REMSAD model performance evaluation.

The observed IMPROVE data used for the performance evaluation was PM_{2.5} mass, sulfate ion, nitrate ion, elemental carbon, organic aerosols, and crustal material (soils). The REMSAD model output species were postprocessed in order to achieve compatibility with the observation species. The following is the translation of the REMSAD output species into PM_{2.5} and related species:

¹¹The dividing line between the West and East was defined as the 100th meridian.

Sulfate Ion:	TSO4 = ASO4 + GSO4
Nitrate Ion:	PNO3
Organic aerosols:	TOA = POA + SOA
Elemental Carbon:	PEC
Crustal Material (soils):	PMFINE
PM _{2.5} :	PM _{2.5} = PMFINE + 1.375 * (ASO4 + GSO4) + 1.29 * (PNO3) + POA + SOA + PEC

where, TSO4 is total sulfate ion, ASO4 is aqueous path sulfate, GSO4 is gaseous path sulfate, PNO3 is nitrate ion, TOA is total organic aerosols, POA is primary organic aerosol, SOA is secondary organic aerosol, PEC is primary elemental carbon, and PMFINE is primary fine particles (other unspesiated primary PM_{2.5}). PM_{2.5} is defined as the sum of the individual species. Sulfate ion is multiplied by 1.375 and nitrate ion is multiplied by 1.29 in order to account for particulate ammonium. It is assumed that sulfate and nitrate exist in the atmosphere and in the model as ammonium sulfate and ammonium nitrate respectively.

1. Statistical Definitions

Below are the definitions of statistics used for the evaluation. The statistics are similar to those used for a previous REMSAD evaluation of a 1990 basecase (Wayland, 1999). The format of all the statistics is such that negative values indicate model predictions that were less than their observed counterparts. Positive statistics indicate model overestimation of observed PM. The statistics were calculated for the entire REMSAD domain and separately for the East and West. The dividing line between East and West is the 100th meridian.

Mean Observation: The mean observed value (in ug/m3) averaged over all monitored days in the year and then averaged over all sites in the region.

$$OBS = \frac{1}{N} \sum_{i=1}^N Obs_{x,t}^i$$

Mean REMSAD Prediction: The mean predicted value (in ug/m3) paired in time and space with the observations and then averaged over all sites in the region.

$$PRED = \frac{1}{N} \sum_{i=1}^N Pred_{x,t}^i$$

Ratio of the Means: Ratio of the predicted over the observed values. A ratio of greater than 1 indicates on overprediction and a ratio of less than 1 indicates an underprediction.

$$RATIO \frac{1}{N} \sum_{i=1}^N \frac{Pred_{x,t}^i}{Obs_{x,t}^i}$$

Mean Bias (ug/m3): This performance statistic averages the difference (model - observed) over all pairs in which the observed values were greater than zero. A mean bias of zero indicates that the model over predictions and model under predictions exactly cancel each other out. Note that the model bias is defined such that it is a positive quantity when model prediction exceeds the observation, and vice versa. This model performance estimate is used to make statements about the absolute or unnormalized bias in the model simulation

$$BIAS \frac{1}{N} \sum_{i=1}^N (Pred_{x,t}^i - Obs_{x,t}^i)$$

Mean Fractional Bias (percent): Normalized bias can become very large when a minimum threshold is not used. Therefore fractional bias is used as a substitute. The fractional bias for cases with factors of 2 under- and over-prediction are -67 and + 67 percent, respectively (as opposed to -50 and +100 percent, when using normalized bias, which is not presented here). Fractional bias is a useful model performance indicator because it has the advantage of equally weighting positive and negative bias estimates. The single largest disadvantage in this estimate of model performance is that the estimated concentration (i.e., prediction, Pred) is found in both the numerator and denominator.

M

$$FBIAS \frac{2}{N} \sum_{i=1}^N \frac{(Pred_{x,t}^i - Obs_{x,t}^i)}{(Pred_{x,t}^i + Obs_{x,t}^i)} \cdot 100$$

Mean Error (ug/m3): This performance statistic averages the absolute value of the difference (model - observed) over all pairs in which the observed values were greater than zero. It is similar to mean bias except that the absolute value of the difference is used so that the error is always positive.

$$ERR \frac{1}{N} \sum_{i=1}^N |Pred_{x,t}^i - Obs_{x,t}^i|$$

Mean Fractional Error: Normalized error can become very large when a minimum threshold is not used. Therefore fractional error is used as a substitute. It is similar to the fractional bias except the absolute value of the difference is used so that the error is always positive.

$$FERROR = \frac{2}{N} \sum_{i=1}^N \frac{Pred_{x,t}^i - Obs_{x,t}^i}{Pred_{x,t}^i + Obs_{x,t}^i} \cdot 100$$

2. Results of REMSAD Performance Evaluation

The statistics described above are presented for the entire domain, the Eastern sites, and the Western sites. The model's ability to replicate annual average PM_{2.5} and PM_{2.5} species concentrations at the IMPROVE sites is as follows:

a. PM_{2.5} Performance

Table IV-4 lists the performance statistics for PM_{2.5} at the IMPROVE sites. For the full domain, PM_{2.5} is underpredicted ~25%. The ratio of the means is 0.77 with a bias of -0.93 ug/m3. It can be seen that most of this underprediction is due to the Western sites. The West is underpredicted by ~35% while the East is overpredicted by ~10%. The fractional bias is less than 10% in the East, while the fractional error is ~40%. The fractional bias and error in the West is 31% and 65% respectively. The observed PM_{2.5} concentrations in the East are relatively high compared to the West. REMSAD displays an ability to differentiate between generally high and low PM_{2.5} areas.

Table IV-4. Annual mean PM_{2.5} performance at IMPROVE sites.

	No. of Sites	Mean REMSAD Predictions (ug/m3)	Mean Observations (ug/m3)	Ratio of Means (pred/obs)	Bias (ug/m3)	Fractional Bias (%)	Error (ug/m3)	Fractional Error (%)
National	59	5.14	6.07	0.77	-0.93	-21.1	3.04	58.2
East	17	11.38	10.55	1.07	0.82	2.8	4.40	41.8
West	42	2.61	4.26	0.65	-1.64	-30.7	2.48	64.9

b. Sulfate Performance

Table IV-5 lists the performance statistics for particulate sulfate at the IMPROVE sites. Domainwide, sulfate performance is better than PM2.5 with a slight overprediction of 9%. The sulfate bias in the West is close to zero, while there is a ~25% overprediction of annual sulfate levels in the East. The biases are relatively low, however the errors are considerably higher indicating that some overpredicted values are canceling out some underpredicted values.

Table IV-5. Annual mean sulfate ion performance at IMPROVE sites.

	No. of Sites	Mean REMSAD Predictions (ug/m3)	Mean Observations (ug/m3)	Ratio of Means (pred/obs)	Bias (ug/m3)	Fractional Bias (%)	Error (ug/m3)	Fractional Error (%)
National	60	1.87	1.63	1.09	0.24	4.4	0.85	51.5
East	18	4.71	3.81	1.25	0.90	9.0	2.00	47.6
West	42	0.65	0.70	1.02	-0.05	2.4	0.35	53.2

c. Elemental Carbon Performance

Table IV-6 lists the performance statistics for primary elemental carbon at the IMPROVE sites. Performance for elemental carbon predictions is similar to that of sulfate with a slight overprediction in the East and a slight underprediction in the West. Model performance between the East and West was remarkably similar. The bias is very low, but the fractional error is ~50% of the observed values.

Table IV-6. Annual mean elemental carbon performance at IMPROVE sites

	No. of Sites	Mean REMSAD Predictions (ug/m3)	Mean Observations (ug/m3)	Ratio of Means (pred/obs)	Bias (ug/m3)	Fractional Bias (%)	Error (ug/m3)	Fractional Error (%)
National	48	0.30	0.31	1.10	-0.01	10.5	0.18	56.2
East	16	0.50	0.47	1.26	0.03	14.8	0.24	50.8
West	32	0.21	0.24	1.02	-0.03	8.3	0.14	58.9

d. Organic Aerosol Performance

Table IV-7 lists the performance statistics for primary organic aerosols at the IMPROVE sites. Organic aerosols are underpredicted nationwide. The East and West are equally underpredicted by about 35%. Both the fractional bias and fractional errors are higher than for PM_{2.5}, sulfate, and elemental carbon. It is clear that the model is not accounting for all of the organics that were observed.

Currently REMSAD has a very crude accounting for secondarily formed organics (SOA). In the atmosphere, SOA is formed from both anthropogenic and biogenic VOC emissions. REMSAD accounts for anthropogenic SOA by estimating the SOA yield from anthropogenic VOC emissions. Currently REMSAD does not account for biogenic SOA which mostly comes from terpene emissions from coniferous trees. It is expected that in the IMPROVE Class I areas, the majority of the SOA will be from biogenic emissions. This is a possible explanation for the modeled underprediction of measured organic aerosols.

Also, at some Class I areas, particularly in the West, wildfires account for a portion of the annual observed organic aerosol measurements. The current emission inventory is lacking in detailed representation of wildfires that occurred in 1996 which may be important for model evaluation, but not necessarily for the HDE analysis.

Table IV-7. Annual mean organic aerosol performance at IMPROVE sites

	No. of Sites	Mean REMSAD Predictions (ug/m3)	Mean Observations (ug/m3)	Ratio of Means (pred/obs)	Bias (ug/m3)	Fractional Bias (%)	Error (ug/m3)	Fractional Error (%)
National	48	0.76	1.25	0.67	-0.48	-44.1	0.81	74.8
East	16	1.11	1.74	0.68	-0.63	-38.3	0.99	64.5
West	32	0.60	1.01	0.67	-0.41	-47.0	0.72	79.9

e. Nitrate Performance

Table IV-8 lists the performance statistics for nitrate ion at the IMPROVE sites. Nitrate is generally overpredicted in the East and somewhat underpredicted in the West. The ratio of the means in the East is 2.80 indicating an overprediction. The fractional bias is close to zero, but the fractional error is > 100%. This indicates that on a day to day basis the model is relatively unbiased, but it does a poor job of predicting individual days (indicated by the high error). When the model overpredicts, it overpredicts by a large margin (which causes the high overall ratio of means). In the western United States, the overall ratio of the means is near unity, but the fractional bias is strongly negative, which indicates an underprediction. And the fractional error is slightly higher than in the East. Again, the model is not accurately predicting day to day concentrations.

It is important to consider these results in the context that the observed nitrate concentrations at the IMPROVE sites are very low. The mean nationwide observations are only 0.40 ug/m3. It is often difficult for models to replicate very low concentrations of secondarily formed pollutants. Nitrate is generally a small percentage of the measured PM_{2.5} at almost all of the IMPROVE sites. Nitrate can be an important contributor to PM_{2.5} in some urban areas (particularly in California) but performance for those areas could not be assessed due to the lack of urban area speciated nitrate data for 1996.

Table IV-8. Annual mean nitrate ion performance at IMPROVE sites

	No. of Sites	Mean REMSAD Predictions (ug/m3)	Mean Observations (ug/m3)	Ratio of Means (pred/obs)	Bias (ug/m3)	Fractional Bias (%)	Error (ug/m3)	Fractional Error (%)
National	51	0.68	0.40	1.64	0.29	-46.7	0.63	134.4
East	17	1.48	0.54	2.80	0.94	-1.1	1.19	126.8
West	33	0.27	0.32	1.04	-.05	-70.3	0.35	138.3

f. PMFINE-Other (crustal) Performance

Table IV-9 lists the performance statistics for PMFINE-other or primary crustal emissions. The observations show crustal PM_{2.5} to be generally higher in the West than in the East. But REMSAD is predicting higher crustal concentrations in the East. The largest categories of PMFINE-other are fugitive dust sources such as paved roads, unpaved roads, construction, and animal feed lots. There is a large uncertainty in the handling of these emissions in the inventory. It is apparent that too much fugitive dust is being emitted in the East. It is evident from the performance statistics that further work needs to be done to study the magnitude of these emissions and how they are emitted into the model.

Table IV-9. Annual mean PMFINE (crustal) performance at IMPROVE sites

	No. of Sites	Mean REMSAD Predictions (ug/m3)	Mean Observations (ug/m3)	Ratio of Means (pred/obs)	Bias (ug/m3)	Fractional Bias (%)	Error (ug/m3)	Fractional Error (%)
National	60	0.96	0.63	2.11	0.33	47.1	0.86	96.0
East	18	1.76	0.52	4.10	1.24	106.1	1.46	118.1
West	42	0.62	0.68	1.26	-0.06	21.8	0.61	86.6

g. Summary of Model Performance Results Using Improve Data

The purpose of this model performance evaluation was to evaluate the capabilities of the REMSAD modeling system in reproducing annual average concentrations for all IMPROVE sites in the contiguous U.S. for fine particulate mass and its associated speciated components. When considering annual average statistics (e.g., predicted versus observed), which are computed and aggregated over all sites and all days, REMSAD underpredicts fine particulate mass (PM_{2.5}), by ~20%. PM_{2.5} in the Eastern U.S. is slightly overpredicted, while PM_{2.5} in the West is underpredicted by about 35%. Eastern sulfate and elemental carbon are slightly overpredicted while nitrate and crustal are largely overpredicted. This is balanced by an underprediction in organic aerosols. Overall the PM_{2.5} performance in the East is relatively unbiased due to the dominance of sulfate in the observations. Western predictions of sulfate,

nitrate, elemental carbon, and crustal are all relatively unbiased, while organic aerosols are underpredicted by ~30%. Since organic aerosols are the largest PM_{2.5} component in the West, overall Western PM_{2.5} is underpredicted by ~35%.

It should be noted that PM_{2.5} modeling is an evolving science. There have been few regional or national scale model applications for primary and secondary PM. In fact, this is the one of the first nationwide applications of a full chemistry Eulerian grid model for the purpose of estimating annual average concentrations of PM_{2.5} and its component species. Also, unlike ozone modeling, there is essentially no database of past performance statistics against which to measure the performance of the HDE PM modeling. Given the state of the science relative to PM modeling, it is inappropriate to judge PM model performance using criteria derived for other pollutants, like ozone. Still, the performance of the HDE PM modeling is very encouraging, especially considering that the results may be limited by our current knowledge of PM science and chemistry, and by the emissions inventories for primary PM and secondary PM precursor pollutants.

h. Comparisons to Other Observational Databases

Although IMPROVE was the largest and most complete nationwide fine particulate network operating in 1996, there were several other smaller networks operating at the time that can provide useful ambient data for comparison with REMSAD results. Among those networks are the CASTNET Dry Deposition network and the California Air Resources Board (CARB) PM_{2.5} monitoring network. There were 26 CASTNET sites which collected weekly average data for several PM species and 16 CARB sites which collected PM_{2.5} mass and several elemental species.

Both datasets are inconsistent with the sampling methodologies and sampling frequency of the IMPROVE sites. Further analysis needs to be completed to determine the reliability of these data. A preliminary review of REMSAD model performance for these networks confirms what was seen relative to the IMPROVE evaluation. Total nitrate values (particulate nitrate plus nitric acid) at the CASTNET sites were overpredicted in the East and underpredicted in the West. At the CARB sites, PM_{2.5} mass was underpredicted similar to what was seen at the Western IMPROVE sites.

E. Visibility Calculations

Several visibility parameters were calculated from the REMSAD model output for use in the benefits analysis. These included light extinction coefficient (b_{ext}) and deciviews. The extinction coefficient values in units of inverse megameters (1/M) were calculated based on the IMPROVE protocol (IMPROVE, 2000). The reconstructed b_{ext} values were calculated as follows:

$$b_{ext} = 10.0 + [3.0 * f(RH) * (1.375 * (GSO4 + ASO4)) + 3.0 * f(RH) * (1.29 * PNO3) + 4.0 * (SOA + POA) + 10.0 * PEC + 1.0 * (PMFINE) + 0.6 * (PMCOARS)]$$

The 10.0 initial value accounts for atmospheric background (i.e., Rayleigh) scattering. $f(RH)$ refers to the relative humidity correction function as defined by IMPROVE (2000). The relative humidity correction factor was calculated from the 3-hour average modeled relative humidity at each grid cell for each time period. The 3-hour average b_{ext} was then calculated. All of the hours in the day were then averaged to derive a daily average b_{ext} for each grid cell. The daily average b_{ext} were averaged to derive the annual average b_{ext} . The annual average b_{ext} were used to calculate the annual average deciviews (dv) using the following formula:

$$dv = 10.0 \ln \left[\frac{(b_{ext})}{10.0 \text{ } Mm^{-1}} \right]$$

F. Need for HDE Rule Based on Unhealthy Annual Mean PM2.5 Concentrations

One component of the analysis to support the need for this rule was the calculation of the number of people living in metropolitan counties that experience annual PM2.5 concentrations above certain concentration levels. This “exposure” type analysis was based on 1999 ambient annual mean PM2.5 concentrations and projected future PM2.5 concentrations, based on modeling of the HDE emissions scenarios. To provide the future-year estimates of PM2.5 concentrations, relative reduction factors (RRFs) were calculated then applied to the ambient data. The procedures for determining the RRFs are similar to those in EPA’s draft guidance for demonstrating attainment of air quality goals for PM2.5 and regional haze (EPA, 2000d). One aspect of the procedures in the guidance is to develop RRFs for each component species of PM2.5 and then to apply these to the corresponding species measured at the monitoring site. However, the only extensive nationwide data base of ambient PM2.5 data available for this analysis does not contain speciated data. Thus, the RRFs were calculated for PM2.5 and applied to the monitoring data as described as follows. First, the REMSAD predictions of individual PM2.5 component species were postprocessed to provide annual mean PM2.5 concentrations in each grid cell for the 1996 base year and each future year scenario modeled (i.e., 2020 base and control and 2030 base and control). The gridded data were used to determine RRFs at each monitoring site with valid annual mean PM2.5 data. The RRFs were calculated as the ratio of mean PM2.5 in the future-year scenario to the mean for the 1996 base year. This value was then multiplied by the ambient PM2.5 concentration at the monitoring site to provide an estimate of the future PM2.5 concentrations at that site. These future concentrations were then used in the “exposure” analysis as described in the HDE docket (Docket A-99-06, item IV-B-01). The annual mean PM2.5 data along with the corresponding future-year estimates, based on RRFs, are provided in Appendix E.

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Appendix A:

Areas in the East with Predicted Exceedances in 2007, 2020, and/or 2030 and 1-Hour Design Values ≥ 125 ppb or ≥ 113 ppb.

MSA/ CMSA / State
Atlanta, GA
Barnstable-Yarmouth, MA
Baton Rouge, LA
Benton Harbor, MI
Beaumont-Port Arthur, TX
Biloxi-Gulfport-Pascagoula, MS
Birmingham, AL
Boston-Worcester-Lawrence, MA-HN-ME-CT
Charleston, WV
Charlotte-Gastonia-Rock Hill, NC-SC
Chicago-Gary-Kenosha, IL-IN-WI
Cincinnati-Hamilton, OH-KY-IN
Cleveland-Akron, OH
Detroit-Ann Arbor-Flint, MI
Grand Rapids-Muskegon-Holland, MI
Hartford, CT
Houma, LA
Houston-Galveston-Brazoria, TX
Huntington-Ashland, WV-KY-OH
Lake Charles, LA
Louisville, KY-IN
Macon, GA MSA
Memphis, TN-AR-MS
Milwaukee-Racine, WI
Nashville, TN
New Orleans, LA
New London-Norwich, CT-RI
New York-Northern New Jersey-Long Island, NY-NJ-CT-PA
Norfolk-Virginia Beach-Newport News, VA-NC
Orlando, FL
Pensacola, FL
Philadelphia-Wilmington- Atlantic City, PA-NJ-DE-MD
Providence-Fall River-Warwick, RI-MA
Richmond-Petersburg, VA
St. Louis, MO-IL
Tampa-St. Petersburg-Clearwater, FL
Washington, DC-Baltimore, DC, MD, VA

Appendix B:
Number of 12km Grid Cells Assigned to Each CMSA/MSA

CMSA/MSAs	Total Number of Grid Cells in Area
Atlanta, GA MSA	115
Barnstable, MA MSA	19
Baton Rouge, LA MSA	30
Beaumont-Port Arthur, TX MSA	39
Benton Harbor, MI MSA	15
Biloxi, MS MSA	41
Birmingham, AL MSA	64
Boston, MA CMSA	189
Charleston, WV MSA	31
Charlotte, NC MSA	69
Chicago, IL CMSA	129
Cincinnati, OH CMSA	71
Cleveland, OH CMSA	68
Detroit, MI CMSA	126
Grand Rapids, MI MSA	58
Hartford, CT MSA	41
Houma, LA MSA	51
Houston, TX CMSA	132
Huntington, WV MSA	47
Lake Charles, LA MSA	20
Louisville, KY MSA	45
Macon, GA MSA	37
Memphis, TN MSA	58
Milwaukee, WI CMSA	39
Nashville, TN MSA	78
New London, CT MSA	12
New Orleans, LA MSA	96
New York City, NY CMSA	195
Norfolk, VA MSA	60

Orlando, FL MSA	61
Pensacola, FL MSA	34
Philadelphia, PA CMSA	118
Providence, RI MSA	20
Richmond, VA MSA	66
St. Louis, MO MSA	127
Tampa, FL MSA	56
Washington, DC-Baltimore, MD CMSA	187

**Appendix C :
1-hour Ozone Metrics**

APPENDIX C
1-Hour Ozone Metrics
Total ppb Increase

Total ppb Increase	Philadelphia	Providence	Richmond	St. Louis	Tampa	Wash-Baltimore
1996 Base vs 2007 Base	0	0	0	0	1.2	0
2020 Base vs 2020 Control	0	0	0	0	0	0.1
2030 Base vs 2030 Control	0	0	0	0	0	12.2
Increase, on Average (ppb)	Philadelphia	Providence	Richmond	St. Louis	Tampa	Wash-Baltimore
1996 Base vs 2007 Base	0.0	0.0	0.0	0.0	0.0	0.0
2020 Base vs 2020 Control	0.0	0.0	0.0	0.0	0.0	0.0
2030 Base vs Control	0.0	0.0	0.0	0.0	0.0	0.2
Note: N.A. is used to denote that there are no exceedances in the Base Case or Control Case						

