August 12, 1999

EPA-SAB-COUNCIL-ADV-99-013

Honorable Carol M. Browner
Administrator
U.S. Environmental Protection Agency
401 M Street, SW
Washington, DC 20460

RE: The Clean Air Act Amendments (CAAA) Section 812 Prospective Study of Costs and Benefits (1999): Advisory by the Air Quality Models Subcommittee on Modeling and Emissions

Dear Ms. Browner:

On May 4 and 5, 1999, the Air Quality Models Subcommittee (AQMS) of the Advisory Council on Clean Air Compliance Analysis (Council) met to provide advice on six charge questions relating to trends in ambient concentrations of air pollutants associated with implementation of the 1990 Clean Air Act Amendments (CAAA of 1990, Section 812, Public Law 101-549, November 15, 1990, 104 Stat. 2399) projected to the year 2010. The Subcommittee reviewed draft material and received briefings from Agency staff and contractors. The AQMS also held a public teleconference call on June 3, 1999 to review and advise the Agency on additional aspects of the study analysis including primary Particulate Matter (PM) emissions, temporal and spatial extrapolation of air quality data, and emissions and air quality modeling uncertainty tables. The Council met on July 13-14, 1999 to review the draft study, *The Benefits and Costs of the Clean Air Act, 1990 to 2010; EPA Report to Congress (*U.S. EPA, Office of Air and Radiation and Office of Policy, June 1999) which presented an analysis of the costs and benefits associated with implementation of the CAAA. The analysis was based, in part, on emissions estimates and air quality reviewed by the AQMS and discussed in this letter.

This AQMS Advisory commends the Agency for the progress made since our last Advisory over a year ago. Many of our major concerns have been addressed and we believe that the current Prospective Study can proceed. In this letter, we are providing advice on three levels: (1) assumptions in the analysis, uncertainties in the results, and implications for overall conclusions that need to be more clearly discussed in the current Prospective Study; (2) changes in the general modeling approach, data bases and analysis to be used in the next prospective study; and (3) recommendations for Agency-wide review of emissions models to enhance validity not only of this 812 Prospective Study, but also other studies. We believe the recommendations calling for review of emission estimation procedures and comparison of emission estimates to observed pollutant concentrations will improve the basis for air quality planning by strengthening the projections of future trends in air pollutants.

This Advisory also identifies gaps in information, data, and methods that need to be filled to strengthen future prospective studies, which the CAAA requires to be submitted to Congress every two years. The current 812 Study will be the first prospective analysis. It is expected that the comprehensiveness of the analysis will increase over time, especially as further research becomes available for use in model simulations of emissions, exposure, health and ecological effects, and cost and benefits.

Future prospective studies could benefit greatly from the recommended Agency-wide analysis of emissions modeling, use of the same, high quality air quality modeling system platform (such as EPA's Models-3) across the entire United States, and further exploration of more robust techniques for dealing with uncertainties in complex assessments. The AQMS will be available for providing additional details on how these recommendations could be implemented in preparation for the next prospective study.

For the current study, the AQMS recommended orally at our meeting on May 3- 4, 1999 that the Agency describe the uncertainties associated with the analytical tools and data used and how those uncertainties could affect the air quality trends analysis and impact the cost/benefit analysis. We have recommended that these considerations be summarized at each step in the analysis in tables that include the data and tools, their limitations, the implications of the limitations for study results, and to the extent possible, provide an estimate of the uncertainty in the findings that result. The Agency responded with a proposed approach that was distributed to the AQMS and discussed at our teleconference on June 3, 1999. The Subcommittee generally found the proposed approach appropriate for the current Prospective Study.

Response to Charge Questions Posed by the Office of Air and Radiation

Charge Question 1. Are the input data used for each component of the analysis sufficiently valid and reliable for the intended analytical purpose?

Response. Yes, the input data are sufficient for the current version, with the following reservations. It will be necessary to improve the input data for subsequent versions by considering the following recommendations, listed in order of importance.

The AQMS interprets input data to include the emissions estimates that are used in the air quality modeling, the results of the air quality modeling, the measured concentration data that are used with the modeling data to determine future air quality trends, and the final resulting air quality trends that are the input for the benefit / cost analyses.