APPENDIX C
1-Hour Ozone Metics
Peak Ozone

Peak 1-Hour Ozone (ppb)	Max	Mean	Atlanta	Barnstable, MA	Baton Rouge	Beaumont	Benton Harbor, MI	Biloxi	Birmingham
1996 Base	219	162	219	160	154	135	160	144	153
2007 Base	191	147	191	134	148	134	148	140	135
2020 Base	183	143	183	124	144	129	144	136	132
2020 Control	171	138	171	116	142	127	140	134	126
2030 Base	191	147	191	128	148	132	148	138	135
2030 Control	176	140	176	118	145	130	143	136	128
Percent Change	Max	Mean	Atlanta	Barnstable, MA	Baton Rouge	Beaumont	Benton Harbor, MI	Biloxi	Birmingham
1996 vs 2007 Base	-12.8%	-9.6%	-12.8%	-16.2%	-3.9%	-0.7%	-7.5%	-2.8%	-11.8%
2007 Base vs 2020 Base	-4.2%	-2.9%	-4.2%	-7.5%	-2.7%	-3.7%	-2.7%	-2.9%	-2.2%
2020 Base vs 2020 Control	-6.6%	-3.4%	-6.6%	-6.5%	-1.4%	-1.6%	-2.8%	-1.5%	-4.5%
2020 Base vs 2030 Base	4.4%	2.7%	4.4%	3.2%	2.8%	2.3%	2.8%	1.5%	2.3%
2030 Base vs 2030 Control	-7.9%	-4.2%	-7.9%	-7.8%	-2.0%	-1.5%	-3.4%	-1.4%	-5.2%
1996 vs 2030 Control	-19.6%	-13.6%	-19.6%	-26.2%	-5.8%	-3.7%	-10.6%	-5.6%	-16.3%

APPENDIX C
1-Hour Ozone Metics
Peak Ozone

Peak 1-Hour Ozone (ppb)	Boston	Charleston, WV	Charlotte	Chicago	Cincinnati	Cleveland	Detroit	Grand Rapids
1996 Base	167	152	153	169	167	144	160	163
2007 Base	145	134	141	150	135	136	146	151
2020 Base	138	129	138	147	135	140	156	147
2020 Control	130	125	132	143	130	139	158	143
2030 Base	142	130	144	151	139	143	157	152
2030 Control	132	124	136	146	134	142	161	146
Percent Change	Boston	Charleston, WV	Charlotte	Chicago	Cincinnati	Cleveland	Detroit	Grand Rapids
1996 vs 2007 Base	-13.2%	-11.8%	-7.8%	-11.2%	-19.2%	-5.6%	-8.7%	-7.4%
2007 Base vs 2020 Base	-4.8%	-3.7%	-2.1%	-2.0%	0.0%	2.9%	6.8%	-2.6%
2020 Base vs 2020 Control	-5.8%	-3.1%	-4.3%	-2.7%	-3.7%	-0.7%	1.3%	-2.7%
2020 Base vs 2030 Base	2.9%	0.8%	4.3%	2.7%	3.0%	2.1%	0.6%	3.4%
2030 Base vs 2030 Control	-7.0%	-4.6%	-5.6%	-3.3%	-3.6%	-0.7%	2.5%	-3.9%
1996 vs 2030 Control	-21.0%	-18.4%	-11.1%	-13.6%	-19.8%	-1.4%	0.6%	-10.4%

APPENDIX C
1-Hour Ozone Metics
Peak Ozone

Peak 1-Hour Ozone (ppb)	Hartford	Houma, LA	Houston	Huntington, WV	Lake Charles, LA	Louisville	Macon, GA	Memphis
1996 Base	188	147	165	171	132	172	173	160
2007 Base	171	143	156	151	129	149	132	151
2020 Base	166	140	155	150	125	148	126	144
2020 Control	159	138	153	147	124	147	118	140
2030 Base	171	143	159	153	128	151	129	148
2030 Control	162	140	157	150	126	152	118	142
Percent Change	Hartford	Houma, LA	Houston	Huntington, WV	Lake Charles, LA	Louisville	Macon, GA	Memphis
1996 vs 2007 Base	-9.0%	-2.7%	-5.5%	-11.7%	-2.3%	-13.4%	-23.7%	-5.6%
2007 Base vs 2020 Base	-2.9%	-2.1%	-0.6%	-0.7%	-3.1%	-0.7%	-4.5%	-4.6%
2020 Base vs 2020 Control	-4.2%	-1.4%	-1.3%	-2.0%	-0.8%	-0.7%	-6.3%	-2.8%
2020 Base vs 2030 Base	3.0%	2.1%	2.6%	2.0%	2.4%	2.0%	2.4%	2.8%
2030 Base vs 2030 Control	-5.3%	-2.1%	-1.3%	-2.0%	-1.6%	0.7%	-8.5%	-4.1%
1996 vs 2030 Control	-13.8%	-4.8%	-4.8%	-12.3%	-4.5%	-11.6%	-31.8%	-11.2%

APPENDIX C
1-Hour Ozone Metics
Peak Ozone

Peak 1-Hour Ozone (ppb)	Milwaukee	Nashville	New London, CT	New Orleans	New York City	Norfolk	Orlando	Pensacola
1996 Base	148	166	180	165	192	146	145	139
2007 Base	130	154	159	160	178	127	138	127
2020 Base	125	149	152	157	175	126	132	121
2020 Control	125	142	145	156	168	123	125	115
2030 Base	130	154	157	160	180	130	137	124
2030 Control	128	145	148	158	171	126	127	116
Percent Change	Milwaukee	Nashville	New London, CT	New Orleans	New York City	Norfolk	Orlando	Pensacola
1996 vs 2007 Base	-12.2%	-7.2%	-11.7%	-3.0%	-7.3%	-13.0%	-4.8%	-8.6%
2007 Base vs 2020 Base	-3.8%	-3.2%	-4.4%	-1.9%	-1.7%	-0.8%	-4.3%	-4.7%
2020 Base vs 2020 Control	0.0%	-4.7%	-4.6%	-0.6%	-4.0%	-2.4%	-5.3%	-5.0%
2020 Base vs 2030 Base	4.0%	3.4%	3.3%	1.9%	2.9%	3.2%	3.8%	2.5%
2030 Base vs 2030 Control	-1.5%	-5.8%	-5.7%	-1.2%	-5.0%	-3.1%	-7.3%	-6.5%
1996 vs 2030 Control	-13.5%	-12.7%	-17.8%	-4.2%	-10.9%	-13.7%	-12.4%	-16.5%

APPENDIX C
1-Hour Ozone Metics
Peak Ozone

Peak 1-Hour Ozone (ppb)	Philadelphia	Providence	Richmond	St. Louis	Tampa	Wash-Baltimore
1996 Base	166	173	170	151	188	172
2007 Base	142	149	150	141	173	154
2020 Base	135	141	141	136	161	150
2020 Control	127	134	137	128	150	143
2030 Base	139	146	145	140	166	154
2030 Control	129	136	139	129	152	145
Percent Change	Philadelphia	Providence	Richmond	St. Louis	Tampa	Wash-Baltimore
1996 vs 2007 Base	-14.5%	-13.9%	-11.8%	-6.6%	-8.0%	-10.5%
2007 Base vs 2020 Base	-4.9%	-5.4%	-6.0%	-3.5%	-6.9%	-2.6%
2020 Base vs 2020 Control	-5.9%	-5.0%	-2.8%	-5.9%	-6.8%	-4.7%
2020 Base vs 2030 Base	3.0%	3.5%	2.8%	2.9%	3.1%	2.7%
2030 Base vs 2030 Control	-7.2%	-6.8%	-4.1%	-7.9%	-8.4%	-5.8%
1996 vs 2030 Control	-22.3%	-21.4%	-18.2%	-14.6%	-19.1%	-15.7%

APPENDIX C
1-Hour Ozone Metrics
Total Nonattainment

Total Nonattainment	Total	Atlanta	Barnstable, MA	Baton Rouge	Beaumont	Benton Harbor, MI	Biloxi	Birmingham
(ppb >= 125)								
1996 Base	39665.2	7738.3	192.8	1176.9	111.1	205.6	191.9	534.2
2007 Base	12743.4	2604.9	11.6	687.4	49.5	65.5	81.6	36.7
2020 Base	8334.2	1319.4	0	389.8	7.8	45.4	28.5	10.7
2020 Control	5288.3	546.6	0	257.9	4	36.1	13.8	2
2030 Base	12129.2	1945.1	3.7	635.4	24.4	61.1	59.8	17.5
2030 Control	6841.1	636.9	0	406	10.5	42.6	29.2	3.5
Percent Change	Total	Atlanta	Barnstable, MA	Baton Rouge	Beaumont	Benton Harbor, MI	Biloxi	Birmingham
1996 vs 2007 Base	-67.9%	-66.3%	-94.0%	-41.6%	-55.4%	-68.1%	-57.5%	-93.1%
2007 Base vs 2020 Base	-34.6%	-49.3%	-100.0%	-43.3%	-84.2%	-30.7%	-65.1%	-70.8%
2020 Base vs 2020 Control	-36.5%	-58.6%	0.0%	-33.8%	-48.7%	-20.5%	-51.6%	-81.3%
2020 Base vs 2030 Base	45.5%	47.4%	N.A.	63.0%	212.8%	34.6%	109.8%	63.6%
2030 Base vs 2030 Control	-43.6%	-67.3%	-100.0%	-36.1%	-57.0%	-30.3%	-51.2%	-80.0%
Note: N.A. denotes predicted exceedances in the 2030 Base, but not in the 2020 Base								

APPENDIX C
1-Hour Ozone Metrics
Total Nonattainment

Total Nonattainment (ppb >= 125)	Boston	Charleston, WV	Charlotte	Chicago	Cincinnati	Cleveland	Detroit	Grand Rapids
1996 Base	608.8	288.2	292	374.9	1025.1	191.9	294.7	1160.5
2007 Base	95.8	9.5	36.5	125.8	50.8	15.4	163.8	491.8
2020 Base	23.5	4.2	22.6	120	33.6	15.4	212.2	343.2
2020 Control	5.5	0.2	7.4	101	14.5	14.1	212	214.5
2030 Base	56.3	5.3	48.3	174.7	72.5	27.5	254.5	472.8
2030 Control	7.5	0	11.6	149.3	28.6	17.8	263.9	275.1
Percent Change	Boston	Charleston, WV	Charlotte	Chicago	Cincinnati	Cleveland	Detroit	Grand Rapids
1996 vs 2007 Base	-84.3%	-96.7%	-87.5%	-66.4%	-95.0%	-92.0%	-44.4%	-57.6%
2007 Base vs 2020 Base	-75.5%	-55.8%	-38.1%	-4.6%	-33.9%	0.0%	29.5%	-30.2%
2020 Base vs 2020 Control	-76.6%	-95.2%	-67.3%	-15.8%	-56.8%	-8.4%	-0.1%	-37.5%
2020 Base vs 2030 Base	139.6%	26.2%	113.7%	45.6%	115.8%	78.6%	19.9%	37.8%
2030 Base vs 2030 Control	-86.7%	-100.0%	-76.0%	-14.5%	-60.6%	-35.3%	3.7%	-41.8%
Note: N.A. denotes predicted exceedances in the 2030 Base, but not in the 2020 Base								

APPENDIX C
1-Hour Ozone Metrics
Total Nonattainment

Total Nonattainment (ppb >= 125)	Hartford	Houma, LA	Houston	Huntington, WV	Lake Charles, LA	Louisville	Macon, GA	Memphis
1996 Base	649.6	586.6	1597.5	1411.4	36.3	1437.1	491.8	284.1
2007 Base	346.7	288.2	640.5	71.7	12.7	267.3	7.6	89
2020 Base	303.5	165.3	437.4	52.7	0.8	277.3	1.6	72.5
2020 Control	219.6	119.5	325.8	36.1	0	229.6	0	47.7
2030 Base	377.9	285	663.2	68.9	8.5	347	4.7	100.5
2030 Control	263.9	182.8	441	44.5	2.3	272	0	63.8
Percent Change	Hartford	Houma, LA	Houston	Huntington, WV	Lake Charles, LA	Louisville	Macon, GA	Memphis
1996 vs 2007 Base	-46.6%	-50.9%	-59.9%	-94.9%	-65.0%	-81.4%	-98.5%	-68.7%
2007 Base vs 2020 Base	-12.5%	-42.6%	-31.7%	-26.5%	-93.7%	3.7%	-78.9%	-18.5%
2020 Base vs 2020 Control	-27.6%	-27.7%	-25.5%	-31.5%	-100.0%	-17.2%	-100.0%	-34.2%
2020 Base vs 2030 Base	24.5%	72.4%	51.6%	30.7%	962.4%	25.1%	193.7%	38.6%
2030 Base vs 2030 Control	-30.2%	-35.9%	-33.5%	-35.4%	-72.9%	-21.6%	-100.0%	-36.5%
Note: N.A. denotes predicted exceedances in the 2030 Base, but not in the 2020 Base								

APPENDIX C
1-Hour Ozone Metrics
Total Nonattainment

Total Nonattainment (ppb >= 125)	Milwaukee	Nashville	New London, CT	New Orleans	New York City	Norfolk	Orlando	Pensacola
1996 Base	69.4	1263.1	612.7	1857.5	5787.7	92.6	100.7	33.6
2007 Base	5.3	103.8	259.6	1108	2190.4	5.5	40.6	2.3
2020 Base	0.8	53	195.1	742.3	1870.2	1.3	11.6	0
2020 Control	0.1	30.4	113.9	581.2	1430.6	0	0.2	0
2030 Base	11.9	76.6	278.5	1130.3	2503.6	8.2	33	0
2030 Control	4.1	36.6	152.5	826.4	1778.2	1.2	2.4	0
Percent Change	Milwaukee	Nashville	New London, CT	New Orleans	New York City	Norfolk	Orlando	Pensacola
1996 vs 2007 Base	-92.4%	-91.8%	-57.6%	-40.3%	-62.2%	-94.1%	-59.7%	-93.2%
2007 Base vs 2020 Base	-84.9%	-48.9%	-24.8%	-33.0%	-14.6%	-76.4%	-71.4%	-100.0%
2020 Base vs 2020 Control	-87.5%	-42.6%	-41.6%	-21.7%	-23.5%	-100.0%	-98.3%	0.0%
2020 Base vs 2030 Base	1387.3%	44.5%	42.7%	52.3%	33.9%	530.7%	184.5%	0.0%
2030 Base vs 2030 Control	-65.5%	-52.2%	-45.2%	-26.9%	-29.0%	-85.4%	-92.7%	0.0%
Note: N.A. denotes predicted exceedances in the 2030 Base, but not in the 2020 Base								

APPENDIX C
1-Hour Ozone Metrics
Total Nonattainment

Total Nonattainment	Philadelphia	Providence	Richmond	St. Louis	Tampa	Wash-Baltimore
(ppb >= 125)						
1996 Base	1588.3	512.6	495.3	591.5	2396.9	3382
2007 Base	162.3	155.4	160.3	74.2	1380.4	845
2020 Base	68.7	79.4	85.3	32.9	803.8	502.4
2020 Control	10.5	29.2	33	4.9	402.2	244.2
2030 Base	150.9	133.6	121.1	61.5	1124.2	781.2
2030 Control	24.3	43.3	42.4	9.9	464.8	302.2
Percent Change	Philadelphia	Providence	Richmond	St. Louis	Tampa	Wash-Baltimore
1996 vs 2007 Base	-89.8%	-69.7%	-67.6%	-87.5%	-42.4%	-75.0%
2007 Base vs 2020 Base	-57.7%	-48.9%	-46.8%	-55.7%	-41.8%	-40.5%
2020 Base vs 2020 Control	-84.7%	-63.2%	-61.3%	-85.1%	-50.0%	-51.4%
2020 Base vs 2030 Base	119.7%	68.3%	42.0%	86.9%	39.9%	55.5%
2030 Base vs 2030 Control	-83.9%	-67.6%	-65.0%	-83.9%	-58.7%	-61.3%
Note: N.A. denotes predicted exceedances in the 2030 Base, but not in the 2020 Base						

APPENDIX C
1-Hour Metrics
Total ppb Reduction

Total ppb Reduction	Philadelphia	Providence	Richmond	St. Louis	Tampa	Wash-Baltimore
1996 Base vs 2007 Base	2431.8	504.5	537.3	1141	1311.1	3867.8
2020 Base vs 2020 Control	93.4	69.4	59	43.6	460.1	383.1
2030 Base vs Control	221.5	118.5	100.3	64.6	862.1	771.3
Reduction, on Average (ppb)	Philadelphia	Providence	Richmond	St. Louis	Tampa	Wash-Baltimore
1996 Base vs 2007 Base	19.6	15.8	17.9	16.8	10.2	17.8
2020 Base vs 2020 Control	6.2	6.9	6.6	7.3	8.1	7.4
2030 Base vs Control	7.9	8.5	9.1	9.2	11.1	10.3
Note: N.A. is used to denote that there are no exceedances in the Base Case or Control Case						

APPENDIX C
1-Hour Ozone Metrics
Total ppb Increase

Total ppb Increase	Philadelphia	Providence	Richmond	St. Louis	Tampa	Wash-Baltimore
1996 Base vs 2007 Base	0	0	0	0	1.2	0
2020 Base vs 2020 Control	0	0	0	0	0	0.1
2030 Base vs 2030 Control	0	0	0	0	0	12.2
Increase, on Average (ppb)	Philadelphia	Providence	Richmond	St. Louis	Tampa	Wash-Baltimore
1996 Base vs 2007 Base	0.0	0.0	0.0	0.0	0.0	0.0
2020 Base vs 2020 Control	0.0	0.0	0.0	0.0	0.0	0.0
2030 Base vs Control	0.0	0.0	0.0	0.0	0.0	0.2
Note: N.A. is used to denote that there are no exceedances in the Base Case or Control Case						

Appendix D:
8 Hour Relative Reduction Factors

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
010270001	AL	CLAY CO	CLAY CO, AL	0.8211	0.7747	0.7277	0.7953	0.7304
010510001	AL	ELMORE CO	MONTGOMERY, AL	0.8784	0.8301	0.7836	0.8546	0.7903
010731003	AL	JEFFERSON CO	BIRMINGHAM, AL	0.8765	0.8145	0.7594	0.8385	0.7623
010731005	AL	JEFFERSON CO	BIRMINGHAM, AL	0.8541	0.8001	0.7532	0.8208	0.7555
010732006	AL	JEFFERSON CO	BIRMINGHAM, AL	0.8734	0.8133	0.7592	0.8370	0.7621
010735002	AL	JEFFERSON CO	BIRMINGHAM, AL	0.8634	0.8103	0.7612	0.8354	0.7679
010736002	AL	JEFFERSON CO	BIRMINGHAM, AL	0.8728	0.8154	0.7625	0.8389	0.7662
010790002	AL	LAWRENCE CO	LAWRENCE CO, AL	0.8428	0.8010	0.7628	0.8224	0.7700
010890014	AL	MADISON CO	HUNTSVILLE, AL	0.8743	0.8272	0.7817	0.8493	0.7872
010970003	AL	MOBILE CO	MOBILE, AL	0.9107	0.8786	0.8464	0.9007	0.8566
010970028	AL	MOBILE CO	MOBILE, AL	0.9035	0.8711	0.8385	0.8932	0.8485
011011002	AL	MONTGOMERY CO	MONTGOMERY, AL	0.8835	0.8398	0.7936	0.8667	0.8033
011170004	AL	SHELBY CO	BIRMINGHAM, AL	0.8632	0.8069	0.7546	0.8300	0.7578
011190002	AL	SUMTER CO	SUMTER CO, AL	0.8460	0.8266	0.7986	0.8497	0.8113
050350005	AR	CRITTENDEN CO	MEMPHIS, TN-AR-MS	0.9027	0.8899	0.8720	0.9102	0.8857
050970001	AR	MONTGOMERY CO	MONTGOMERY CO, AR	0.8917	0.8432	0.8071	0.8614	0.8118
051010002	AR	NEWTON CO	NEWTON CO, AR	0.8744	0.8421	0.8164	0.8580	0.8224
051190007	AR	PULASKI CO	LITTLE ROCK-NORTH LITTLE ROCK, AR	0.9008	0.8425	0.7992	0.8674	0.8071
051191002	AR	PULASKI CO	LITTLE ROCK-NORTH LITTLE ROCK, AR	0.9008	0.8426	0.7994	0.8675	0.8072
090010017	CT	FAIRFIELD CO	NEW YORK CMSA	0.9458	0.9508	0.9392	0.9690	0.9550
090011123	CT	FAIRFIELD CO	NEW YORK CMSA	0.9323	0.9324	0.9135	0.9516	0.9288
090013007	CT	FAIRFIELD CO	NEW YORK CMSA	0.9329	0.9197	0.8958	0.9423	0.9115
090019003	CT	FAIRFIELD CO	NEW YORK CMSA	0.9396	0.9437	0.9311	0.9622	0.9474
090031003	CT	HARTFORD CO	HARTFORD, CT	0.9059	0.8735	0.8332	0.8978	0.8447
090050006	CT	LITCHFIELD CO	HARTFORD, CT	0.8993	0.8672	0.8306	0.8921	0.8437
090070007	CT	MIDDLESEX CO	HARTFORD, CT	0.9197	0.8974	0.8657	0.9226	0.8812
090091123	CT	NEW HAVEN CO	NEW YORK CMSA	0.9274	0.9148	0.8899	0.9376	0.9064
090093002	CT	NEW HAVEN CO	NEW YORK CMSA	0.9165	0.8956	0.8663	0.9210	0.8822
090110008	CT	NEW LONDON CO	NEW YORK CMSA	0.9130	0.8929	0.8612	0.9184	0.8771
090131001	CT	TOLLAND CO	HARTFORD, CT	0.8935	0.8528	0.8173	0.8767	0.8283
100010002	DE	KENT CO	PHILADELPHIA CMSA	0.8729	0.8377	0.7971	0.8595	0.8040
100031003	DE	NEW CASTLE CO	PHILADELPHIA CMSA	0.9003	0.8823	0.8509	0.9020	0.8596
100031007	DE	NEW CASTLE CO	PHILADELPHIA CMSA	0.8726	0.8441	0.8033	0.8667	0.8110
100031010	DE	NEW CASTLE CO	PHILADELPHIA CMSA	0.8933	0.8733	0.8418	0.8933	0.8504
100051002	DE	SUSSEX CO	SUSSEX CO, DE	0.8759	0.8388	0.7973	0.8622	0.8053
100051003	DE	SUSSEX CO	SUSSEX CO, DE	0.8809	0.8473	0.8111	0.8680	0.8184
110010025	DC	WASHINGTON	WASHINGTON, DC-MD-VA-WV	0.9282	0.9206	0.8933	0.9410	0.9070
110010041	DC	WASHINGTON	WASHINGTON, DC-MD-VA-WV	0.9022	0.8828	0.8562	0.9018	0.8685
110010043	DC	WASHINGTON	WASHINGTON, DC-MD-VA-WV	0.9282	0.9206	0.8933	0.9410	0.9070
120013011	FL	ALACHUA CO	GAINESVILLE, FL	0.8972	0.8472	0.7903	0.8736	0.7935
120030002	FL	BAKER CO	BAKER CO, FL	0.8909	0.8416	0.7923	0.8652	0.7965
120094001	FL	BREVARD CO	MELBOURNE-TITUSVILLE-PALM BAY, FL	0.9393	0.8850	0.8357	0.9145	0.8446
120095001	FL	BREVARD CO	MELBOURNE-TITUSVILLE-PALM BAY, FL	0.9407	0.8882	0.8409	0.9166	0.8499
120310070	FL	DUVAL CO	JACKSONVILLE, FL	0.9173	0.8499	0.7976	0.8761	0.8025

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
120310077	FL	DUVAL CO	JACKSONVILLE, FL	0.9117	0.8570	0.8100	0.8831	0.8177
120330004	FL	ESCAMBIA CO	PENSACOLA, FL	0.9224	0.8859	0.8480	0.9086	0.8564
120330018	FL	ESCAMBIA CO	PENSACOLA, FL	0.9223	0.8857	0.8486	0.9085	0.8573
120330024	FL	ESCAMBIA CO	PENSACOLA, FL	0.9223	0.8857	0.8486	0.9085	0.8573
120570081	FL	HILLSBOROUGH CO	TAMPA-ST. PETERSBURG-CLEARWA	0.9513	0.9105	0.8676	0.9390	0.8792
120571035	FL	HILLSBOROUGH CO	TAMPA-ST. PETERSBURG-CLEARWA	0.9524	0.9090	0.8621	0.9372	0.8720
120571065	FL	HILLSBOROUGH CO	TAMPA-ST. PETERSBURG-CLEARWA	0.9656	0.9336	0.8895	0.9630	0.9018
120590004	FL	HOLMES CO	HOLMES CO, FL	0.9059	0.8648	0.8232	0.8880	0.8303
120712001	FL	LEE CO	FORT MYERS-CAPE CORAL, FL	0.9655	0.9179	0.8719	0.9481	0.8822
120713002	FL	LEE CO	FORT MYERS-CAPE CORAL, FL	0.9644	0.9146	0.8664	0.9468	0.8780
120813002	FL	MANATEE CO	SARASOTA-BRADENTON, FL	0.9590	0.9292	0.8875	0.9609	0.9035
120814010	FL	MANATEE CO	SARASOTA-BRADENTON, FL	0.9496	0.9108	0.8641	0.9445	0.8803
120950008	FL	ORANGE CO	ORLANDO, FL	0.9370	0.8892	0.8341	0.9233	0.8482
120952002	FL	ORANGE CO	ORLANDO, FL	0.9368	0.8889	0.8330	0.9236	0.8477
120972002	FL	OSCEOLA CO	ORLANDO, FL	0.9328	0.8846	0.8330	0.9159	0.8433
120990007	FL	PALM BEACH CO	MIAMI CMSA	0.9260	0.8553	0.8086	0.8868	0.8212
120992004	FL	PALM BEACH CO	MIAMI CMSA	0.9237	0.8512	0.8009	0.8849	0.8146
121012001	FL	PASCO CO	TAMPA-ST. PETERSBURG-CLEARWA	0.9499	0.9020	0.8475	0.9320	0.8563
121030004	FL	PINELLAS CO	TAMPA-ST. PETERSBURG-CLEARWA	0.9688	0.9411	0.8979	0.9710	0.9111
121030018	FL	PINELLAS CO	TAMPA-ST. PETERSBURG-CLEARWA	0.9726	0.9505	0.9093	0.9808	0.9238
121035002	FL	PINELLAS CO	TAMPA-ST. PETERSBURG-CLEARWA	0.9548	0.9141	0.8642	0.9440	0.8747
121056005	FL	POLK CO	LAKELAND-WINTER HAVEN, FL	0.9370	0.8854	0.8374	0.9121	0.8447
121056006	FL	POLK CO	LAKELAND-WINTER HAVEN, FL	0.9411	0.8955	0.8491	0.9209	0.8558
121111002	FL	ST LUCIE CO	FORT PIERCE-PORT ST. LUCIE, FL	0.9516	0.9068	0.8640	0.9340	0.8733
121151002	FL	SARASOTA CO	SARASOTA-BRADENTON, FL	0.9459	0.9058	0.8600	0.9393	0.8759
121151005	FL	SARASOTA CO	SARASOTA-BRADENTON, FL	0.9459	0.9058	0.8600	0.9393	0.8759
121171002	FL	SEMINOLE CO	ORLANDO, FL	0.9297	0.8762	0.8184	0.9100	0.8299
121272001	FL	VOLUSIA CO	DAYTONA BEACH, FL	0.9150	0.8603	0.8061	0.8876	0.8115
121275002	FL	VOLUSIA CO	DAYTONA BEACH, FL	0.9108	0.8575	0.7999	0.8857	0.8048
130210012	GA	BIBB CO	MACON, GA	0.8144	0.7683	0.7188	0.7903	0.7222
130510021	GA	CHATHAM CO	SAVANNAH, GA	0.8960	0.8665	0.8282	0.8900	0.8375
130850001	GA	DAWSON CO	DAWSON CO, GA	0.8365	0.7706	0.7007	0.8022	0.7056
130890002	GA	DE KALB CO	ATLANTA, GA	0.8898	0.8497	0.7965	0.8784	0.8081
130893001	GA	DE KALB CO	ATLANTA, GA	0.9073	0.8728	0.8190	0.9018	0.8318
130970004	GA	DOUGLAS CO	ATLANTA, GA	0.8781	0.8232	0.7641	0.8551	0.7747
131110094	GA	FANNIN CO	FANNIN CO, GA	0.8221	0.7641	0.7038	0.7892	0.7057
131130001	GA	FAYETTE CO	ATLANTA, GA	0.8700	0.8117	0.7458	0.8443	0.7546
131210055	GA	FULTON CO	ATLANTA, GA	0.8992	0.8626	0.8075	0.8925	0.8200
131350002	GA	GWINNETT CO	ATLANTA, GA	0.8766	0.8119	0.7360	0.8458	0.7433
132150008	GA	MUSCOGEE CO	COLUMBUS, GA-AL	0.8694	0.8047	0.7473	0.8313	0.7526
132151003	GA	MUSCOGEE CO	COLUMBUS, GA-AL	0.8694	0.8047	0.7473	0.8313	0.7526
132230003	GA	PAULDING CO	ATLANTA, GA	0.8432	0.7945	0.7399	0.8206	0.7458
132450091	GA	RICHMOND CO	AUGUSTA-AIKEN, GA-SC	0.8531	0.7869	0.7367	0.8149	0.7458
132470001	GA	ROCKDALE CO	ATLANTA, GA	0.8660	0.8018	0.7275	0.8328	0.7310

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
132611001	GA	SUMTER CO	SUMTER CO, GA	0.8616	0.8145	0.7635	0.8383	0.7680
170010006	IL	ADAMS CO	ADAMS CO, IL	0.8903	0.8575	0.8329	0.8745	0.8405
170190004	IL	CHAMPAIGN CO	CHAMPAIGN-URBANA, IL	0.8658	0.8318	0.8023	0.8511	0.8105
170310001	IL	COOK CO	CHICAGO CMSA	0.9265	0.9462	0.9537	0.9610	0.9730
170310032	IL	COOK CO	CHICAGO CMSA	0.9111	0.9071	0.8958	0.9240	0.9094
170310050	IL	COOK CO	CHICAGO CMSA	0.9111	0.9071	0.8958	0.9240	0.9094
170310063	IL	COOK CO	CHICAGO CMSA	0.9163	0.9165	0.9087	0.9325	0.9226
170310064	IL	COOK CO	CHICAGO CMSA	0.9163	0.9165	0.9087	0.9325	0.9226
170310072	IL	COOK CO	CHICAGO CMSA	0.9363	0.9444	0.9451	0.9592	0.9607
170311003	IL	COOK CO	CHICAGO CMSA	0.9022	0.8897	0.8963	0.9046	0.9124
170311601	IL	COOK CO	CHICAGO CMSA	0.9292	0.9254	0.9183	0.9422	0.9333
170314002	IL	COOK CO	CHICAGO CMSA	0.9114	0.8994	0.8883	0.9166	0.9020
170314006	IL	COOK CO	CHICAGO CMSA	0.9310	0.9423	0.9612	0.9534	0.9811
170314201	IL	COOK CO	CHICAGO CMSA	0.9171	0.9268	0.9302	0.9408	0.9472
170317002	IL	COOK CO	CHICAGO CMSA	0.9171	0.9268	0.9302	0.9408	0.9472
170318003	IL	COOK CO	CHICAGO CMSA	0.9030	0.9094	0.9014	0.9257	0.9158
170436001	IL	DU PAGE CO	CHICAGO CMSA	0.9390	0.9441	0.9391	0.9594	0.9559
170491001	IL	EFFINGHAM CO	EFFINGHAM CO, IL	0.8431	0.8059	0.7762	0.8240	0.7828
170650001	IL	HAMILTON CO	HAMILTON CO, IL	0.8280	0.7748	0.7501	0.7887	0.7545
170831001	IL	JERSEY CO	ST. LOUIS, MO-IL	0.8936	0.8451	0.8014	0.8713	0.8117
170890005	IL	KANE CO	CHICAGO CMSA	0.9417	0.9441	0.9427	0.9619	0.9624
170970001	IL	LAKE CO	CHICAGO CMSA	0.9193	0.9200	0.9314	0.9339	0.9508
170971002	IL	LAKE CO	CHICAGO CMSA	0.9168	0.9044	0.8904	0.9237	0.9067
170971007	IL	LAKE CO	CHICAGO CMSA	0.9250	0.9226	0.9149	0.9417	0.9327
170973001	IL	LAKE CO	CHICAGO CMSA	0.9165	0.9100	0.9014	0.9282	0.9181
171110001	IL	MC HENRY CO	CHICAGO CMSA	0.9389	0.9404	0.9368	0.9591	0.9563
171150013	IL	MACON CO	DECATUR, IL	0.8580	0.8280	0.8011	0.8471	0.8097
171170002	IL	MACOUPIN CO	ST. LOUIS, MO-IL	0.8536	0.8140	0.7763	0.8390	0.7869
171190008	IL	MADISON CO	ST. LOUIS, MO-IL	0.8922	0.8501	0.8123	0.8732	0.8213
171191009	IL	MADISON CO	ST. LOUIS, MO-IL	0.8929	0.8521	0.8126	0.8745	0.8205
171192007	IL	MADISON CO	ST. LOUIS, MO-IL	0.8992	0.8570	0.8177	0.8809	0.8281
171193007	IL	MADISON CO	ST. LOUIS, MO-IL	0.8992	0.8570	0.8177	0.8809	0.8281
171430024	IL	PEORIA CO	PEORIA-PEKIN, IL	0.9056	0.8803	0.8570	0.8970	0.8653
171431001	IL	PEORIA CO	PEORIA-PEKIN, IL	0.9056	0.8803	0.8570	0.8970	0.8653
171570001	IL	RANDOLPH CO	RANDOLPH CO, IL	0.8538	0.8230	0.7939	0.8400	0.7996
171610003	IL	ROCK ISLAND CO	DAVENPORT-MOLINE-ROCK ISLAND,	0.9264	0.8983	0.8772	0.9163	0.8876
171630010	IL	ST CLAIR CO	ST. LOUIS, MO-IL	0.9078	0.8693	0.8298	0.8919	0.8381
171670010	IL	SANGAMON CO	SPRINGFIELD, IL	0.8632	0.8297	0.7961	0.8509	0.8046
171971008	IL	WILL CO	CHICAGO CMSA	0.9281	0.9268	0.9139	0.9449	0.9288
171971011	IL	WILL CO	CHICAGO CMSA	0.8908	0.8722	0.8503	0.8903	0.8611
172010009	IL	WINNEBAGO CO	ROCKFORD, IL	0.9129	0.8875	0.8604	0.9095	0.8728
172012001	IL	WINNEBAGO CO	ROCKFORD, IL	0.9059	0.8783	0.8497	0.9005	0.8620
180030002	IN	ALLEN CO	FORT WAYNE, IN	0.8919	0.8557	0.8268	0.8750	0.8349
180030004	IN	ALLEN CO	FORT WAYNE, IN	0.8954	0.8602	0.8306	0.8797	0.8389

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
180190003	IN	CLARK CO	LOUISVILLE, KY-IN	0.8857	0.8729	0.8538	0.8892	0.8638
180390002	IN	ELKHART CO	ELKHART-GOSHEN, IN	0.8810	0.8471	0.8189	0.8655	0.8266
180431004	IN	FLOYD CO	LOUISVILLE, KY-IN	0.8914	0.8859	0.8731	0.9022	0.8858
180571001	IN	HAMILTON CO	INDIANAPOLIS, IN	0.8918	0.8620	0.8332	0.8819	0.8428
180590003	IN	HANCOCK CO	INDIANAPOLIS, IN	0.8899	0.8621	0.8342	0.8812	0.8436
180810002	IN	JOHNSON CO	INDIANAPOLIS, IN	0.8542	0.8227	0.7932	0.8402	0.7997
180890022	IN	LAKE CO	CHICAGO CMSA	0.9042	0.8940	0.8778	0.9115	0.8902
180890024	IN	LAKE CO	CHICAGO CMSA	0.8893	0.8669	0.8434	0.8841	0.8521
180892008	IN	LAKE CO	CHICAGO CMSA	0.9049	0.9015	0.8881	0.9191	0.9018
180910005	IN	LA PORTE CO	LA PORTE CO, IN	0.9180	0.9026	0.8855	0.9207	0.8974
180910010	IN	LA PORTE CO	LA PORTE CO, IN	0.9104	0.8892	0.8677	0.9070	0.8781
180950010	IN	MADISON CO	INDIANAPOLIS, IN	0.8833	0.8466	0.8144	0.8673	0.8229
180970042	IN	MARION CO	INDIANAPOLIS, IN	0.8865	0.8648	0.8411	0.8825	0.8501
180970050	IN	MARION CO	INDIANAPOLIS, IN	0.8960	0.8802	0.8603	0.8982	0.8716
180970057	IN	MARION CO	INDIANAPOLIS, IN	0.9062	0.9035	0.8873	0.9202	0.8992
180970073	IN	MARION CO	INDIANAPOLIS, IN	0.8960	0.8802	0.8603	0.8982	0.8716
181090005	IN	MORGAN CO	INDIANAPOLIS, IN	0.8688	0.8431	0.8181	0.8602	0.8260
181230008	IN	PERRY CO	PERRY CO, IN	0.8203	0.8058	0.7842	0.8189	0.7889
181270020	IN	PORTER CO	CHICAGO CMSA	0.9161	0.9077	0.8943	0.9251	0.9069
181270024	IN	PORTER CO	CHICAGO CMSA	0.9042	0.8940	0.8778	0.9115	0.8902
181270026	IN	PORTER CO	CHICAGO CMSA	0.9246	0.9113	0.8938	0.9281	0.9045
181290003	IN	POSEY CO	EVANSVILLE-HENDERSON, IN-KY	0.8773	0.8506	0.8325	0.8659	0.8408
181410010	IN	ST JOSEPH CO	SOUTH BEND, IN	0.8853	0.8547	0.8278	0.8725	0.8358
181411007	IN	ST JOSEPH CO	SOUTH BEND, IN	0.8889	0.8620	0.8368	0.8796	0.8450
181411008	IN	ST JOSEPH CO	SOUTH BEND, IN	0.8889	0.8622	0.8377	0.8801	0.8467
181630012	IN	VAN DERBURGH CO	EVANSVILLE-HENDERSON, IN-KY	0.8800	0.8529	0.8311	0.8685	0.8382
181630013	IN	VAN DERBURGH CO	EVANSVILLE-HENDERSON, IN-KY	0.8633	0.8364	0.8140	0.8511	0.8201
181670018	IN	VIGO CO	TERRE HAUTE, IN	0.8695	0.8393	0.8134	0.8550	0.8191
181730002	IN	WARRICK CO	EVANSVILLE-HENDERSON, IN-KY	0.8336	0.8140	0.7921	0.8275	0.7969
181730008	IN	WARRICK CO	EVANSVILLE-HENDERSON, IN-KY	0.8315	0.8109	0.7887	0.8243	0.7935
181730009	IN	WARRICK CO	EVANSVILLE-HENDERSON, IN-KY	0.8424	0.8188	0.7962	0.8329	0.8015
190851101	IA	HARRISON CO	HARRISON CO, IA	0.9155	0.8819	0.8590	0.8980	0.8662
191130033	IA	LINN CO	CEDAR RAPIDS, IA	0.9185	0.8886	0.8653	0.9069	0.8749
191131015	IA	LINN CO	CEDAR RAPIDS, IA	0.9183	0.8919	0.8703	0.9108	0.8814
191530058	IA	POLK CO	DES MOINES, IA	0.9051	0.8646	0.8360	0.8839	0.8445
191632011	IA	SCOTT CO	DAVENPORT-MOLINE-ROCK ISLAND,	0.9283	0.9011	0.8792	0.9194	0.8892
191690011	IA	STORY CO	STORY CO, IA	0.9052	0.8657	0.8377	0.8847	0.8460
191770004	IA	VAN BUREN CO	VAN BUREN CO, IA	0.9032	0.8725	0.8489	0.8899	0.8572
191810022	IA	WARREN CO	DES MOINES, IA	0.8980	0.8596	0.8316	0.8784	0.8398
201730001	KS	SEDGWICK CO	WICHITA, KS	0.9406	0.8963	0.8669	0.9157	0.8752
201730010	KS	SEDGWICK CO	WICHITA, KS	0.9408	0.8966	0.8673	0.9159	0.8756
202090001	KS	WYANDOTTE CO	KANSAS CITY, MO-KS	0.9366	0.9083	0.8848	0.9264	0.8943
210130002	KY	BELL CO	BELL CO, KY	0.7997	0.7395	0.6929	0.7561	0.6914
210150003	KY	BOONE CO	CINCINNATI CMSA	0.8478	0.8205	0.7965	0.8383	0.8055

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
210190015	KY	BOYD CO	HUNTINGTON-ASHLAND, WV-KY-OH	0.8522	0.8276	0.8033	0.8430	0.8104
210290006	KY	BULLITT CO	LOUISVILLE, KY-IN	0.8603	0.8479	0.8287	0.8632	0.8365
210371001	KY	CAMPBELL CO	CINCINNATI CMSA	0.8988	0.8804	0.8628	0.9005	0.8776
210430500	KY	CARTER CO	HUNTINGTON-ASHLAND, WV-KY-OH	0.8055	0.7818	0.7572	0.7953	0.7619
210470006	KY	CHRISTIAN CO	CHRISTIAN CO, KY	0.7743	0.7452	0.7214	0.7578	0.7250
210590005	KY	DAVISS CO	OWENSBORO, KY	0.8295	0.8131	0.7919	0.8260	0.7965
210610501	KY	EDMONSON CO	EDMONSON CO, KY	0.7963	0.7700	0.7441	0.7839	0.7481
210670001	KY	FAYETTE CO	LEXINGTON, KY	0.8567	0.8365	0.8094	0.8559	0.8189
210670012	KY	FAYETTE CO	LEXINGTON, KY	0.8702	0.8477	0.8192	0.8685	0.8297
210830003	KY	GRAVES CO	GRAVES CO, KY	0.8414	0.7950	0.7699	0.8097	0.7753
210890007	KY	GREENUP CO	HUNTINGTON-ASHLAND, WV-KY-OH	0.8454	0.8238	0.8015	0.8377	0.8076
210910012	KY	HANCOCK CO	OWENSBORO, KY	0.8107	0.7966	0.7752	0.8099	0.7802
210930005	KY	HARDIN CO	HARDIN CO, KY	0.8262	0.8077	0.7844	0.8221	0.7901
211010013	KY	HENDERSON CO	EVANSVILLE-HENDERSON, IN-KY	0.8737	0.8523	0.8319	0.8667	0.8385
211010014	KY	HENDERSON CO	EVANSVILLE-HENDERSON, IN-KY	0.8559	0.8375	0.8179	0.8510	0.8239
211110027	KY	JEFFERSON CO	LOUISVILLE, KY-IN	0.8918	0.8929	0.8832	0.9105	0.8979
211110051	KY	JEFFERSON CO	LOUISVILLE, KY-IN	0.8929	0.8866	0.8713	0.9024	0.8812
211111021	KY	JEFFERSON CO	LOUISVILLE, KY-IN	0.8946	0.8846	0.8703	0.9019	0.8833
211130001	KY	JESSAMINE CO	LEXINGTON, KY	0.8684	0.8485	0.8198	0.8700	0.8314
211170007	KY	KENTON CO	CINCINNATI CMSA	0.8940	0.8787	0.8611	0.8987	0.8758
211390003	KY	LIVINGSTON CO	LIVINGSTON CO, KY	0.8319	0.7814	0.7572	0.7960	0.7626
211390004	KY	LIVINGSTON CO	LIVINGSTON CO, KY	0.8306	0.7834	0.7592	0.7980	0.7646
211451024	KY	MC CRACKEN CO	MC CRACKEN CO, KY	0.8341	0.7802	0.7566	0.7948	0.7624
211490001	KY	MC LEAN CO	MC LEAN CO, KY	0.8412	0.8261	0.8045	0.8386	0.8087
211850004	KY	OLDHAM CO	LOUISVILLE, KY-IN	0.8678	0.8494	0.8296	0.8658	0.8384
211930002	KY	PERRY CO	PERRY CO, KY	0.7778	0.7387	0.7039	0.7513	0.7034
211950002	KY	PIKE CO	PIKE CO, KY	0.7805	0.7392	0.6984	0.7529	0.6966
211990003	KY	PULASKI CO	PULASKI CO, KY	0.8096	0.7977	0.7643	0.8118	0.7657
212090001	KY	SCOTT CO	LEXINGTON, KY	0.8302	0.8027	0.7734	0.8203	0.7799
212130004	KY	SIMPSON CO	SIMPSON CO, KY	0.8091	0.7747	0.7456	0.7906	0.7504
220050004	LA	ASCENSION PAR	BATON ROUGE, LA	0.9647	0.9364	0.9171	0.9597	0.9343
220110002	LA	BEAUREGARD PAR	LAKE CHARLES, LA	0.9552	0.9230	0.9023	0.9435	0.9155
220150008	LA	BOSSIER PAR	SHREVEPORT-BOSSIER CITY, LA	0.9307	0.8880	0.8550	0.9075	0.8630
220170001	LA	CADDO PAR	SHREVEPORT-BOSSIER CITY, LA	0.9329	0.8899	0.8587	0.9081	0.8661
220190002	LA	CALCASIEU PAR	LAKE CHARLES, LA	0.9680	0.9377	0.9220	0.9585	0.9376
220190008	LA	CALCASIEU PAR	LAKE CHARLES, LA	0.9638	0.9348	0.9175	0.9563	0.9338
220190009	LA	CALCASIEU PAR	LAKE CHARLES, LA	0.9708	0.9369	0.9212	0.9577	0.9367
220330003	LA	EAST BATON ROUGE PAR	BATON ROUGE, LA	0.9565	0.9173	0.8938	0.9401	0.9092
220330009	LA	EAST BATON ROUGE PAR	BATON ROUGE, LA	0.9513	0.9077	0.8809	0.9308	0.8956
220330013	LA	EAST BATON ROUGE PAR	BATON ROUGE, LA	0.9471	0.9013	0.8727	0.9232	0.8853
220331001	LA	EAST BATON ROUGE PAR	BATON ROUGE, LA	0.9472	0.9007	0.8713	0.9238	0.8852
220430001	LA	GRANT PAR	ALEXANDRIA, LA	0.9443	0.8978	0.8695	0.9171	0.8789
220470002	LA	IBERVILLE PAR	BATON ROUGE, LA	0.9663	0.9395	0.9230	0.9606	0.9388
220470007	LA	IBERVILLE PAR	BATON ROUGE, LA	0.9565	0.9166	0.8932	0.9395	0.9086