With respect to the emissions inventory information, we recommended in our oral comments to the Agency on May 4-5, 1999 that the discrepancies between the partitioning of the PM sources based on the inventory of emissions versus partitioning based on observational data for PM be discussed in the report. We note, based on our conference call of June 3, 1999, that the Agency is planning to respond to this recommendation.More detail on this issue is provided in our response to Question 4. In addition, current controversies over volatile organic

carbon (VOC) emissions and particulate carbonaceous emissions from the transportation sector need to be noted. The observational data limitations with respect to PM and ozone need discussion.

The 812 Study provides processes for specifying quality of the concentration data used. However, as noted in more detail in the discussions for Charges 5 and 6, we recommend that the Agency carefully assess the use of the data and the techniques for treating data gaps. The air quality models, as well as the data processing tools used to develop the projected air quality trends for use in the cost/benefit analyses, are discussed in the response to Charge 2.Each of the limitations and the impacts of these data limitations on the resulting data set needs to be succinctly presented in the report. By providing a careful analysis of uncertainty and its implications for the findings and next steps in the impacts analysis, the limits in the cost and benefit conclusions reachable by the current Prospective Study will be clarified.

Charge Question 2. Are the models, and the methodologies they employ, used for each component of the analysis sufficiently valid and reliable for the intended analytical purpose?

Response. The AQMS interprets the Charge Question to pertain to the emission models used to develop the emissions data, the air quality models used to develop projected air quality concentrations, and the techniques used to develop adjustment factors and fill data gaps (i.e., establish trends at locations where there are no observational data available). Our responses to Charges 5 and 6 below provide more detail to the techniques for developing adjustment factors and filling data gaps.

As noted in our response to Question 1, we strongly recommended in our oral advice on May 4-5, 1999 that the Agency summarize the model limitations and their impact on the analysis findings. We observe, based on materials provided for the June 3, 1999 teleconference call, that the Agency is proposing such a summary in a concise table format, based on the model used for the Retrospective Study. The Subcommittee finds that a summary in such a format would be useful, but has not reviewed the content.

For the next Prospective Study, we recommend careful assessment of the overall approach to emissions modeling and evaluation of resulting emissions in light of measured components of particulate matter and of air quality data trends. In addition, we recommend the use of a single, much more comprehensive modeling system platform (such as EPA Models-3) allowing use of consistent , appropriate and best available process descriptions throughout the country. This advice echoes recommendations in our January 1998 Letter Advisory (*The CAA Section 812 Prospective Study of Costs and Benefits-Air Quality Models and Emissions Estimates Initial Studies,* EPA-SAB-COUNCIL-ADV-98-002) on the 812 Study. We understand that Models-3 may be available for the next Prospective Study and, if so, use of this model should be considered. Comprehensive review of the emissions inventory development process and resulting estimates, with particular emphasis on the reconciliation of emission inventory estimates and modeling results with ambient measurements, is needed to strengthen many other studies in addition to the 812 Study. For the current study, the Agency needs to

outline carefully the limitations of the models that were used, along with the implications of these limitations for the overall study results.

Charge Question 3. If the answers to either of the two questions above is negative, what specific alternative assumptions, data or methodologies does the Council recommend the Agency consider using for the first prospective analysis?

Response: To reiterate, the AQMS suggests that limitations and implications be presented in a table at each major step of the analysis (i.e., emission estimates, air quality analyses, adjustment factor derivation and data gap treatment). These descriptions of uncertainties need to clearly distinguish between those associated with data availability and analysis and model formulations and limitations. We also recommend that the Prospective Study team follow our suggestions regarding use of the Voronoi Neighbor Averaging (VNA) technique as is outlined in our response to Question 6. We also emphasize the need to explore use of the same modeling system across the United States in the next Prospective Study.

Charge Question 4. Do the revisions made to the particulate matter emissions inventories -- as described in the draft Report to Congress Emissions Appendix-- adequately address the concerns raised by the Council and the AQMS during the January - February 1998 review meetings? If not, are there further adjustments which the Council and AQMS would recommend be made in future assessments; and do residual potential errors in the inventories warrant --in the judgment of the Council and AQMS-- inclusion in EPA's pending report specific caveats regarding the magnitude and direction of potential biases which might be introduced through reliance on these inventories?

Response. We compliment EPA's effort to improve the emissions estimates used in this Prospective Study. The primary PM emissions inventory now partially reflects the downward direction present in the ambient measurement data sets. We note that the Agency has responded to oral advice we gave in May by developing a method to reduce the discrepancy between emissions category partitioning for the PM and observational data for PM. The Subcommittee will need to analyze more detailed information on the methodologies used for these adjustments before it can comment fully on the technical basis for the adjustments.