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
220470009	LA	IBERVILLE PAR	BATON ROUGE, LA	0.9659	0.9372	0.9208	0.9581	0.9363
220511001	LA	JEFFERSON PAR	NEW ORLEANS, LA	0.9510	0.9279	0.9107	0.9451	0.9226
220550005	LA	LAFAYETTE PAR	LAFAYETTE, LA	0.9468	0.9061	0.8814	0.9259	0.8927
220570002	LA	LAFOURCHE PAR	HOUMA, LA	0.9616	0.9382	0.9211	0.9596	0.9369
220630002	LA	LIVINGSTON PAR	BATON ROUGE, LA	0.9626	0.9369	0.9185	0.9599	0.9353
220710012	LA	ORLEANS PAR	NEW ORLEANS, LA	0.9469	0.9409	0.9303	0.9527	0.9390
220730004	LA	OUACHITA PAR	MONROE, LA	0.9421	0.9137	0.8900	0.9323	0.8995
220770001	LA	POINTE COUPEE PAR	BATON ROUGE, LA	0.9466	0.9007	0.8719	0.9226	0.8845
220870002	LA	ST BERNARD PAR	NEW ORLEANS, LA	0.9534	0.9396	0.9260	0.9551	0.9371
220890003	LA	ST CHARLES PAR	NEW ORLEANS, LA	0.9529	0.9464	0.9343	0.9620	0.9464
220930002	LA	ST JAMES PAR	BATON ROUGE, LA	0.9629	0.9394	0.9221	0.9613	0.9385
220950002	LA	ST JOHN THE BAPTIST PAR	NEW ORLEANS, LA	0.9592	0.9392	0.9224	0.9593	0.9374
221010003	LA	ST MARY PAR	ST MARY PAR, LA	0.9656	0.9448	0.9307	0.9633	0.9445
221210001	LA	WEST BATON ROUGE PAR	BATON ROUGE, LA	0.9513	0.9077	0.8809	0.9308	0.8956
230052003	ME	CUMBERLAND CO	PORTLAND, ME	0.9038	0.8662	0.8281	0.8915	0.8399
230090102	ME	HANCOCK CO	HANCOCK CO, ME	0.8928	0.8448	0.8011	0.8716	0.8123
230090103	ME	HANCOCK CO	HANCOCK CO, ME	0.8928	0.8448	0.8011	0.8716	0.8123
230112005	ME	KENNEBEC CO	LEWISTON-AUBURN, ME	0.8970	0.8492	0.8076	0.8755	0.8188
230130004	ME	KNOX CO	KNOX CO, ME	0.8984	0.8576	0.8163	0.8834	0.8276
230173001	ME	OXFORD CO	OXFORD CO, ME	0.9190	0.8980	0.8651	0.9207	0.8774
230194008	ME	PENOBSCOT CO	PENOBSCOT CO, ME	0.8873	0.8379	0.7965	0.8641	0.8075
230230003	ME	SAGADAHOC CO	SAGADAHOC CO, ME	0.9005	0.8652	0.8251	0.8901	0.8366
230312002	ME	YORK CO	PORTLAND, ME	0.9030	0.8690	0.8299	0.8934	0.8414
230313002	ME	YORK CO	PORTLAND, ME	0.9128	0.8793	0.8453	0.9020	0.8566
240030014	MD	ANNE ARUNDEL CO	BALTIMORE, MD	0.8853	0.8518	0.8089	0.8764	0.8185
240030019	MD	ANNE ARUNDEL CO	BALTIMORE, MD	0.9012	0.8707	0.8293	0.8953	0.8407
240051007	MD	BALTIMORE CO	BALTIMORE, MD	0.9071	0.8816	0.8468	0.9040	0.8575
240053001	MD	BALTIMORE CO	BALTIMORE, MD	0.9162	0.8985	0.8667	0.9188	0.8779
240090010	MD	CALVERT CO	WASHINGTON, DC-MD-VA-WV	0.8663	0.8252	0.7814	0.8483	0.7883
240130001	MD	CARROLL CO	BALTIMORE, MD	0.8873	0.8569	0.8147	0.8802	0.8249
240150003	MD	CECIL CO	PHILADELPHIA CMSA	0.8783	0.8488	0.8060	0.8726	0.8141
240170010	MD	CHARLES CO	WASHINGTON, DC-MD-VA-WV	0.8614	0.8171	0.7689	0.8403	0.7746
240210037	MD	FREDERICK CO	WASHINGTON, DC-MD-VA-WV	0.8822	0.8488	0.8061	0.8731	0.8160
240251001	MD	HARFORD CO	BALTIMORE, MD	0.9129	0.8885	0.8543	0.9099	0.8642
240259001	MD	HARFORD CO	BALTIMORE, MD	0.9021	0.8734	0.8321	0.8974	0.8413
240290002	MD	KENT CO	PHILADELPHIA CMSA	0.8826	0.8576	0.8199	0.8795	0.8282
240313001	MD	MONTGOMERY CO	WASHINGTON, DC-MD-VA-WV	0.9097	0.8907	0.8535	0.9149	0.8671
240330002	MD	PRINCE GEORGES CO	WASHINGTON, DC-MD-VA-WV	0.9012	0.8707	0.8293	0.8953	0.8407
240338001	MD	PRINCE GEORGES CO	WASHINGTON, DC-MD-VA-WV	0.8922	0.8731	0.8464	0.8909	0.8562
245100051	MD	BALTIMORE	BALTIMORE, MD	0.9084	0.8903	0.8602	0.9110	0.8723
250010002	MA	BARNSTABLE CO	BOSTON CMSA	0.9026	0.8622	0.8214	0.8884	0.8337
250051002	MA	BRISTOL CO	BOSTON CMSA	0.8972	0.8662	0.8283	0.8941	0.8434
250051005	MA	BRISTOL CO	BOSTON CMSA	0.8983	0.8530	0.8097	0.8787	0.8205
250090005	MA	ESSEX CO	BOSTON CMSA	0.9128	0.8863	0.8592	0.9069	0.8694

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
250092006	MA	ESSEX CO	BOSTON CMSA	0.9226	0.8943	0.8622	0.9145	0.8726
250094004	MA	ESSEX CO	BOSTON CMSA	0.9180	0.8802	0.8451	0.9041	0.8572
250130003	MA	HAMPDEN CO	SPRINGFIELD, MA	0.9100	0.8820	0.8491	0.9062	0.8625
250130008	MA	HAMPDEN CO	SPRINGFIELD, MA	0.9120	0.8863	0.8577	0.9080	0.8710
250150103	MA	HAMPSHIRE CO	SPRINGFIELD, MA	0.9275	0.8991	0.8706	0.9228	0.8835
250154002	MA	HAMPSHIRE CO	SPRINGFIELD, MA	0.9262	0.9033	0.8739	0.9248	0.8868
250171102	MA	MIDDLESEX CO	BOSTON CMSA	0.9067	0.8780	0.8453	0.8969	0.8549
250171801	MA	MIDDLESEX CO	BOSTON CMSA	0.9067	0.8780	0.8453	0.8969	0.8549
250174003	MA	MIDDLESEX CO	BOSTON CMSA	0.9148	0.8875	0.8553	0.9048	0.8638
250251003	MA	SUFFOLK CO	BOSTON CMSA	0.9068	0.8725	0.8409	0.8922	0.8493
250270015	MA	WORCESTER CO	WORCESTER, MA-CT	0.9021	0.8649	0.8264	0.8880	0.8368
260050003	MI	ALLEGAN CO	ALLEGAN CO, MI	0.9196	0.9023	0.8821	0.9230	0.8968
260190003	MI	BENZIE CO	BENZIE CO, MI	0.9080	0.8779	0.8466	0.8991	0.8570
260210014	MI	BERRIEN CO	BENTON HARBOR, MI	0.9019	0.8740	0.8461	0.8953	0.8573
260270003	MI	CASS CO	CASS CO, MI	0.8844	0.8528	0.8233	0.8721	0.8317
260370001	MI	CLINTON CO	LANSING-EAST LANSING, MI	0.9092	0.8804	0.8507	0.9012	0.8609
260490021	MI	GENESEE CO	FLINT, MI	0.9051	0.8759	0.8456	0.8961	0.8551
260492001	MI	GENESEE CO	FLINT, MI	0.9016	0.8679	0.8396	0.8875	0.8495
260630007	MI	HURON CO	HURON CO, MI	0.9174	0.8978	0.8757	0.9164	0.8869
260650012	MI	INGHAM CO	LANSING-EAST LANSING, MI	0.9003	0.8736	0.8474	0.8933	0.8578
260770008	MI	KALAMAZOO CO	KALAMAZOO-BATTLE CREEK, MI	0.8917	0.8612	0.8309	0.8813	0.8401
260810020	MI	KENT CO	GRAND RAPIDS-MUSKEGON-HOLLAND	0.9041	0.8781	0.8515	0.8989	0.8632
260812001	MI	KENT CO	GRAND RAPIDS-MUSKEGON-HOLLAND	0.9040	0.8726	0.8422	0.8941	0.8525
260910007	MI	LENAWEE CO	LENAWEE CO, MI	0.9115	0.8825	0.8553	0.9020	0.8653
260990009	MI	MACOMB CO	DETROIT CMSA	0.9387	0.9447	0.9392	0.9606	0.9546
260991003	MI	MACOMB CO	DETROIT CMSA	0.9480	0.9580	0.9656	0.9723	0.9811
261050007	MI	MASON CO	MASON CO, MI	0.9074	0.8823	0.8545	0.9044	0.8668
261130001	MI	MISSAUKEE CO	MISSAUKEE CO, MI	0.8944	0.8593	0.8296	0.8783	0.8375
261210039	MI	MUSKEGON CO	GRAND RAPIDS-MUSKEGON-HOLLAND	0.9185	0.8984	0.8783	0.9183	0.8910
261250001	MI	OAKLAND CO	DETROIT CMSA	0.9391	0.9641	0.9823	0.9757	0.9997
261390005	MI	OTTAWA CO	GRAND RAPIDS-MUSKEGON-HOLLAND	0.9123	0.8891	0.8652	0.9097	0.8783
261470005	MI	ST CLAIR CO	DETROIT CMSA	0.9197	0.9061	0.8849	0.9263	0.8990
261610007	MI	WASHTENAW CO	DETROIT CMSA	0.9230	0.9048	0.8839	0.9229	0.8958
261630001	MI	WAYNE CO	DETROIT CMSA	0.9292	0.9227	0.9282	0.9414	0.9448
261630016	MI	WAYNE CO	DETROIT CMSA	0.9305	0.9388	0.9479	0.9508	0.9634
261630019	MI	WAYNE CO	DETROIT CMSA	0.9305	0.9388	0.9479	0.9508	0.9634
270031001	MN	ANOKA CO	MINNEAPOLIS-ST. PAUL, MN-WI	0.9440	0.9090	0.8822	0.9305	0.8950
270031002	MN	ANOKA CO	MINNEAPOLIS-ST. PAUL, MN-WI	0.9324	0.9258	0.9167	0.9378	0.9272
270376018	MN	DAKOTA CO	MINNEAPOLIS-ST. PAUL, MN-WI	0.9254	0.9074	0.8926	0.9208	0.9018
280010004	MS	ADAMS CO	ADAMS CO, MS	0.9361	0.8952	0.8702	0.9171	0.8831
280330002	MS	DE SOTO CO	MEMPHIS, TN-AR-MS	0.8943	0.8534	0.8233	0.8739	0.8326
280450001	MS	HANCOCK CO	BILOXI-GULFPORT-PASCAGOULA, MS	0.9546	0.9149	0.8908	0.9320	0.8995
280490010	MS	HINDS CO	JACKSON, MS	0.9069	0.8556	0.8124	0.8782	0.8193
280590006	MS	JACKSON CO	BILOXI-GULFPORT-PASCAGOULA, MS	0.9427	0.9226	0.8978	0.9436	0.9098

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
280750003	MS	LAUDERDALE CO	LAUDERDALE CO, MS	0.8624	0.8265	0.7837	0.8480	0.7896
280810005	MS	LEE CO	LEE CO, MS	0.8347	0.7886	0.7505	0.8079	0.7557
280890002	MS	MADISON CO	JACKSON, MS	0.9322	0.9075	0.8865	0.9202	0.8911
281490004	MS	WARREN CO	WARREN CO, MS	0.9453	0.9220	0.9026	0.9452	0.9192
290390001	MO	CEDAR CO	CEDAR CO, MO	0.9287	0.8852	0.8523	0.9033	0.8575
290470003	MO	CLAY CO	KANSAS CITY, MO-KS	0.9176	0.8770	0.8458	0.8966	0.8532
290470005	MO	CLAY CO	KANSAS CITY, MO-KS	0.9270	0.8917	0.8638	0.9108	0.8722
290470025	MO	CLAY CO	KANSAS CITY, MO-KS	0.9244	0.8905	0.8635	0.9094	0.8720
290770026	MO	GREENE CO	SPRINGFIELD, MO	0.8574	0.8097	0.7578	0.8341	0.7610
290770036	MO	GREENE CO	SPRINGFIELD, MO	0.8567	0.8091	0.7573	0.8336	0.7605
290950036	MO	JACKSON CO	KANSAS CITY, MO-KS	0.9260	0.8946	0.8689	0.9132	0.8780
290990012	MO	JEFFERSON CO	ST. LOUIS, MO-IL	0.8919	0.8405	0.7965	0.8630	0.8013
291370001	MO	MONROE CO	MONROE CO, MO	0.8910	0.8566	0.8295	0.8743	0.8365
291650023	MO	PLATTE CO	KANSAS CITY, MO-KS	0.9381	0.9096	0.8859	0.9277	0.8953
291831002	MO	ST CHARLES CO	ST. LOUIS, MO-IL	0.9032	0.8577	0.8138	0.8824	0.8229
291831004	MO	ST CHARLES CO	ST. LOUIS, MO-IL	0.8825	0.8206	0.7668	0.8482	0.7738
291860005	MO	STE GENEVIEVE CO	STE GENEVIEVE CO, MO	0.8689	0.8299	0.7930	0.8495	0.7985
291890004	MO	ST LOUIS CO	ST. LOUIS, MO-IL	0.9096	0.8653	0.8227	0.8878	0.8291
291890006	MO	ST LOUIS CO	ST. LOUIS CO	0.9126	0.8719	0.8265	0.8958	0.8348
291893001	MO	ST LOUIS CO	ST. LOUIS, MO-IL	0.9126	0.8719	0.8265	0.8958	0.8348
291895001	MO	ST LOUIS CO	ST. LOUIS, MO-IL	0.9071	0.8630	0.8195	0.8856	0.8272
291897002	MO	ST LOUIS CO	ST. LOUIS, MO-IL	0.9093	0.8639	0.8168	0.8887	0.8248
295100007	MO	ST LOUIS	ST. LOUIS, MO-IL	0.9082	0.8661	0.8274	0.8873	0.8340
295100072	MO	ST LOUIS	ST. LOUIS, MO-IL	0.9147	0.8753	0.8331	0.8986	0.8415
295100080	MO	ST LOUIS	ST. LOUIS, MO-IL	0.9071	0.8630	0.8195	0.8856	0.8272
310550028	NE	DOUGLAS CO	OMAHA, NE-IA	0.9204	0.8874	0.8626	0.9055	0.8709
310550032	NE	DOUGLAS CO	OMAHA, NE-IA	0.9196	0.8843	0.8594	0.9024	0.8674
310550035	NE	DOUGLAS CO	OMAHA, NE-IA	0.9204	0.8874	0.8626	0.9055	0.8709
311090016	NE	LANCASTER CO	LINCOLN, NE	0.9190	0.8823	0.8523	0.9031	0.8618
330012003	NH	BELKNAP CO	BELKNAP CO, NH	0.9263	0.8963	0.8594	0.9184	0.8700
330031002	NH	CARROLL CO	CARROLL CO, NH	0.9102	0.8813	0.8452	0.9034	0.8557
330050007	NH	CHESHIRE CO	CHESHIRE CO, NH	0.8926	0.8451	0.7992	0.8712	0.8100
330090008	NH	GRAFTON CO	GRAFTON CO, NH	0.8885	0.8370	0.7895	0.8643	0.7998
330110016	NH	HILLSBOROUGH CO	HILLSBOROUGH CO, NH	0.9073	0.8712	0.8364	0.8929	0.8469
330111010	NH	HILLSBOROUGH CO	BOSTON CMSA	0.9011	0.8648	0.8287	0.8875	0.8396
330130007	NH	MERRIMACK CO	MANCHESTER, NH	0.9030	0.8638	0.8230	0.8876	0.8328
330150009	NH	ROCKINGHAM CO	PORTSMOUTH-ROCHESTER, NH-ME	0.9128	0.8793	0.8453	0.9020	0.8566
330150012	NH	ROCKINGHAM CO	PORTSMOUTH-ROCHESTER, NH-ME	0.9128	0.8793	0.8453	0.9020	0.8566
330173002	NH	STRAFFORD CO	PORTSMOUTH-ROCHESTER, NH-ME	0.9125	0.8771	0.8360	0.9028	0.8487
330190003	NH	SULLIVAN CO	SULLIVAN CO, NH	0.9016	0.8476	0.8033	0.8759	0.8163
340010005	NJ	ATLANTIC CO	ATLANTIC-CAPE MAY, NJ	0.8894	0.8659	0.8294	0.8894	0.8398
340070003	NJ	CAMDEN CO	PHILADELPHIA CMSA	0.9193	0.9126	0.8940	0.9307	0.9062
340071001	NJ	CAMDEN CO	PHILADELPHIA CMSA	0.9057	0.8877	0.8561	0.9085	0.8657
340110007	NJ	CUMBERLAND CO	PHILADELPHIA CMSA	0.8747	0.8463	0.8104	0.8670	0.8181

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
340130011	NJ	ESSEX CO	NEW YORK CMSA	0.9339	0.9268	0.9067	0.9464	0.9201
340150002	NJ	GLOUCESTER CO	PHILADELPHIA CMSA	0.9024	0.8862	0.8594	0.9039	0.8685
340170006	NJ	HUDSON CO	NEW YORK CMSA	0.9339	0.9268	0.9067	0.9464	0.9201
340190001	NJ	HUNTERDON CO	NEW YORK CMSA	0.9270	0.9062	0.8741	0.9282	0.8858
340210005	NJ	MERCER CO	PHILADELPHIA CMSA	0.9412	0.9355	0.9107	0.9553	0.9237
340230011	NJ	MIDDLESEX CO	NEW YORK CMSA	0.9255	0.9102	0.8778	0.9312	0.8896
340250005	NJ	MONMOUTH CO	NEW YORK CMSA	0.9227	0.9045	0.8701	0.9265	0.8809
340273001	NJ	MORRIS CO	NEW YORK CMSA	0.9054	0.8865	0.8571	0.9062	0.8670
340290006	NJ	OCEAN CO	NEW YORK CMSA	0.9198	0.9053	0.8781	0.9264	0.8907
340315001	NJ	PASSAIC CO	NEW YORK CMSA	0.9178	0.9018	0.8791	0.9189	0.8884
360010012	NY	ALBANY CO	ALBANY-SCHENECTADY-TROY, NY	0.9095	0.8673	0.8271	0.8910	0.8359
360050080	NY	BRONX CO	NEW YORK CMSA	0.9626	0.9847	0.9826	0.9966	0.9974
360050083	NY	BRONX CO	NEW YORK CMSA	0.9626	0.9847	0.9826	0.9966	0.9974
360130011	NY	CHAUTAUQUA CO	JAMESTOWN, NY	0.8935	0.8653	0.8410	0.8845	0.8514
360150003	NY	CHEMUNG CO	ELMIRA, NY	0.8853	0.8471	0.8118	0.8665	0.8183
360270007	NY	DUTCHESS CO	DUTCHESS COUNTY, NY	0.9030	0.8816	0.8508	0.9028	0.8626
360290002	NY	ERIE CO	BUFFALO CMSA	0.9081	0.8910	0.8734	0.9072	0.8841
360310002	NY	ESSEX CO	ESSEX CO, NY	0.9070	0.8786	0.8577	0.8926	0.8637
360310003	NY	ESSEX CO	ESSEX CO, NY	0.9070	0.8786	0.8577	0.8926	0.8637
360410005	NY	HAMILTON CO	HAMILTON CO, NY	0.8987	0.8677	0.8410	0.8847	0.8484
360430005	NY	HERKIMER CO	HERKIMER CO, NY	0.9043	0.8778	0.8558	0.8929	0.8628
360450002	NY	JEFFERSON CO	JEFFERSON CO, NY	0.9041	0.8802	0.8581	0.8966	0.8662
360530006	NY	MADISON CO	SYRACUSE, NY	0.9047	0.8625	0.8305	0.8799	0.8363
360551004	NY	MONROE CO	ROCHESTER, NY	0.9042	0.8773	0.8558	0.8951	0.8654
360610010	NY	NEW YORK CO	NEW YORK CMSA	0.9143	0.8968	0.8709	0.9167	0.8827
360631006	NY	NIAGARA CO	BUFFALO CMSA	0.9006	0.8667	0.8392	0.8849	0.8476
360650004	NY	ONEIDA CO	UTICA-ROME, NY	0.8844	0.8502	0.8199	0.8700	0.8284
360671015	NY	ONONDAGA CO	SYRACUSE, NY	0.8930	0.8539	0.8221	0.8746	0.8310
360715001	NY	ORANGE CO	NEWBURGH, NY-PA	0.9119	0.9010	0.8755	0.9200	0.8869
360790005	NY	PUTNAM CO	NEW YORK CMSA	0.9184	0.9071	0.8828	0.9275	0.8962
360810097	NY	QUEENS CO	NEW YORK CMSA	0.9115	0.8905	0.8607	0.9122	0.8720
360850067	NY	RICHMOND CO	NEW YORK CMSA	0.9231	0.9145	0.8906	0.9350	0.9032
360910004	NY	SARATOGA CO	ALBANY-SCHENECTADY-TROY, NY	0.8735	0.8286	0.7877	0.8521	0.7963
360930003	NY	SCHENECTADY CO	ALBANY-SCHENECTADY-TROY, NY	0.9028	0.8771	0.8431	0.8987	0.8545
361030002	NY	SUFFOLK CO	NEW YORK CMSA	0.9081	0.8907	0.8703	0.9115	0.8848
361030004	NY	SUFFOLK CO	NEW YORK CMSA	0.9197	0.9129	0.8927	0.9337	0.9077
361111005	NY	ULSTER CO	ULSTER CO, NY	0.8898	0.8608	0.8249	0.8825	0.8345
361173001	NY	WAYNE CO	ROCHESTER, NY	0.9101	0.8892	0.8667	0.9092	0.8787
361192004	NY	WESTCHESTER CO	NEW YORK CMSA	0.9343	0.9357	0.9231	0.9536	0.9374
370030003	NC	ALEXANDER CO	HICKORY-MORGANTON, NC	0.8421	0.8006	0.7559	0.8238	0.7609
370210030	NC	BUNCOMBE CO	ASHEVILLE, NC	0.8175	0.7771	0.7237	0.8010	0.7269
370270003	NC	CALDWELL CO	CALDWELL CO, NC	0.8307	0.7869	0.7391	0.8093	0.7427
370290099	NC	CAMDEN CO	CAMDEN CO, NC	0.9116	0.8866	0.8574	0.9077	0.8681
370330001	NC	CASWELL CO	CASWELL CO, NC	0.8497	0.8179	0.7767	0.8395	0.7807

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
370370004	NC	CHATHAM CO	RALEIGH-DURHAM-CHAPEL HILL, NC	0.8542	0.8160	0.7693	0.8419	0.7771
370510008	NC	CUMBERLAND CO	FAYETTEVILLE, NC	0.8644	0.8169	0.7617	0.8440	0.7667
370511003	NC	CUMBERLAND CO	FAYETTEVILLE, NC	0.8534	0.8043	0.7477	0.8309	0.7515
370590002	NC	DAVIE CO	GREENSBORO--WINSTON-SALEM--H	0.8328	0.7742	0.7221	0.8004	0.7276
370610002	NC	DUPLIN CO	WILMINGTON, NC	0.8504	0.8109	0.7659	0.8342	0.7711
370630013	NC	DURHAM CO	RALEIGH-DURHAM-CHAPEL HILL, NC	0.8734	0.8282	0.7802	0.8565	0.7883
370650099	NC	EDGECOMBE CO	EDGECOMBE CO, NC	0.8608	0.8250	0.7825	0.8485	0.7888
370670022	NC	FORSYTH CO	GREENSBORO--WINSTON-SALEM--H	0.8534	0.8042	0.7504	0.8314	0.7564
370670027	NC	FORSYTH CO	GREENSBORO--WINSTON-SALEM--H	0.8404	0.7943	0.7453	0.8163	0.7471
370670028	NC	FORSYTH CO	GREENSBORO--WINSTON-SALEM--H	0.8537	0.8030	0.7482	0.8288	0.7517
370671008	NC	FORSYTH CO	GREENSBORO--WINSTON-SALEM--H	0.8667	0.8200	0.7653	0.8479	0.7725
370690001	NC	FRANKLIN CO	RALEIGH-DURHAM-CHAPEL HILL, NC	0.8556	0.8121	0.7614	0.8393	0.7685
370770001	NC	GRANVILLE CO	RALEIGH-DURHAM-CHAPEL HILL, NC	0.8617	0.8195	0.7714	0.8456	0.7790
370810011	NC	GUILFORD CO	GREENSBORO--WINSTON-SALEM--H	0.8629	0.8224	0.7735	0.8474	0.7797
370870035	NC	HAYWOOD CO	HAYWOOD CO, NC	0.8235	0.7798	0.7258	0.8050	0.7296
370870036	NC	HAYWOOD CO	HAYWOOD CO, NC	0.8106	0.7710	0.7207	0.7945	0.7249
371010002	NC	JOHNSTON CO	RALEIGH-DURHAM-CHAPEL HILL, NC	0.8656	0.8159	0.7618	0.8443	0.7685
371070004	NC	LENOIR CO	LENOIR CO, NC	0.8578	0.8185	0.7730	0.8418	0.7783
371090004	NC	LINCOLN CO	CHARLOTTE-GASTONIA-ROCK HILL,	0.8625	0.8223	0.7743	0.8480	0.7817
371170001	NC	MARTIN CO	MARTIN CO, NC	0.8834	0.8517	0.8147	0.8738	0.8227
371190034	NC	MECKLENBURG CO	CHARLOTTE-GASTONIA-ROCK HILL,	0.8771	0.8325	0.7854	0.8604	0.7965
371191005	NC	MECKLENBURG CO	CHARLOTTE-GASTONIA-ROCK HILL,	0.8917	0.8569	0.8161	0.8846	0.8299
371191009	NC	MECKLENBURG CO	CHARLOTTE-GASTONIA-ROCK HILL,	0.8598	0.8113	0.7616	0.8389	0.7704
371290002	NC	NEW HANOVER CO	WILMINGTON, NC	0.8793	0.8465	0.8080	0.8734	0.8210
371310002	NC	NORTHAMPTON CO	NORTHAMPTON CO, NC	0.8632	0.8339	0.7974	0.8539	0.8033
371450003	NC	PERSON CO	RALEIGH-DURHAM-CHAPEL HILL, NC	0.8516	0.8232	0.7833	0.8442	0.7879
371470099	NC	PITT CO	PITT CO, NC	0.8614	0.8231	0.7773	0.8478	0.7839
371570099	NC	ROCKINGHAM CO	ROCKINGHAM CO, NC	0.8528	0.8056	0.7570	0.8300	0.7625
371590021	NC	ROWAN CO	CHARLOTTE-GASTONIA-ROCK HILL,	0.8366	0.7873	0.7323	0.8149	0.7382
371590022	NC	ROWAN CO	CHARLOTTE-GASTONIA-ROCK HILL,	0.8552	0.7987	0.7513	0.8250	0.7586
371730002	NC	SWAIN CO	SWAIN CO, NC	0.8249	0.7797	0.7345	0.7993	0.7366
371830014	NC	WAKE CO	RALEIGH-DURHAM-CHAPEL HILL, NC	0.8886	0.8464	0.7923	0.8761	0.8021
371830015	NC	WAKE CO	RALEIGH-DURHAM-CHAPEL HILL, NC	0.8886	0.8464	0.7923	0.8761	0.8021
371830016	NC	WAKE CO	RALEIGH-DURHAM-CHAPEL HILL, NC	0.8792	0.8257	0.7681	0.8567	0.7757
371830017	NC	WAKE CO	RALEIGH-DURHAM-CHAPEL HILL, NC	0.8867	0.8495	0.7977	0.8772	0.8072
371990003	NC	YANCEY CO	YANCEY CO, NC	0.8241	0.7819	0.7329	0.8052	0.7373
390030002	OH	ALLEN CO	LIMA, OH	0.8955	0.8687	0.8441	0.8888	0.8559
390071001	OH	ASHTABULA CO	CLEVELAND CMSA	0.9007	0.8771	0.8528	0.8974	0.8648
390170004	OH	BUTLER CO	CINCINNATI CMSA	0.8957	0.8710	0.8455	0.8917	0.8572
390171004	OH	BUTLER CO	CINCINNATI CMSA	0.8816	0.8507	0.8225	0.8711	0.8325
390230001	OH	CLARK CO	DAYTON-SPRINGFIELD, OH	0.8749	0.8360	0.8037	0.8573	0.8131
390230003	OH	CLARK CO	DAYTON-SPRINGFIELD, OH	0.8748	0.8399	0.8098	0.8606	0.8194
390250020	OH	CLERMONT CO	CINCINNATI CMSA	0.8834	0.8600	0.8335	0.8796	0.8445
390271002	OH	CLINTON CO	CINCINNATI CMSA	0.8560	0.8191	0.7877	0.8384	0.7953

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
390350034	OH	CUYAHOGA CO	CLEVELAND CMSA	0.8929	0.8671	0.8465	0.8876	0.8604
390350064	OH	CUYAHOGA CO	CLEVELAND CMSA	0.9165	0.9039	0.8881	0.9218	0.9020
390355002	OH	CUYAHOGA CO	CLEVELAND CMSA	0.8996	0.8761	0.8557	0.8970	0.8693
390410002	OH	DELAWARE CO	COLUMBUS, OH	0.8731	0.8374	0.8068	0.8574	0.8154
390490004	OH	FRANKLIN CO	COLUMBUS, OH	0.8923	0.8780	0.8613	0.8958	0.8751
390490081	OH	FRANKLIN CO	COLUMBUS, OH	0.8884	0.8715	0.8554	0.8905	0.8692
390550004	OH	GEAUGA CO	CLEVELAND-LORAIN-ELYRIA, OH	0.8938	0.8634	0.8358	0.8849	0.8478
390570006	OH	GREENE CO	DAYTON-SPRINGFIELD, OH	0.8665	0.8333	0.8026	0.8536	0.8116
390610006	OH	HAMILTON CO	CINCINNATI CMSA	0.8949	0.8771	0.8570	0.8973	0.8709
390610010	OH	HAMILTON CO	CINCINNATI CMSA	0.8826	0.8749	0.8654	0.8915	0.8796
390610037	OH	HAMILTON CO	CINCINNATI CMSA	0.9095	0.8969	0.8819	0.9171	0.8974
390830002	OH	KNOX CO	COLUMBUS, OH	0.8767	0.8526	0.8261	0.8722	0.8363
390850003	OH	LAKE CO	CLEVELAND CMSA	0.9004	0.8787	0.8577	0.9002	0.8723
390853002	OH	LAKE CO	CLEVELAND CMSA	0.9019	0.8777	0.8544	0.8995	0.8685
390870006	OH	LAWRENCE CO	HUNTINGTON-ASHLAND, WV-KY-OH	0.8522	0.8276	0.8033	0.8430	0.8104
390870011	OH	LAWRENCE CO	HUNTINGTON-ASHLAND, WV-KY-OH	0.8531	0.8231	0.7978	0.8379	0.8036
390890005	OH	LICKING CO	COLUMBUS, OH	0.8679	0.8412	0.8127	0.8608	0.8221
390911001	OH	LOGAN CO	LOGAN CO, OH	0.8771	0.8389	0.8063	0.8597	0.8154
390931003	OH	LORAIN CO	CLEVELAND CMSA	0.9174	0.9079	0.8933	0.9250	0.9063
390950034	OH	LUCAS CO	TOLEDO, OH	0.9056	0.8901	0.8717	0.9060	0.8823
390950081	OH	LUCAS CO	TOLEDO, OH	0.8990	0.8793	0.8590	0.8919	0.8659
390970007	OH	MADISON CO	COLUMBUS, OH	0.8742	0.8421	0.8131	0.8623	0.8228
390990009	OH	MAHONING CO	YOUNGSTOWN-WARREN, OH	0.8693	0.8275	0.7903	0.8479	0.7978
391030003	OH	MEDINA CO	CLEVELAND CMSA	0.8814	0.8510	0.8213	0.8714	0.8321
391090005	OH	MIAMI CO	DAYTON-SPRINGFIELD, OH	0.8756	0.8400	0.8097	0.8615	0.8202
391130019	OH	MONTGOMERY CO	DAYTON-SPRINGFIELD, OH	0.8786	0.8502	0.8216	0.8711	0.8325
391331001	OH	PORTAGE CO	CLEVELAND CMSA	0.8838	0.8510	0.8178	0.8728	0.8284
391351001	OH	PREBLE CO	DAYTON-SPRINGFIELD, OH	0.8594	0.8209	0.7886	0.8390	0.7944
391510016	OH	STARK CO	CANTON-MASSILLON, OH	0.8734	0.8397	0.8054	0.8603	0.8143
391510019	OH	STARK CO	CANTON-MASSILLON, OH	0.8649	0.8367	0.8055	0.8559	0.8136
391511009	OH	STARK CO	CANTON-MASSILLON, OH	0.8736	0.8388	0.8043	0.8595	0.8130
391514005	OH	STARK CO	CANTON-MASSILLON, OH	0.8811	0.8464	0.8126	0.8675	0.8220
391530020	OH	SUMMIT CO	CLEVELAND CMSA	0.8951	0.8709	0.8431	0.8899	0.8543
391550008	OH	TRUMBULL CO	YOUNGSTOWN-WARREN, OH	0.8709	0.8290	0.7916	0.8500	0.7997
391550009	OH	TRUMBULL CO	YOUNGSTOWN-WARREN, OH	0.8678	0.8284	0.7938	0.8494	0.8024
391591001	OH	UNION CO	UNION CO, OH	0.8732	0.8356	0.8037	0.8551	0.8116
391650006	OH	WARREN CO	CINCINNATI CMSA	0.8851	0.8576	0.8292	0.8791	0.8407
391670004	OH	WASHINGTON CO	PARKERSBURG-MARIETTA, WV-OH	0.8203	0.7896	0.7627	0.8033	0.7665
391730003	OH	WOOD CO	TOLEDO, OH	0.9002	0.8756	0.8516	0.8935	0.8615
400270049	OK	CLEVELAND CO	OKLAHOMA CITY, OK	0.9306	0.8694	0.8296	0.8904	0.8351
400770440	OK	LATIMER CO	LATIMER CO, OK	0.9519	0.9187	0.8940	0.9348	0.9011
400870073	OK	MC CLAIN CO	OKLAHOMA CITY, OK	0.9320	0.8711	0.8313	0.8914	0.8360
401090033	OK	OKLAHOMA CO	OKLAHOMA CITY, OK	0.9362	0.8758	0.8373	0.8971	0.8434
401091037	OK	OKLAHOMA CO	OKLAHOMA CITY, OK	0.9340	0.8726	0.8342	0.8933	0.8399

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
401430127	OK	TULSA CO	TULSA, OK	0.9375	0.8825	0.8433	0.9066	0.8534
401430137	OK	TULSA CO	TULSA, OK	0.9375	0.8828	0.8451	0.9071	0.8556
401430174	OK	TULSA CO	TULSA, OK	0.9327	0.8781	0.8390	0.9003	0.8467
420030008	PA	ALLEGHENY CO	PITTSBURGH CMSA	0.9122	0.8904	0.8627	0.9096	0.8719
420030010	PA	ALLEGHENY CO	PITTSBURGH CMSA	0.9120	0.8961	0.8739	0.9145	0.8850
420030067	PA	ALLEGHENY CO	PITTSBURGH CMSA	0.8809	0.8661	0.8425	0.8832	0.8520
420030088	PA	ALLEGHENY CO	PITTSBURGH CMSA	0.9028	0.8824	0.8540	0.9013	0.8629
420031005	PA	ALLEGHENY CO	PITTSBURGH CMSA	0.9025	0.8814	0.8554	0.8996	0.8642
420050001	PA	ARMSTRONG CO	ARMSTRONG CO, PA	0.8708	0.8395	0.8093	0.8568	0.8154
420070002	PA	BEAVER CO	PITTSBURGH CMSA	0.8987	0.8701	0.8434	0.8858	0.8498
420070005	PA	BEAVER CO	PITTSBURGH CMSA	0.9088	0.8812	0.8566	0.8982	0.8645
420070014	PA	BEAVER CO	PITTSBURGH CMSA	0.9191	0.8945	0.8704	0.9109	0.8780
420110001	PA	BERKS CO	READING, PA	0.8819	0.8375	0.7969	0.8584	0.8030
420110009	PA	BERKS CO	READING, PA	0.8804	0.8472	0.8103	0.8679	0.8181
420130801	PA	BLAIR CO	ALTOONA, PA	0.8482	0.8213	0.7900	0.8361	0.7932
420170012	PA	BUCKS CO	PHILADELPHIA CMSA	0.9287	0.9258	0.9064	0.9444	0.9195
420210011	PA	CAMBRIA CO	JOHNSTOWN, PA	0.8770	0.8582	0.8314	0.8725	0.8356
420274000	PA	CENTRE CO	STATE COLLEGE, PA	0.8530	0.8153	0.7768	0.8344	0.7819
420334000	PA	CLEARFIELD CO	CLEARFIELD CO, PA	0.8516	0.8177	0.7840	0.8353	0.7890
420430401	PA	DAUPHIN CO	HARRISBURG-LEBANON-CARLISLE, P	0.8826	0.8306	0.7834	0.8511	0.7874
420431100	PA	DAUPHIN CO	HARRISBURG-LEBANON-CARLISLE, P	0.8867	0.8355	0.7883	0.8562	0.7928
420450002	PA	DELAWARE CO	PHILADELPHIA CMSA	0.8997	0.8786	0.8500	0.8980	0.8587
420490003	PA	ERIE CO	ERIE, PA	0.8956	0.8703	0.8461	0.8902	0.8573
420550001	PA	FRANKLIN CO	FRANKLIN CO, PA	0.8455	0.8052	0.7622	0.8245	0.7655
420590002	PA	GREENE CO	GREENE CO, PA	0.8087	0.7774	0.7506	0.7907	0.7539
420690101	PA	LACKAWANNA CO	SCRANTON--WILKES-BARRE--HAZLE	0.8660	0.8217	0.7811	0.8419	0.7867
420692006	PA	LACKAWANNA CO	SCRANTON--WILKES-BARRE--HAZLE	0.8647	0.8232	0.7845	0.8438	0.7913
420710007	PA	LANCASTER CO	LANCASTER, PA	0.8974	0.8653	0.8270	0.8873	0.8351
420730015	PA	LAWRENCE CO	LAWRENCE CO, PA	0.8774	0.8387	0.8041	0.8583	0.8110
420770004	PA	LEHIGH CO	ALLENTOWN-BETHLEHEM-EASTON,	0.8955	0.8628	0.8286	0.8824	0.8360
420791100	PA	LUZERNE CO	SCRANTON--WILKES-BARRE--HAZLE	0.8487	0.8060	0.7677	0.8243	0.7723
420791101	PA	LUZERNE CO	SCRANTON--WILKES-BARRE--HAZLE	0.8687	0.8262	0.7866	0.8472	0.7934
420810403	PA	LYCOMING CO	WILLIAMSPORT, PA	0.8636	0.8265	0.7892	0.8447	0.7937
420814000	PA	LYCOMING CO	WILLIAMSPORT, PA	0.8490	0.8155	0.7808	0.8335	0.7859
420850100	PA	MERCER CO	YOUNGSTOWN-WARREN, OH	0.8627	0.8208	0.7831	0.8412	0.7902
420890001	PA	MONROE CO	MONROE CO, PA	0.8966	0.8652	0.8325	0.8842	0.8398
420910013	PA	MONTGOMERY CO	PHILADELPHIA CMSA	0.9060	0.9055	0.8898	0.9224	0.9026
420950025	PA	NORTHAMPTON CO	ALLENTOWN-BETHLEHEM-EASTON,	0.8955	0.8628	0.8286	0.8824	0.8360
420950100	PA	NORTHAMPTON CO	ALLENTOWN-BETHLEHEM-EASTON,	0.8992	0.8635	0.8297	0.8833	0.8371
420990301	PA	PERRY CO	HARRISBURG-LEBANON-CARLISLE, P	0.8563	0.8108	0.7688	0.8296	0.7720
421010004	PA	PHILADELPHIA CO	PHILADELPHIA CMSA	0.9310	0.9286	0.9091	0.9471	0.9218
421010014	PA	PHILADELPHIA CO	PHILADELPHIA CMSA	0.9053	0.8967	0.8766	0.9155	0.8883
421010024	PA	PHILADELPHIA CO	PHILADELPHIA CMSA	0.9310	0.9286	0.9091	0.9471	0.9218
421010136	PA	PHILADELPHIA CO	PHILADELPHIA CMSA	0.9042	0.8901	0.8662	0.9082	0.8760

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
421250005	PA	WASHINGTON CO	PITTSBURGH CMSA	0.8648	0.8394	0.8141	0.8554	0.8206
421250200	PA	WASHINGTON CO	PITTSBURGH CMSA	0.8394	0.8073	0.7783	0.8226	0.7826
421255001	PA	WASHINGTON CO	PITTSBURGH CMSA	0.9044	0.8816	0.8582	0.8980	0.8662
421290006	PA	WESTMORELAND CO	PITTSBURGH CMSA	0.9147	0.8947	0.8671	0.9140	0.8761
421330008	PA	YORK CO	YORK, PA	0.8871	0.8497	0.8098	0.8718	0.8165
440030002	RI	KENT CO	PROVIDENCE CMSA	0.9094	0.8806	0.8440	0.9060	0.8579
440071010	RI	PROVIDENCE CO	PROVIDENCE CMSA	0.9020	0.8634	0.8228	0.8892	0.8358
440090007	RI	WASHINGTON CO	PROVIDENCE CMSA	0.8972	0.8688	0.8322	0.8961	0.8477
450010001	SC	ABBEVILLE CO	ABBEVILLE CO, SC	0.8424	0.7909	0.7296	0.8169	0.7324
450030003	SC	AIKEN CO	AUGUSTA-AIKEN, GA-SC	0.8421	0.7831	0.7367	0.8089	0.7454
450070003	SC	ANDERSON CO	GREENVILLE-SPARTANBURG-ANDEF	0.8518	0.8015	0.7469	0.8269	0.7527
450110001	SC	BARNWELL CO	BARNWELL CO, SC	0.8444	0.8072	0.7620	0.8308	0.7684
450150002	SC	BERKELEY CO	CHARLESTON-NORTH CHARLESTON	0.8663	0.8325	0.7894	0.8575	0.7986
450190042	SC	CHARLESTON CO	CHARLESTON-NORTH CHARLESTON	0.8663	0.8325	0.7894	0.8575	0.7986
450190046	SC	CHARLESTON CO	CHARLESTON-NORTH CHARLESTON	0.8573	0.8275	0.7886	0.8500	0.7963
450210002	SC	CHEROKEE CO	CHEROKEE CO, SC	0.8445	0.8074	0.7562	0.8352	0.7639
450230002	SC	CHESTER CO	CHARLOTTE-GASTONIA-ROCK HILL,	0.8719	0.8389	0.7945	0.8651	0.8039
450290002	SC	COLLETON CO	COLLETON CO, SC	0.8500	0.8127	0.7666	0.8341	0.7702
450310003	SC	DARLINGTON CO	DARLINGTON CO, SC	0.8780	0.8548	0.8126	0.8827	0.8252
450370001	SC	EDGEFIELD CO	EDGEFIELD CO, SC	0.8422	0.7963	0.7446	0.8209	0.7497
450730001	SC	OCONEE CO	OCONEE CO, SC	0.8253	0.7763	0.7205	0.8003	0.7231
450770002	SC	PICKENS CO	GREENVILLE-SPARTANBURG-ANDEF	0.8424	0.7888	0.7285	0.8136	0.7303
450790007	SC	RICHLAND CO	COLUMBIA, SC	0.8607	0.8134	0.7526	0.8408	0.7581
450791002	SC	RICHLAND CO	COLUMBIA, SC	0.8653	0.8168	0.7570	0.8447	0.7623
450830009	SC	SPARTANBURG CO	GREENVILLE-SPARTANBURG-ANDEF	0.8489	0.8095	0.7601	0.8337	0.7654
450870001	SC	UNION CO	UNION CO, SC	0.8444	0.8070	0.7592	0.8315	0.7649
450910006	SC	YORK CO	CHARLOTTE-GASTONIA-ROCK HILL,	0.8749	0.8404	0.7953	0.8676	0.8055
470010101	TN	ANDERSON CO	KNOXVILLE, TN	0.8271	0.7622	0.7126	0.7814	0.7133
470090101	TN	BLOUNT CO	KNOXVILLE, TN	0.8387	0.7780	0.7244	0.7983	0.7246
470090102	TN	BLOUNT CO	KNOXVILLE, TN	0.8355	0.7775	0.7264	0.7972	0.7269
470370011	TN	DAVIDSON CO	NASHVILLE, TN	0.8893	0.8531	0.8192	0.8748	0.8295
470370026	TN	DAVIDSON CO	NASHVILLE, TN	0.8853	0.8474	0.8142	0.8689	0.8240
470650028	TN	HAMILTON CO	CHATTANOOGA, TN-GA	0.8492	0.7851	0.7248	0.8094	0.7266
470651011	TN	HAMILTON CO	CHATTANOOGA, TN-GA	0.8493	0.7811	0.7185	0.8058	0.7198
470750003	TN	HAYWOOD CO	HAYWOOD CO, TN	0.8672	0.8235	0.7949	0.8407	0.8012
470890001	TN	JEFFERSON CO	JEFFERSON CO, TN	0.8120	0.7519	0.7057	0.7700	0.7062
470890002	TN	JEFFERSON CO	JEFFERSON CO, TN	0.8120	0.7519	0.7057	0.7700	0.7062
470930021	TN	KNOX CO	KNOXVILLE, TN	0.8472	0.7900	0.7406	0.8091	0.7413
470931020	TN	KNOX CO	KNOXVILLE, TN	0.8450	0.7854	0.7344	0.8050	0.7353
470990002	TN	LAWRENCE CO	LAWRENCE CO, TN	0.7858	0.7505	0.7183	0.7678	0.7238
471410004	TN	PUTNAM CO	PUTNAM CO, TN	0.8160	0.7610	0.7201	0.7782	0.7217
471490101	TN	RUTHERFORD CO	NASHVILLE, TN	0.8625	0.8140	0.7721	0.8363	0.7791
471550101	TN	SEVIER CO	KNOXVILLE, TN	0.8176	0.7634	0.7162	0.7813	0.7161
471550102	TN	SEVIER CO	KNOXVILLE, TN	0.7977	0.7537	0.7106	0.7720	0.7121

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
471570021	TN	SHELBY CO	MEMPHIS, TN-AR-MS	0.9229	0.9125	0.8952	0.9328	0.9099
471571004	TN	SHELBY CO	MEMPHIS, TN-AR-MS	0.8980	0.8596	0.8327	0.8783	0.8414
471632002	TN	SULLIVAN CO	JOHNSON CITY-KINGSPORT-BRISTO	0.8353	0.8043	0.7687	0.8237	0.7746
471632003	TN	SULLIVAN CO	JOHNSON CITY-KINGSPORT-BRISTO	0.8357	0.8041	0.7683	0.8236	0.7743
471650007	TN	SUMNER CO	NASHVILLE, TN	0.8813	0.8441	0.8104	0.8645	0.8192
471650101	TN	SUMNER CO	NASHVILLE, TN	0.8401	0.7961	0.7605	0.8154	0.7663
471870106	TN	WILLIAMSON CO	NASHVILLE, TN	0.8044	0.7662	0.7343	0.7860	0.7428
471890103	TN	WILSON CO	NASHVILLE, TN	0.8433	0.7980	0.7598	0.8168	0.7645
480391003	TX	BRAZORIA CO	HOUSTON CMSA	0.9632	0.9339	0.9186	0.9512	0.9304
480430101	TX	BREWSTER CO	BREWSTER CO, TX					
480850005	TX	COLLIN CO	DALLAS CMSA	0.9301	0.8867	0.8532	0.9117	0.8653
481130045	TX	DALLAS CO	DALLAS CMSA	0.9352	0.9097	0.8796	0.9314	0.8909
481130069	TX	DALLAS CO	DALLAS CMSA	0.9361	0.9099	0.8782	0.9318	0.8895
481130087	TX	DALLAS CO	DALLAS CMSA	0.9381	0.9131	0.8818	0.9348	0.8931
481210034	TX	DENTON CO	DALLAS CMSA	0.9271	0.8739	0.8360	0.9000	0.8479
481210054	TX	DENTON CO	DALLAS CMSA	0.9309	0.8946	0.8617	0.9184	0.8734
481390015	TX	ELLIS CO	DALLAS CMSA	0.9268	0.8632	0.8256	0.8866	0.8346
481670014	TX	GALVESTON CO	HOUSTON CMSA	0.9524	0.9423	0.9283	0.9600	0.9409
481671002	TX	GALVESTON CO	HOUSTON CMSA	0.9508	0.9406	0.9255	0.9588	0.9376
481830001	TX	GREGG CO	LONGVIEW-MARSHALL, TX	0.9292	0.8772	0.8428	0.8943	0.8469
482010024	TX	HARRIS CO	HOUSTON CMSA	0.9485	0.9679	0.9643	0.9816	0.9792
482010029	TX	HARRIS CO	HOUSTON CMSA	0.9400	0.9064	0.8811	0.9278	0.8934
482010046	TX	HARRIS CO	HOUSTON CMSA	0.9491	0.9782	0.9787	0.9907	0.9942
482010047	TX	HARRIS CO	HOUSTON CMSA	0.9472	0.9727	0.9727	0.9858	0.9883
482010051	TX	HARRIS CO	HOUSTON CMSA	0.9501	0.9598	0.9562	0.9747	0.9713
482010055	TX	HARRIS CO	HOUSTON CMSA	0.9494	0.9819	0.9842	0.9938	1.0001
482010062	TX	HARRIS CO	HOUSTON CMSA	0.9505	0.9636	0.9610	0.9781	0.9762
482010066	TX	HARRIS CO	HOUSTON CMSA	0.9441	0.9486	0.9391	0.9651	0.9545
482011034	TX	HARRIS CO	HOUSTON CMSA	0.9510	0.9884	0.9922	1.0002	1.0084
482011035	TX	HARRIS CO	HOUSTON CMSA	0.9510	0.9884	0.9922	1.0002	1.0084
482011037	TX	HARRIS CO	HOUSTON CMSA	0.9494	0.9819	0.9842	0.9938	1.0001
482011039	TX	HARRIS CO	HOUSTON CMSA	0.9526	0.9873	0.9922	0.9989	1.0082
482450009	TX	JEFFERSON CO	BEAUMONT-PORT ARTHUR, TX	0.9685	0.9323	0.9158	0.9536	0.9310
482450011	TX	JEFFERSON CO	BEAUMONT-PORT ARTHUR, TX	0.9679	0.9479	0.9358	0.9675	0.9511
483550025	TX	NUECES CO	CORPUS CHRISTI, TX					
483550026	TX	NUECES CO	CORPUS CHRISTI, TX					
483611001	TX	ORANGE CO	BEAUMONT-PORT ARTHUR, TX	0.9718	0.9415	0.9276	0.9620	0.9431
484230004	TX	SMITH CO	TYLER, TX	0.9270	0.8656	0.8275	0.8851	0.8322
484390057	TX	TARRANT CO	DALLAS CMSA	0.9373	0.9059	0.8742	0.9286	0.8863
484391002	TX	TARRANT CO	DALLAS CMSA	0.9337	0.8883	0.8522	0.9125	0.8645
484392003	TX	TARRANT CO	DALLAS CMSA	0.9312	0.8881	0.8527	0.9120	0.8646
484530014	TX	TRAVIS CO	AUSTIN-SAN MARCOS, TX	0.9304	0.8831	0.8506	0.9067	0.8619
484530020	TX	TRAVIS CO	AUSTIN-SAN MARCOS, TX	0.9290	0.8794	0.8448	0.9034	0.8557
484690003	TX	VICTORIA CO	VICTORIA, TX	0.9438	0.9120	0.8905	0.9290	0.8995

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
500030004	VT	BENNINGTON CO	BENNINGTON CO, VT	0.8789	0.8257	0.7832	0.8502	0.7920
500070007	VT	CHITTENDEN CO	CHITTENDEN CO, VT	0.8847	0.8385	0.7993	0.8594	0.8055
510130020	VA	ARLINGTON CO	WASHINGTON, DC-MD-VA-WV	0.9204	0.9124	0.8836	0.9318	0.8957
510330001	VA	CAROLINE CO	CAROLINE CO, VA	0.8694	0.8238	0.7760	0.8472	0.7821
510360002	VA	CHARLES CITY CO	RICHMOND-PETERSBURG, VA	0.8744	0.8440	0.8104	0.8642	0.8180
510410004	VA	CHESTERFIELD CO	RICHMOND-PETERSBURG, VA	0.8772	0.8318	0.7853	0.8541	0.7906
510590005	VA	FAIRFAX CO	WASHINGTON, DC-MD-VA-WV	0.8970	0.8677	0.8277	0.8915	0.8401
510590018	VA	FAIRFAX CO	WASHINGTON, DC-MD-VA-WV	0.9012	0.8819	0.8562	0.9005	0.8671
510590030	VA	FAIRFAX CO	WASHINGTON, DC-MD-VA-WV	0.9012	0.8819	0.8562	0.9005	0.8671
510591004	VA	FAIRFAX CO	WASHINGTON, DC-MD-VA-WV	0.9204	0.9124	0.8836	0.9318	0.8957
510595001	VA	FAIRFAX CO	WASHINGTON, DC-MD-VA-WV	0.9235	0.9157	0.8904	0.9357	0.9049
510610002	VA	FAUQUIER CO	FAUQUIER CO, VA	0.8588	0.8187	0.7742	0.8417	0.7815
510690010	VA	FREDERICK CO	FREDERICK CO, VA	0.8516	0.8181	0.7836	0.8366	0.7893
510850001	VA	HANOVER CO	RICHMOND-PETERSBURG, VA	0.8683	0.8296	0.7857	0.8523	0.7920
510870014	VA	HENRICO CO	RICHMOND-PETERSBURG, VA	0.8763	0.8325	0.7857	0.8563	0.7926
511071005	VA	LOUDOUN CO	WASHINGTON, DC-MD-VA-WV	0.8969	0.8693	0.8301	0.8941	0.8437
511130003	VA	MADISON CO	CHARLOTTESVILLE, VA	0.8093	0.7706	0.7288	0.7898	0.7324
511530009	VA	PRINCE WILLIAM CO	WASHINGTON, DC-MD-VA-WV	0.8793	0.8461	0.8047	0.8712	0.8165
511611004	VA	ROANOKE CO	ROANOKE, VA	0.8322	0.7865	0.7432	0.8076	0.7484
511790001	VA	STAFFORD CO	WASHINGTON, DC-MD-VA-WV	0.8774	0.8290	0.7781	0.8539	0.7851
511970002	VA	WYTHE CO	WYTHE CO, VA	0.7877	0.7462	0.7029	0.7632	0.7033
515100009	VA	ALEXANDRIA	WASHINGTON, DC-MD-VA-WV	0.9204	0.9124	0.8836	0.9318	0.8957
516500004	VA	HAMPTON	NORFOLK-VIRGINIA BEACH-NEWPORT NEWS, VA	0.9099	0.8864	0.8568	0.9089	0.8684
518000004	VA	SUFFOLK	NORFOLK-VIRGINIA BEACH-NEWPORT NEWS, VA	0.9042	0.8844	0.8585	0.9059	0.8696
518000005	VA	SUFFOLK	NORFOLK-VIRGINIA BEACH-NEWPORT NEWS, VA	0.8708	0.8375	0.8026	0.8588	0.8113
540110006	WV	CABELL CO	HUNTINGTON-ASHLAND, WV-KY-OH	0.8605	0.8347	0.8099	0.8502	0.8170
540250003	WV	GREENBRIER CO	GREENBRIER CO, WV	0.7290	0.6921	0.6642	0.7034	0.6649
540291004	WV	HANCOCK CO	STEUBENVILLE-WEIRTON, OH-WV	0.8802	0.8523	0.8244	0.8686	0.8303
540390004	WV	KANAWHA CO	CHARLESTON, WV	0.8574	0.8209	0.7912	0.8329	0.7917
540690007	WV	OHIO CO	WHEELING, WV-OH	0.8564	0.8275	0.7999	0.8421	0.8043
541071002	WV	WOOD CO	PARKERSBURG-MARIETTA, WV-OH	0.8299	0.7943	0.7674	0.8074	0.7706
550090026	WI	BROWN CO	GREEN BAY, WI	0.9074	0.8750	0.8458	0.8943	0.8543
550210015	WI	COLUMBIA CO	MADISON, WI	0.8973	0.8606	0.8269	0.8809	0.8349
550250041	WI	DANE CO	MADISON, WI	0.9122	0.8776	0.8430	0.8997	0.8531
550270007	WI	DODGE CO	DODGE CO, WI	0.9043	0.8710	0.8389	0.8921	0.8482
550290004	WI	DOOR CO	DOOR CO, WI	0.9160	0.8931	0.8688	0.9155	0.8827
550370001	WI	FLORENCE CO	FLORENCE CO, WI					
550390006	WI	FOND DU LAC CO	FOND DU LAC CO, WI	0.9040	0.8696	0.8392	0.8886	0.8471
550550002	WI	JEFFERSON CO	MILWAUKEE-RACINE CMSA	0.9075	0.8754	0.8449	0.8959	0.8543
550590002	WI	Kenosha Co.	CHICAGO CMSA	0.9212	0.9167	0.9049	0.9366	0.9227
550590019	WI	Kenosha Co.	CHICAGO CMSA	0.9250	0.9226	0.9149	0.9417	0.9327
550590022	WI	Kenosha Co.		0.9167	0.9048	0.8886	0.9254	0.9047
550610002	WI	KEWAUNEE CO	KEWAUNEE CO, WI	0.9085	0.8818	0.8561	0.9029	0.8684
550710004	WI	MANITOWOC CO	MANITOWOC CO, WI	0.9100	0.8843	0.8600	0.9046	0.8718

APPENDIX D
8-Hour Relative Reduction Factors

Site Id.	State	County	Area Name	RRF 2007 Base	RRF 2020 Base	RRF 2020 Control	RRF 2030 Base	RRF 2030 Control
550710007	WI	MANITOWOC CO	MANITOWOC CO, WI	0.9147	0.8929	0.8690	0.9143	0.8820
550730012	WI	MARATHON CO	WAUSAU, WI	0.8919	0.8558	0.8245	0.8742	0.8315
550790041	WI	MILWAUKEE CO	MILWAUKEE-RACINE CMSA	0.9132	0.8979	0.8789	0.9189	0.8946
550790044	WI	MILWAUKEE CO	MILWAUKEE-RACINE CMSA	0.9186	0.9096	0.8965	0.9288	0.9125
550790048	WI	MILWAUKEE CO	MILWAUKEE-RACINE CMSA	0.9164	0.8994	0.8791	0.9217	0.8950
550790085	WI	MILWAUKEE CO	MILWAUKEE-RACINE CMSA	0.9026	0.8814	0.8609	0.9034	0.8758
550791025	WI	MILWAUKEE CO	MILWAUKEE-RACINE CMSA	0.9164	0.8994	0.8791	0.9217	0.8950
550850004	WI	ONEIDA CO	ONEIDA CO, WI	0.8905	0.8553	0.8238	0.8740	0.8309
550870009	WI	OUTAGAMIE CO	APPLETON-OSHKOSH-NEENAH, WI	0.9044	0.8722	0.8444	0.8897	0.8516
550890008	WI	OZAUKEE CO	MILWAUKEE-RACINE CMSA	0.9091	0.8939	0.8740	0.9160	0.8897
550890009	WI	OZAUKEE CO	MILWAUKEE-RACINE CMSA	0.9183	0.9064	0.8901	0.9275	0.9063
551010017	WI	RACINE CO	MILWAUKEE-RACINE CMSA	0.9214	0.9196	0.9126	0.9391	0.9319
551050021	WI	ROCK CO	JANESVILLE-BELOIT, WI	0.9052	0.8758	0.8505	0.8959	0.8615
551050024	WI	ROCK CO	JANESVILLE-BELOIT, WI	0.9017	0.8696	0.8408	0.8911	0.8516
551091002	WI	ST CROIX CO	MINNEAPOLIS-ST. PAUL, MN-WI	0.9305	0.8886	0.8620	0.9065	0.8703
551110007	WI	SAUK CO	SAUK CO, WI	0.9007	0.8632	0.8314	0.8830	0.8393
551170006	WI	SHEBOYGAN CO	SHEBOYGAN, WI	0.9199	0.9080	0.8910	0.9292	0.9072
551230008	WI	VERNON CO	VERNON CO, WI	0.9021	0.8653	0.8354	0.8841	0.8426
551250001	WI	Vilas Co.		0.8822	0.8482	0.8158	0.8676	0.8235
551270005	WI	WALWORTH CO	MILWAUKEE-RACINE CMSA	0.9089	0.8821	0.8555	0.9039	0.8679
551310009	WI	WASHINGTON CO	MILWAUKEE-RACINE CMSA	0.9174	0.9026	0.8843	0.9231	0.8989
551330017	WI	WAUKESHA CO	MILWAUKEE-RACINE CMSA	0.9176	0.9006	0.8786	0.9207	0.8923
551390011	WI	WINNEBAGO CO	APPLETON-OSHKOSH-NEENAH, WI	0.8999	0.8661	0.8377	0.8834	0.8443

**Appendix E:
1999 Annual Mean PM2.5 Values and Future Year Predictions Based on
RRfs**

APPENDIX E
1999 Annual Mean PM2.5 Values and Future-Year Predictions Based on RRFs

			PM2.5 Concentrations				
MONITOR ID	STATE	COUNTY	1999 Ambient	2020 Base	2020 Control	2030 Base	2030 Control
40139990	ARIZONA	MARICOPA	10.8	14.6	14.2	16.1	15.4
40139991	ARIZONA	MARICOPA CO	13.0	17.6	16.9	19.4	18.5
40139992	ARIZONA	MARICOPA	11.4	15.5	14.9	17.1	16.3
40139997	ARIZONA	MARICOPA	12.6	17.1	16.4	18.9	18.0
40190011	ARIZONA	PIMA CO	9.7	12.0	11.8	13.1	12.7
40191028	ARIZONA	PIMA	8.8	11.7	11.3	12.7	12.2
60011001	CALIFORNIA	ALAMEDA CO	13.9	15.3	14.4	16.6	15.3
60070002	CALIFORNIA	BUTTE CO	17.5	18.6	18.1	19.3	18.6
60090001	CALIFORNIA	CALAVERAS	11.1	12.1	11.5	12.7	11.8
60111002	CALIFORNIA	COLUSA	13.2	13.4	13.0	13.7	13.2
60170011	CALIFORNIA	EL DORADO CO	8.3	8.3	7.9	8.8	8.1
60170011	CALIFORNIA	EL DORADO	8.1	8.1	7.6	8.5	7.9
60190008	CALIFORNIA	FRESNO CO	27.7	28.1	26.5	30.2	27.8
60190008	CALIFORNIA	FRESNO	21.4	21.7	20.4	23.3	21.5
60195001	CALIFORNIA	FRESNO	20.0	20.3	19.1	21.8	20.1
60231002	CALIFORNIA	HUMBOLDT	9.0	10.2	10.1	10.5	10.3
60250005	CALIFORNIA	IMPERIAL	15.4	16.2	15.0	17.2	15.5
60251003	CALIFORNIA	IMPERIAL	11.5	12.4	11.5	13.3	12.0
60290010	CALIFORNIA	KERN	26.2	26.9	25.3	28.3	26.0
60290014	CALIFORNIA	KERN	27.8	28.4	26.8	30.0	27.6
60310004	CALIFORNIA	KINGS	22.2	21.9	20.4	23.1	20.9
60371002	CALIFORNIA	LOS ANGELES	22.8	27.5	26.0	30.0	27.9
60371103	CALIFORNIA	LOS ANGELES	23.9	28.8	27.2	31.4	29.2
60371201	CALIFORNIA	LOS ANGELES CO	17.5	22.7	21.7	24.4	23.0
60371301	CALIFORNIA	LOS ANGELES	24.6	31.4	30.1	34.2	32.3
60371601	CALIFORNIA	LOS ANGELES	25.9	31.2	29.5	34.0	31.6
60374002	CALIFORNIA	LOS ANGELES	21.3	27.1	26.0	29.6	28.0
60379002	CALIFORNIA	LOS ANGELES	10.8	11.2	10.5	11.8	10.8
60450006	CALIFORNIA	MENDOCINO	8.7	9.0	8.7	9.3	8.9
60490001	CALIFORNIA	MODOC	7.9	8.7	8.6	8.8	8.6
60570005	CALIFORNIA	NEVADA	7.6	7.4	7.1	7.7	7.3
60610006	CALIFORNIA	PLACER CO	13.4	13.7	13.1	14.6	13.7
60651003	CALIFORNIA	RIVERSIDE CO	27.1	35.2	33.4	38.5	36.0
60652002	CALIFORNIA	RIVERSIDE	12.8	15.2	13.9	16.7	14.9
60658001	CALIFORNIA	RIVERSIDE	30.2	36.5	34.3	39.7	36.6
60670010	CALIFORNIA	SACRAMENTO	16.5	17.4	16.3	18.8	17.2

APPENDIX E
1999 Annual Mean PM2.5 Values and Future-Year Predictions Based on RRFs

			PM2.5 Concentrations				
MONITOR ID	STATE	COUNTY	1999 Ambient	2020 Base	2020 Control	2030 Base	2030 Control
60674001	CALIFORNIA	SACRAMENTO	16.2	17.0	15.9	18.3	16.9
60710025	CALIFORNIA	SAN BERNARDINO CO	25.4	31.4	30.0	33.9	31.9
60712002	CALIFORNIA	SAN BERNARDINO	25.3	31.3	29.9	33.8	31.8
60718001	CALIFORNIA	SAN BERNARDINO	10.3	12.5	11.8	13.7	12.6
60719004	CALIFORNIA	SAN BERNARDINO	25.6	30.9	29.1	33.6	31.0
60730001	CALIFORNIA	SAN DIEGO CO	14.7	17.9	17.1	19.5	18.3
60730003	CALIFORNIA	SAN DIEGO	16.6	21.1	19.9	23.2	21.5
60730006	CALIFORNIA	SAN DIEGO	13.7	17.8	16.9	19.6	18.3
60731002	CALIFORNIA	SAN DIEGO	17.8	22.2	20.5	24.5	22.0
60731007	CALIFORNIA	SAN DIEGO	17.5	22.8	21.7	25.2	23.5
60771002	CALIFORNIA	SAN JOAQUIN CO	19.8	20.5	19.1	22.0	20.1
60792002	CALIFORNIA	SAN LUIS OBISPO CO	8.2	8.5	8.1	8.9	8.4
60798001	CALIFORNIA	SAN LUIS OBISPO	9.6	9.8	9.5	10.3	9.7
60798001	CALIFORNIA	SAN LUIS OBISPO	9.5	9.7	9.4	10.2	9.6
60811001	CALIFORNIA	SAN MATEO CO	12.1	13.4	12.8	14.5	13.6
60830010	CALIFORNIA	SANTA BARBARA	13.3	16.5	15.9	17.4	16.6
60890004	CALIFORNIA	SHASTA CO	12.9	13.9	13.6	14.4	13.9
60970003	CALIFORNIA	SONOMA CO	11.7	11.6	11.0	12.2	11.4
60990005	CALIFORNIA	STANISLAUS CO	24.4	24.6	22.7	26.2	23.5
61010003	CALIFORNIA	SUTTER	15.9	15.8	15.3	16.4	15.6
61072002	CALIFORNIA	TULARE CO	27.6	28.4	26.3	30.3	27.2
61110007	CALIFORNIA	VENTURA	12.0	15.5	14.8	16.7	15.7
61110007	CALIFORNIA	VENTURA	13.8	17.9	17.2	19.3	18.2
61112002	CALIFORNIA	VENTURA	13.8	17.9	17.1	19.3	18.1
61113001	CALIFORNIA	VENTURA CO	12.1	16.6	16.1	17.7	16.9
61131003	CALIFORNIA	YOLO CO	16.3	16.7	16.0	17.7	16.6
80010001	COLORADO	ADAMS CO	8.5	11.6	11.3	12.6	12.2
80130003	COLORADO	BOULDER CO	8.3	10.2	9.9	10.8	10.5
80130012	COLORADO	BOULDER	6.9	8.5	8.3	9.0	8.7
80770003	COLORADO	MESA	6.9	8.3	8.1	8.6	8.4
81230006	COLORADO	WELD	7.6	9.0	8.6	9.5	9.1
100010002	DELAWARE	KENT CO	11.6	11.4	10.9	12.0	11.3
100010003	DELAWARE	KENT	12.4	12.5	12.0	13.2	12.5
100031003	DELAWARE	NEW CASTLE	13.8	15.0	14.5	16.0	15.3
100031011	DELAWARE	NEW CASTLE	13.3	13.8	13.3	14.6	13.8
100032004	DELAWARE	NEW CASTLE	15.6	16.1	15.5	17.0	16.2

APPENDIX E
1999 Annual Mean PM2.5 Values and Future-Year Predictions Based on RRFs

			PM2.5 Concentrations				
MONITOR ID	STATE	COUNTY	1999 Ambient	2020 Base	2020 Control	2030 Base	2030 Control
100051002	DELAWARE	SUSSEX	14.2	14.1	13.6	14.8	14.0
110010041	DISTRICT OF COLU	WASHINGTON	15.2	16.1	15.5	17.1	16.2
110010043	DISTRICT OF COLU	WASHINGTON	14.9	16.4	15.7	17.7	16.6
120111002	FLORIDA	BROWARD CO	9.3	11.9	11.7	12.9	12.5
120251016	FLORIDA	DADE	12.1	15.3	14.9	16.5	16.0
120256001	FLORIDA	DADE CO	8.6	9.6	9.4	10.1	9.9
120330004	FLORIDA	ESCAMBIA CO	14.8	15.6	15.1	16.4	15.6
120570030	FLORIDA	HILLSBOROUGH CO	12.8	14.6	14.1	15.7	15.0
120571075	FLORIDA	HILLSBOROUGH	13.0	14.5	13.8	15.5	14.5
120710005	FLORIDA	LEE CO	10.2	11.1	10.8	11.8	11.3
120730012	FLORIDA	LEON CO	14.0	14.6	14.2	15.3	14.7
120814012	FLORIDA	MANATEE CO	11.6	12.8	12.5	13.4	13.1
120830003	FLORIDA	MARION CO	11.4	11.8	11.4	12.5	11.8
120951004	FLORIDA	ORANGE CO	11.3	13.8	13.3	14.8	14.1
120952002	FLORIDA	ORANGE	11.4	13.9	13.5	15.0	14.3
120992003	FLORIDA	PALM BEACH CO	9.3	11.1	10.8	11.9	11.5
121030018	FLORIDA	PINELLAS CO	11.9	13.6	13.3	14.7	14.1
121031008	FLORIDA	PINELLAS	11.8	12.6	12.3	13.5	12.9
121056006	FLORIDA	POLK CO	11.1	12.1	11.6	12.8	12.1
121111002	FLORIDA	ST LUCIE CO	9.7	10.0	9.9	10.5	10.2
121150013	FLORIDA	SARASOTA CO	10.6	10.9	10.7	11.3	11.1
121171002	FLORIDA	SEMINOLE CO	10.9	12.2	11.8	13.1	12.4
121275002	FLORIDA	VOLUSIA CO	11.4	12.4	12.0	13.1	12.6
130210007	GEORGIA	BIBB CO	19.6	20.6	20.0	21.7	20.9
130210012	GEORGIA	BIBB	17.8	18.7	18.2	19.7	19.0
130510017	GEORGIA	CHATHAM CO	18.2	19.6	19.1	20.5	19.8
130590001	GEORGIA	CLARKE CO	17.9	18.1	17.2	19.1	17.9
130630091	GEORGIA	CLAYTON CO	20.9	22.7	21.6	24.4	22.8
130890002	GEORGIA	DE KALB CO	21.0	25.1	24.0	27.5	25.8
130892001	GEORGIA	DE KALB	21.6	25.8	24.6	28.2	26.5
131150005	GEORGIA	FLOYD	21.1	21.3	20.3	22.6	21.2
131210032	GEORGIA	FULTON	20.3	24.3	23.2	26.6	25.0
131210039	GEORGIA	FULTON	23.0	27.5	26.2	30.1	28.3
131211001	GEORGIA	FULTON CO	18.9	20.6	19.5	22.1	20.6
131390003	GEORGIA	HALL	17.9	17.1	16.0	18.3	16.6
132150011	GEORGIA	MUSCOGEE	18.5	19.6	19.2	20.5	19.8

APPENDIX E
1999 Annual Mean PM2.5 Values and Future-Year Predictions Based on RRFs

			PM2.5 Concentrations				
MONITOR ID	STATE	COUNTY	1999 Ambient	2020 Base	2020 Control	2030 Base	2030 Control
132230003	GEORGIA	PAULDING CO	18.5	18.7	17.9	19.8	18.6
132450005	GEORGIA	RICHMOND	19.4	19.5	18.7	20.6	19.4
132450091	GEORGIA	RICHMOND CO	19.9	20.3	19.6	21.4	20.3
133030001	GEORGIA	WASHINGTON	18.2	18.8	18.4	19.6	19.1
160010017	DAHO	ADA	8.0	8.4	8.2	8.7	8.4
160050006	DAHO	BANNOCK	8.1	8.6	8.4	9.0	8.7
160270004	DAHO	CANYON CO	8.7	8.2	8.0	8.3	8.0
160270005	DAHO	CANYON	9.9	9.3	9.1	9.4	9.1
170310014	ILLINOIS	COOK	18.0	20.1	19.5	21.6	20.8
170310022	ILLINOIS	COOK	17.4	19.4	18.8	20.8	20.1
170310050	ILLINOIS	COOK	17.2	19.2	18.6	20.6	19.9
170311016	ILLINOIS	COOK	21.8	24.3	23.6	26.2	25.2
170311701	ILLINOIS	COOK	18.2	20.3	19.7	21.8	21.0
170313301	ILLINOIS	COOK	17.5	19.5	18.9	21.0	20.2
170314006	ILLINOIS	COOK	15.1	16.6	16.1	17.7	17.0
170314201	ILLINOIS	COOK	15.5	17.0	16.5	18.1	17.4
170434002	ILLINOIS	DU PAGE CO	15.5	17.2	16.7	18.3	17.6
171191007	ILLINOIS	MADISON	17.2	17.7	17.1	18.9	18.0
171430037	ILLINOIS	PEORIA CO	16.0	16.4	16.0	17.2	16.5
171610003	ILLINOIS	ROCK ISLAND CO	16.4	16.7	16.2	17.4	16.7
171670012	ILLINOIS	SANGAMON CO	15.9	15.5	15.0	16.2	15.5
171971002	ILLINOIS	WILL	15.5	16.6	16.1	17.5	16.9
180030004	INDIANA	ALLEN CO	12.3	12.4	11.9	13.1	12.4
180190005	INDIANA	CLARK CO	15.9	16.2	15.6	17.1	16.4
180431004	INDIANA	FLOYD CO	14.1	14.4	13.9	15.2	14.6
180890006	INDIANA	LAKE	14.3	15.1	14.6	15.9	15.3
180890022	INDIANA	LAKE	15.5	16.4	15.9	17.3	16.6
180891003	INDIANA	LAKE	13.6	14.3	13.9	15.2	14.5
180891016	INDIANA	LAKE	15.4	16.2	15.7	17.1	16.4
181270024	INDIANA	PORTER	12.0	12.7	12.3	13.4	12.9
190130008	IOWA	BLACK HAWK CO	12.1	12.1	11.7	12.6	12.0
190450021	IOWA	CLINTON	12.7	12.8	12.3	13.3	12.7
191032001	IOWA	JOHNSON CO	12.3	12.3	11.9	12.8	12.2
191130036	IOWA	LINN CO	11.8	11.8	11.4	12.3	11.7
191130037	IOWA	LINN	11.7	11.7	11.3	12.2	11.6
191390016	IOWA	MUSCATINE	12.9	13.1	12.7	13.7	13.1

APPENDIX E
1999 Annual Mean PM2.5 Values and Future-Year Predictions Based on RRFs

			PM2.5 Concentrations				
MONITOR ID	STATE	COUNTY	1999 Ambient	2020 Base	2020 Control	2030 Base	2030 Control
191532510	IOWA	POLK	11.3	11.6	11.2	12.1	11.6
191532520	IOWA	POLK	11.7	12.1	11.6	12.6	12.0
191630015	IOWA	SCOTT CO	13.1	13.3	12.9	13.9	13.3
191930017	IOWA	WOODBURY CO	9.9	10.4	10.1	10.8	10.4
200910008	KANSAS	JOHNSON	12.3	13.0	12.6	13.6	13.0
200910009	KANSAS	JOHNSON	11.5	12.1	11.7	12.7	12.2
201730008	KANSAS	SEDGWICK CO	12.0	12.6	12.3	13.0	12.6
201730009	KANSAS	SEDGWICK	11.9	12.5	12.2	12.9	12.5
201730010	KANSAS	SEDGWICK	12.5	13.0	12.7	13.5	13.0
201770010	KANSAS	SHAWNEE CO	12.3	12.7	12.3	13.2	12.6
201770011	KANSAS	SHAWNEE	12.5	12.8	12.4	13.3	12.7
210190017	KENTUCKY	BOYD CO	14.9	15.0	14.6	15.7	15.2
210290006	KENTUCKY	BULLITT CO	15.4	14.3	13.8	14.9	14.2
210370003	KENTUCKY	CAMPBELL CO	15.4	15.5	14.9	16.4	15.5
210430500	KENTUCKY	CARTER CO	11.9	11.7	11.5	12.1	11.8
210590014	KENTUCKY	DAVIESS CO	15.4	14.8	14.3	15.5	14.9
210670012	KENTUCKY	FAYETTE	15.4	14.0	13.4	14.7	13.8
210670014	KENTUCKY	FAYETTE CO	16.4	15.3	14.7	16.1	15.2
210730006	KENTUCKY	FRANKLIN	14.1	13.2	12.6	13.8	13.1
211110043	KENTUCKY	JEFFERSON CO	17.5	17.8	17.2	18.9	18.1
211110044	KENTUCKY	JEFFERSON	16.9	17.2	16.6	18.2	17.5
211110048	KENTUCKY	JEFFERSON	17.2	17.5	16.9	18.5	17.7
211110051	KENTUCKY	JEFFERSON	15.2	15.5	15.0	16.4	15.7
211170007	KENTUCKY	KENTON CO	15.7	16.0	15.4	17.0	16.1
211451004	KENTUCKY	MC CRACKEN	15.7	14.9	14.5	15.6	15.0
211950002	KENTUCKY	PIKE	17.7	17.6	17.3	18.3	17.8
212270007	KENTUCKY	WARREN	16.1	14.7	14.1	15.3	14.6
220171002	LOUISIANA	CADDO PAR	14.2	15.3	14.9	16.0	15.4
220190010	LOUISIANA	CALCASIEU	13.0	14.7	14.4	15.6	15.1
220290002	LOUISIANA	CONCORDIA	13.8	15.0	14.7	15.8	15.4
220330002	LOUISIANA	EAST BATON ROUGE PAR	15.3	18.1	17.8	19.2	18.7
220330009	LOUISIANA	EAST BATON ROUGE	15.1	17.9	17.6	19.0	18.5
220331001	LOUISIANA	EAST BATON ROUGE	13.5	16.1	15.7	17.0	16.6
220470005	LOUISIANA	IBERVILLE	15.3	17.9	17.5	18.7	18.2
220470009	LOUISIANA	IBERVILLE	12.6	14.7	14.4	15.4	15.0
220511001	LOUISIANA	JEFFERSON	13.8	16.6	16.3	17.6	17.1

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			PM2.5 Concentrations				
MONITOR ID	STATE	COUNTY	1999 Ambient	2020 Base	2020 Control	2030 Base	2030 Control
220512001	LOUISIANA	JEFFERSON PAR	14.8	18.8	18.4	20.0	19.5
220550005	LOUISIANA	LAFAYETTE PAR	12.9	14.1	13.7	14.7	14.2
220710010	LOUISIANA	ORLEANS PAR	15.1	19.2	18.8	20.4	19.9
220710012	LOUISIANA	ORLEANS	15.0	19.1	18.7	20.3	19.7
220730004	LOUISIANA	OUACHITA PAR	13.9	15.3	15.0	16.0	15.6
220790001	LOUISIANA	RAPIDES PAR	14.3	15.2	14.9	15.9	15.4
221050001	LOUISIANA	TANGIPAHOA	13.9	16.2	15.9	17.0	16.5
221210001	LOUISIANA	WEST BATON ROUGE PAR	14.9	17.6	17.3	18.7	18.2
230010011	MAINE	ANDROSCOGGIN CO	10.0	13.1	13.0	14.8	14.6
230010011	MAINE	ANDROSCOGGIN CO	10.0	13.1	13.0	14.8	14.6
230030013	MAINE	AROOSTOOK	10.6	11.0	11.0	11.4	11.4
230031011	MAINE	AROOSTOOK	8.1	9.2	9.1	9.8	9.8
230050027	MAINE	CUMBERLAND CO	10.0	12.7	12.6	14.3	14.1
230172011	MAINE	OXFORD	10.2	11.6	11.5	12.5	12.4
230190002	MAINE	PENOBSCOT CO	8.9	11.5	11.4	12.9	12.8
230194003	MAINE	PENOBSCOT CO	8.6	11.0	10.9	12.4	12.3
260050003	MICHIGAN	ALLEGAN CO	12.2	12.2	11.8	12.9	12.2
260210014	MICHIGAN	BERRIEN CO	12.3	12.3	11.8	12.8	12.2
260490021	MICHIGAN	GENESEE CO	12.0	12.0	11.7	12.6	12.1
260650012	MICHIGAN	INGHAM CO	12.6	12.4	12.0	13.0	12.4
260650012	MICHIGAN	INGHAM	12.9	12.7	12.2	13.3	12.6
260770008	MICHIGAN	KALAMAZOO CO	14.9	14.9	14.3	15.6	14.8
260770008	MICHIGAN	KALAMAZOO	14.7	14.7	14.1	15.4	14.6
260810020	MICHIGAN	KENT CO	13.8	14.0	13.5	14.8	14.0
260990009	MICHIGAN	MACOMB CO	12.7	12.8	12.5	13.3	12.9
261210040	MICHIGAN	MUSKEGON CO	12.2	12.4	12.0	13.1	12.5
261250001	MICHIGAN	OAKLAND CO	14.2	15.2	14.7	16.2	15.5
261390005	MICHIGAN	OTTAWA CO	12.9	13.1	12.6	13.9	13.1
261450018	MICHIGAN	SAGINAW	10.4	10.3	10.0	10.8	10.4
261470005	MICHIGAN	ST CLAIR CO	13.2	13.2	13.0	13.6	13.3
290210010	MISSOURI	BUCHANAN CO	12.5	12.7	12.3	13.2	12.6
290390001	MISSOURI	CEDAR	11.2	11.0	10.6	11.4	10.9
290470005	MISSOURI	CLAY	11.3	11.4	11.0	11.9	11.4
290470026	MISSOURI	CLAY CO	12.3	13.1	12.7	13.8	13.3
290470041	MISSOURI	CLAY	11.6	11.7	11.3	12.3	11.7
290770032	MISSOURI	GREENE CO	12.2	12.2	11.8	12.7	12.1

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MONITOR ID	STATE	COUNTY	1999 Ambient	2020 Base	2020 Control	2030 Base	2030 Control
290910003	MISSOURI	HOWELL	13.1	13.3	13.1	13.9	13.6
290950036	MISSOURI	JACKSON CO	10.9	11.4	11.1	12.0	11.5
290952002	MISSOURI	JACKSON	14.1	15.0	14.6	15.8	15.2
290990012	MISSOURI	JEFFERSON CO	15.1	15.8	15.2	16.8	16.0
291370001	MISSOURI	MONROE	10.9	10.6	10.3	11.0	10.6
291831002	MISSOURI	ST CHARLES CO	14.1	14.6	14.1	15.5	14.8
291860006	MISSOURI	STE GENEVIEVE	13.7	13.3	12.9	13.9	13.3
291892003	MISSOURI	ST LOUIS CO	15.3	16.0	15.4	17.0	16.2
291895001	MISSOURI	ST LOUIS	14.6	15.1	14.6	16.0	15.4
295100086	MISSOURI	ST LOUIS (CITY)	15.1	15.6	15.1	16.6	15.9
300290039	MONTANA	FLATHEAD	10.5	11.3	11.1	11.5	11.3
300490018	MONTANA	LEWIS AND CLARK	6.3	6.9	6.9	7.1	7.0
300530018	MONTANA	LINCOLN	15.9	18.3	18.1	18.6	18.3
300630024	MONTANA	MISSOULA	9.0	10.6	10.5	10.8	10.6
300630031	MONTANA	MISSOULA	9.8	11.2	11.0	11.4	11.2
300930005	MONTANA	SILVER BOW	7.3	8.3	8.2	8.6	8.4
301111065	MONTANA	YELLOWSTONE CO	8.0	8.8	8.7	9.1	8.9
311090022	NEBRASKA	LANCASTER CO	10.6	11.2	10.9	11.6	11.2
311090022	NEBRASKA	LANCASTER	11.6	12.2	11.9	12.6	12.2
320030022	NEVADA	CLARK	4.7	5.6	5.4	5.9	5.6
320030560	NEVADA	CLARK	11.2	17.3	16.6	19.3	18.2
320310016	NEVADA	WASHOE	9.9	11.3	10.7	12.1	11.4
320310016	NEVADA	WASHOE	9.8	11.1	10.6	12.0	11.2
340030003	NEW JERSEY	BERGEN CO	13.4	14.9	14.5	15.9	15.4
340171003	NEW JERSEY	HUDSON CO	14.4	15.5	15.1	16.6	16.0
340210008	NEW JERSEY	MERCER CO	12.4	13.2	12.8	14.0	13.4
340230006	NEW JERSEY	MIDDLESEX CO	10.9	11.4	11.1	12.2	11.8
340292002	NEW JERSEY	OCEAN CO	10.4	10.9	10.7	11.5	11.1
340310005	NEW JERSEY	PASSAIC CO	12.4	13.3	12.9	14.3	13.7
340390004	NEW JERSEY	UNION CO	14.7	15.5	15.1	16.5	16.0
340390006	NEW JERSEY	UNION	13.5	14.6	14.1	15.6	15.0
350010024	NEW MEXICO	BERNALILLO	6.3	7.4	7.2	7.8	7.6
350050005	NEW MEXICO	CHAVES	7.0	7.5	7.4	7.8	7.6
350130017	NEW MEXICO	DONA ANA CO	11.2	11.8	11.4	12.3	11.8
350131006	NEW MEXICO	DONA ANA	6.6	6.6	6.4	6.8	6.6
350171002	NEW MEXICO	GRANT	5.6	5.8	5.7	6.1	6.0

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MONITOR ID	STATE	COUNTY	1999 Ambient	2020 Base	2020 Control	2030 Base	2030 Control
350250007	NEW MEXICO	LEA	7.2	7.4	7.3	7.6	7.5
350431003	NEW MEXICO	SANDOVAL CO	5.2	6.1	6.0	6.5	6.3
350450006	NEW MEXICO	SAN JUAN	5.8	5.7	5.6	5.9	5.8
350490020	NEW MEXICO	SANTA FE CO	4.9	6.6	6.5	6.7	6.6
370210034	NORTH CAROLINA	BUNCOMBE	16.4	16.3	15.9	17.1	16.5
370670022	NORTH CAROLINA	FORSYTH CO	16.4	16.4	15.7	17.5	16.4
370670024	NORTH CAROLINA	FORSYTH	16.4	16.4	15.7	17.5	16.4
380150003	NORTH DAKOTA	BURLEIGH CO	7.6	8.2	8.1	8.4	8.3
380171004	NORTH DAKOTA	CASS CO	9.4	10.1	9.9	10.4	10.1
380350004	NORTH DAKOTA	GRAND FORKS CO	10.2	11.1	10.9	11.3	11.1
380570004	NORTH DAKOTA	MERCER	6.9	7.3	7.2	7.4	7.3
390090003	OHIO	ATHENS	13.7	12.6	12.4	13.1	12.7
390170003	OHIO	BUTLER CO	18.7	18.4	17.7	19.4	18.4
390350013	OHIO	CUYAHOGA CO	17.9	19.0	18.4	20.1	19.4
390350027	OHIO	CUYAHOGA	18.2	19.3	18.8	20.5	19.7
390350038	OHIO	CUYAHOGA	20.9	22.2	21.6	23.5	22.7
390350060	OHIO	CUYAHOGA	18.6	19.7	19.2	20.9	20.2
390350065	OHIO	CUYAHOGA	17.6	18.7	18.2	19.8	19.1
390350066	OHIO	CUYAHOGA	15.0	15.9	15.4	16.8	16.2
390351002	OHIO	CUYAHOGA	15.3	16.3	15.8	17.2	16.6
390490024	OHIO	FRANKLIN CO	18.3	18.5	17.9	19.4	18.7
390490025	OHIO	FRANKLIN	17.1	17.3	16.8	18.2	17.4
390490081	OHIO	FRANKLIN	17.0	17.0	16.4	17.8	17.1
390610014	OHIO	HAMILTON	19.9	20.1	19.3	21.2	20.1
390617001	OHIO	HAMILTON	17.2	17.3	16.6	18.3	17.4
390810016	OHIO	JEFFERSON	19.3	18.7	18.3	19.5	19.0
390811001	OHIO	JEFFERSON CO	18.3	17.0	16.5	17.6	17.0
390851001	OHIO	LAKE CO	13.8	14.6	14.3	15.3	14.9
390932003	OHIO	LORAIN CO	14.4	14.5	14.1	15.1	14.6
390950024	OHIO	LUCAS CO	14.9	15.4	15.0	16.3	15.6
390990005	OHIO	MAHONING CO	16.9	16.7	16.2	17.5	16.9
391130014	OHIO	MONTGOMERY CO	17.6	17.9	17.2	18.9	18.0
391130031	OHIO	MONTGOMERY	16.0	16.3	15.6	17.2	16.3
391330002	OHIO	PORTAGE CO	15.0	15.1	14.7	15.9	15.3
391450013	OHIO	SCIOTO	24.2	23.0	22.4	23.9	23.2
391510017	OHIO	STARK CO	18.4	17.9	17.3	18.8	17.9

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			PM2.5 Concentrations				
MONITOR ID	STATE	COUNTY	1999 Ambient	2020 Base	2020 Control	2030 Base	2030 Control
391510020	OHIO	STARK	17.4	16.9	16.3	17.7	16.9
391530017	OHIO	SUMMIT	18.0	18.1	17.6	19.0	18.3
391550007	OHIO	TRUMBULL CO	16.7	16.4	16.0	17.2	16.6
410030013	OREGON	BENTON	7.1	7.5	7.4	7.7	7.5
410290133	OREGON	JACKSON CO	11.8	13.8	13.6	14.0	13.7
410291001	OREGON	JACKSON	6.4	6.9	6.8	7.0	6.9
410350004	OREGON	KLAMATH	10.7	11.4	11.2	11.6	11.3
410370001	OREGON	LAKE	8.7	9.3	9.2	9.4	9.2
410390060	OREGON	LANE	8.5	9.4	9.3	9.6	9.4
410392013	OREGON	LANE	12.8	14.4	14.3	14.6	14.4
410470040	OREGON	MARION CO	7.5	7.8	7.6	8.0	7.8
410510080	OREGON	MULTNOMAH CO	8.8	10.0	9.8	10.6	10.3
410510244	OREGON	MULTNOMAH	8.5	9.6	9.4	10.2	9.9
410590121	OREGON	UMATILLA	8.8	9.5	9.4	9.7	9.5
410670111	OREGON	WASHINGTON CO	7.3	8.3	8.1	8.8	8.5
420010001	PENNSYLVANIA	ADAMS	13.1	12.5	11.9	13.2	12.3
420030064	PENNSYLVANIA	ALLEGHENY	18.8	17.0	16.4	17.7	16.8
420030064	PENNSYLVANIA	ALLEGHENY	22.0	19.9	19.1	20.7	19.7
420030116	PENNSYLVANIA	ALLEGHENY	16.4	16.3	15.8	17.1	16.4
420110009	PENNSYLVANIA	BERKS CO	13.5	13.3	12.7	14.0	13.2
420170012	PENNSYLVANIA	BUCKS CO	12.0	12.8	12.4	13.6	13.0
420210011	PENNSYLVANIA	CAMBRIA CO	14.8	13.8	13.4	14.3	13.7
420430401	PENNSYLVANIA	DAUPHIN CO	14.4	13.7	13.0	14.4	13.4
420450002	PENNSYLVANIA	DELAWARE CO	13.1	14.3	13.8	15.2	14.6
420692006	PENNSYLVANIA	LACKAWANNA CO	11.0	10.7	10.4	11.1	10.7
420710007	PENNSYLVANIA	LANCASTER CO	15.6	14.5	13.7	15.3	14.1
420770004	PENNSYLVANIA	LEHIGH CO	11.9	12.4	12.0	13.1	12.5
420791101	PENNSYLVANIA	LUZERNE CO	12.5	12.3	12.0	12.9	12.4
420910013	PENNSYLVANIA	MONTGOMERY CO	13.0	14.0	13.5	14.9	14.3
420950025	PENNSYLVANIA	NORTHAMPTON CO	12.9	13.4	12.9	14.2	13.5
421010004	PENNSYLVANIA	PHILADELPHIA	14.4	15.5	14.9	16.5	15.7
421250005	PENNSYLVANIA	WASHINGTON	15.4	14.0	13.4	14.5	13.8
421250200	PENNSYLVANIA	WASHINGTON CO	14.6	13.6	13.2	14.1	13.6
421255001	PENNSYLVANIA	WASHINGTON	13.0	12.9	12.5	13.5	13.0
421290008	PENNSYLVANIA	WESTMORELAND CO	14.9	13.5	12.9	14.0	13.3
421330008	PENNSYLVANIA	YORK CO	15.4	14.9	14.2	15.7	14.7

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MONITOR ID	STATE	COUNTY	1999 Ambient	2020 Base	2020 Control	2030 Base	2030 Control
450190049	SOUTH CAROLINA	CHARLESTON	13.1	13.9	13.7	14.5	14.2
450410002	SOUTH CAROLINA	FLORENCE CO	14.3	14.7	14.3	15.4	14.8
450430009	SOUTH CAROLINA	GEORGETOWN	13.5	14.0	13.8	14.6	14.2
450430009	SOUTH CAROLINA	GEORGETOWN	12.9	13.4	13.1	13.9	13.6
450470003	SOUTH CAROLINA	GREENWOOD	15.5	15.8	15.3	16.5	15.7
450790007	SOUTH CAROLINA	RICHLAND	15.4	15.9	15.4	16.7	16.0
450790019	SOUTH CAROLINA	RICHLAND CO	15.9	16.5	15.9	17.3	16.4
450830010	SOUTH CAROLINA	SPARTANBURG CO	16.0	16.6	15.9	17.5	16.5
481130050	TEXAS	DALLAS	17.0	20.3	19.6	21.9	20.9
481410037	TEXAS	EL PASO CO	9.4	9.8	9.6	10.3	9.9
484393006	TEXAS	TARRANT	12.6	14.8	14.2	15.9	15.1
490110001	UTAH	DAVIS CO	7.9	10.1	9.8	10.8	10.5
490350003	UTAH	SALT LAKE CO	10.9	13.9	13.4	15.0	14.4
490350012	UTAH	SALT LAKE	12.5	16.0	15.6	17.3	16.7
490353006	UTAH	SALT LAKE	9.9	12.7	12.4	13.7	13.2
490353007	UTAH	SALT LAKE	10.2	13.0	12.6	14.0	13.5
490450002	UTAH	TOOELE	9.3	10.9	10.7	11.6	11.2
490490002	UTAH	UTAH CO	9.4	11.0	10.7	11.8	11.3
490494001	UTAH	UTAH	9.3	11.9	11.5	12.9	12.3
490495010	UTAH	UTAH	7.7	9.1	8.8	9.8	9.4
490570001	UTAH	WEBER CO	9.9	11.3	11.1	11.9	11.5
490570007	UTAH	WEBER	8.1	9.2	9.1	9.7	9.4
500030005	VERMONT	BENNINGTON	9.9	9.9	9.7	10.3	10.0
500070007	VERMONT	CHITTENDEN CO	7.0	6.8	6.7	7.1	6.9
500210002	VERMONT	RUTLAND	10.9	10.8	10.6	11.2	10.9
500230005	VERMONT	WASHINGTON	10.8	10.5	10.4	10.9	10.6
500230005	VERMONT	WASHINGTON	10.6	10.3	10.1	10.6	10.4
510130020	VIRGINIA	ARLINGTON CO	13.8	15.2	14.5	16.4	15.4
510590030	VIRGINIA	FAIRFAX CO	13.3	14.7	14.0	15.8	14.9
510591004	VIRGINIA	FAIRFAX	14.5	15.9	15.2	17.2	16.2
510870015	VIRGINIA	HENRICO CO	13.3	13.8	13.5	14.5	14.0
511071005	VIRGINIA	LOUDOUN CO	12.7	13.4	12.8	14.3	13.4
515200006	VIRGINIA	BRISTOL CITY	16.4	15.4	14.9	16.1	15.4
515500012	VIRGINIA	CHESAPEAKE CITY	12.9	14.9	14.5	15.8	15.2
516500004	VIRGINIA	HAMPTON CITY	12.1	13.7	13.5	14.5	14.1
517000013	VIRGINIA	NEWPORT NEWS CITY	12.5	14.1	13.8	14.9	14.4

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MONITOR ID	STATE	COUNTY	1999 Ambient	2020 Base	2020 Control	2030 Base	2030 Control
517600020	VIRGINIA	RICHMOND CITY	14.5	15.9	15.4	16.8	16.1
517750010	VIRGINIA	SALEM CITY	13.2	12.7	12.3	13.2	12.7
518100008	VIRGINIA	VIRGINIA BEACH CITY	13.5	15.6	15.2	16.5	15.9
530110013	WASHINGTON	CLARK CO	9.4	10.6	10.4	11.2	10.9
530330021	WASHINGTON	KING	10.3	12.8	12.4	13.9	13.4
530330057	WASHINGTON	KING	11.5	14.3	13.9	15.5	14.9
530330080	WASHINGTON	KING	8.9	11.1	10.7	12.0	11.5
530332004	WASHINGTON	KING	10.9	13.6	13.1	14.7	14.1
530530031	WASHINGTON	PIERCE	11.1	13.7	13.2	14.7	14.1
530531018	WASHINGTON	PIERCE	9.7	11.9	11.5	12.8	12.2
530611007	WASHINGTON	SNOHOMISH	10.0	11.4	11.1	12.1	11.7
530630016	WASHINGTON	SPOKANE CO	10.3	13.1	12.9	13.4	13.1
530630047	WASHINGTON	SPOKANE	8.5	10.7	10.5	11.0	10.8
530670013	WASHINGTON	THURSTON CO	9.3	10.7	10.4	11.4	10.9
530730015	WASHINGTON	WHATCOM CO	8.1	8.5	8.4	8.8	8.6
540030003	WEST VIRGINIA	BERKEKEY CO	16.1	15.3	14.7	16.0	15.1
540090005	WEST VIRGINIA	BROOKE CO	17.8	17.2	16.9	18.0	17.5
540110006	WEST VIRGINIA	CABELL CO	18.2	18.2	17.9	19.0	18.5
540290011	WEST VIRGINIA	HANCOCK CO	16.9	16.4	16.0	17.1	16.6
540290011	WEST VIRGINIA	HANCOCK	17.3	16.7	16.4	17.4	16.9
540291004	WEST VIRGINIA	HANCOCK	16.8	16.3	15.9	16.9	16.5
540330003	WEST VIRGINIA	HARRISON	15.0	14.1	13.8	14.6	14.2
540390009	WEST VIRGINIA	KANAWHA CO	17.1	17.8	17.4	18.5	18.1
540391005	WEST VIRGINIA	KANAWHA	18.3	19.0	18.6	19.8	19.3
540391005	WEST VIRGINIA	KANAWHA	19.6	20.4	20.0	21.3	20.7
540511002	WEST VIRGINIA	MARSHALL CO	17.1	15.9	15.6	16.5	16.1
540610003	WEST VIRGINIA	MONONGALIA	14.9	13.9	13.6	14.3	13.9
540690008	WEST VIRGINIA	OHIO CO	15.9	14.8	14.4	15.4	14.8
540810002	WEST VIRGINIA	RALEIGH	14.0	13.4	13.1	13.9	13.5
540890001	WEST VIRGINIA	SUMMERS	11.8	11.2	11.0	11.6	11.3
541071002	WEST VIRGINIA	WOOD CO	17.8	17.3	17.0	18.0	17.5
550090005	WISCONSIN	BROWN CO	11.1	11.1	10.7	11.6	11.1
550090026	WISCONSIN	BROWN	10.6	10.6	10.2	11.1	10.6
550250025	WISCONSIN	DANE CO	13.1	13.3	12.8	14.0	13.3
550250047	WISCONSIN	DANE	13.4	13.6	13.1	14.4	13.6
550310025	WISCONSIN	DOUGLAS CO	8.6	9.7	9.5	10.3	10.1

APPENDIX E
1999 Annual Mean PM2.5 Values and Future-Year Predictions Based on RRFs

				PM2.5 Concentrations				
MONITOR ID	STATE	COUNTY		1999 Ambient	2020 Base	2020 Control	2030 Base	2030 Control
550550008	WISCONSIN	JEFFERSON		13.5	13.6	13.1	14.3	13.6
550790010	WISCONSIN	MILWAUKEE		14.5	15.9	15.4	17.0	16.2
550790026	WISCONSIN	MILWAUKEE		13.8	15.2	14.7	16.2	15.5
550790059	WISCONSIN	MILWAUKEE		15.0	16.1	15.6	17.1	16.4
550870009	WISCONSIN	OUTAGAMIE CO		11.2	11.4	11.0	12.0	11.4
551050002	WISCONSIN	ROCK CO		14.3	14.6	14.1	15.3	14.6
551330027	WISCONSIN	WAUKESHA CO		14.9	15.8	15.2	16.7	15.9
551330034	WISCONSIN	WAUKESHA		13.5	14.2	13.7	15.1	14.4
551390011	WISCONSIN	WINNEBAGO CO		11.6	11.6	11.2	12.1	11.6
551410016	WISCONSIN	WOOD		11.2	10.9	10.6	11.4	10.9
560210001	WYOMING	LARAMIE CO		5.6	6.6	6.4	6.9	6.7
560330001	WYOMING	SHERIDAN		8.5	9.3	9.2	9.5	9.3
560330002	WYOMING	SHERIDAN		9.5	10.4	10.2	10.6	10.4

**Appendix F:
IMPROVE Monitoring Sites used in the REMSAD Model Performance
Evaluation**

IMPROVE Site Code	Site Name	State
ACAD1	Acadia National Park	Maine
BADL1	Badlands National Park	South Dakota
BAND1	Bandelier National Monument	New Mexico
BIBE1	Big Bend National Park	Texas
BLIS1	Bliss State Park(TRPA)	California
BOWA1	Boundary Waters Canoe Area	Minnesota
BRCA1	Bryce Canyon National Park	Colorado
BRID1	Bridger Wilderness	Wyoming
BRIG1	Brigantine National Wildlife Refu	New Jersey
BRLA1	Brooklyn Lake	Wyoming
CANY1	Canyonlands National Park	Utah
CHAS1	Chassahowitzka National Wildlife	Florida
CHIR1	Chiricahua National Monument	Arizona
CORI1	Columbia River Gorge	Washington
CRLA1	Crater Lake National Park	Oregon
CRMO1	Craters of the Moon NM(US DOE)	Idaho
DEVA1	Death Valley Monument	California
DOLA1	Dome Lands Wilderness	California
DOSO1	Dolly Sods /Otter Creek Wildernes	West Virginia
EVER1	Everglades National Park	Florida
GICL1	Gila Wilderness	New Mexico
GLAC1	Glacier National Park	Montana
GRBA1	Great Basin National Park	Nevada
GRCA1	Grand Canyon NP- Hopi Point	Arizona
GRSA1	Great Sand Dunes National Monument	Colorado
GRSM1	Great Smoky Mountains National Park	Tennessee
GUMO1	Guadalupe Mountains National Park	Texas
JARB1	Jarbidge Wilderness	Nevada
JEFF1	Jefferson/James River Face Wildern	Virginia
LAVO1	Lassen Volcanic National Park	California
LOPE1	Lone Peak Wilderness	Utah
LYBR1	Lye Brook Wilderness	Vermont
MACA1	Mammoth Cave National Park	Kentucky
MEVE1	Mesa Verde National Park	Colorado
MOOS1	Moosehorn NWR	Maine
MORA1	Mount Rainier National Park	Washington
MOZI1	Mount Zirkel Wilderness	Colorado
OKEF1	Okefenokee National Wildlife Refu	Georgia
PEFO1	Petrified Forest National Park	Arizona
PINN1	Pinnacles National Monument	California
PORE1	Point Reyes National Seashore	California

APPENDIX F**IMPROVE Monitoring Sites used in the REMSAD Performance Evaluation
(Continued)**

IMPROVE Site Code	Site Name	State
PUSO1	Puget Sound	Washington
REDW1	Redwood National Park	California
ROMA1	Cape Romain National Wildlife Ref	South Carolina
ROMO2	Rocky Mountain National Park	Colorado
SAGO1	San Geronio Wilderness	California
SALM1	Salmon National Forest	Idaho
SAWT1	Sawtooth National Forest	Idaho
SCOV1	Scoville (US DOE)	Idaho
SEQU1	Sequoia National Park	California
SHEN1	Shenandoah National Park	Virginia
SHRO1	Shining Rock Wilderness	North Carolina
SIPS1	Sipsy Wilderness	Alabama
SNPA1	Snoqualamie Pass, Snoqualamie N.F	Washington
SOLA1	South Lake Tahoe (TRPA)	California
SULA1	Sula (Selway Bitterroot Wilderness)	Montana
THSI1	Three Sisters Wilderness	Idaho
TONT1	Tonto National Monument	Arizona
UPBU1	Upper Buffalo Wilderness	Arkansas
WASH1	Washington D.C.	Washington D.C.