The current Criteria Document for PM, *Air Quality Criteria for Particulate Matter* (EPA/600/P-95/001aF/cF, 1996), has pie charts that show typical crustal contributions to PM 2.5 and PM 10 in both eastern and western cities based on air quality observations. The AQMS concurs that the urban crustal component of PM 2.5 is on the order of 10 per cent or less of the mass based on ambient data. The inventories used in this Prospective Study indicate that crustal material constitutes more than half of the directly emitted PM 2.5. The Subcommittee recognizes that the deposition rate of larger, crustal components of PM 2.5 is greater than that of smaller, combustion generated particles and this difference can therefore reduce the subsequent downwind concentration of crustal derived particles relative to combustion generated particles. However, the Subcommittee believes that the ratio of crustal to combustion emission rates was substantially overestimated in the analysis reviewed at the May 4-5 meeting.

The further analysis of crustal material emission estimates reviewed at the June 3, 1999 teleconference call appears to be a substantial move in the right direction. The further analysis indicating a larger contribution of carbonaceous materials from diesel vehicles also appears to be in the right direction. The available emissions data on gasoline powered vehicles remain inadequate to produce emission inventory estimates large enough to account for attribution (based on tracer compounds of motor vehicle emissions measured in ambient air) of the carbonaceous component of ambient PM 2.5 to these vehicles in different parts of the country.

The AQMS wishes to comment further on the deficiencies in the emissions inventory that relate to this issue. The Subcommittee believes that one explanation for the discrepancy between emissions category partitioning and observational data for PM could be that emission inventories underestimate the directly emitted carbonaceous material. Data from both the Los Angeles basin and from the Northern Front Range Air Quality Study indicate that carbonaceous emissions from the fleet of spark ignition vehicles are of the same order of magnitude as emissions from the diesel fleet. Detailed analysis of ambient data from the Los Angeles basin shows that diesel and gasoline mobile sources contribute about 30 to 50 per cent of the approximately 7 μ/m^3 average organic carbon concentration in the downtown Los Angeles area[1]. In this area sulfate plus nitrate and ammonium make up about 12 μ/m^3. The Schauer Study shows that ambient concentrations of primary organic materials in the PM 2.5 fraction are over three times as high as would be indicated from crustal emissions.

This finding is consistent with the Sepulveda tunnel study which showed that organic and elemental carbonaceous materials were responsible for 30 to 40 per cent of the PM 2.5 in the tunnel, and that crustal material contributed only 7.8 percent of the PM 2.5.[2] The Subcommittee members have the impression that the ratio of exhaust emissions to crustal emissions from the roadway shown in the Cadle et al. review is indicative of the ratio of actual emissions determining particulate air quality in the United States.

The available information strongly suggests that mobile source carbonaceous emissions are currently large contributors to public exposure to PM 2.5 and that they are underestimated in current emission inventories. As a result, we think that the current draft 812 Prospective Study does not include a reliable means for estimating the extent to which mobile source programs under the CAAA provisions would reduce public exposure to carbonaceous material. The study

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[1]Schauer, James J.; Rogge, Wolfgang F.; Hildemann, Lynn M.; Mazurek, Monica A.; Cass, Glenn R.; Simoneit, Bernd R.T., "Source apportionment of airborne particulate matter using organic compounds as tracers," *Atmospheric Environment*, Vol. 30, 1996, No. 22, pp. 3837-3855,.

[2]As described in Cadle, Steven H.; Gorse, Robert A.; Belian, Timothy C.; Lawson, Douglas R., 1993, "Real-world vehicle emissions: A Summary of the Eighth Coordinating Research Council On-Road Vehicle Emissions Workshop", *Journal of the Air and Waste Management Association*, v.49, p.242-255.

must acknowledge this omission, since neglect of the mobile source contribution results in a potentially large underestimate of the benefits of reducing directly emitted PM.

This emissions inventory issue could distort the air quality simulations. The study Appendix C states on page 45, that the Regional Acid Deposition Model-Regional Particulate Matter (RADM-RPM) organic aerosol estimates were not included in the final analysis because the model significantly underestimated organics and the reason for this systematic underestimation has not yet been characterized. These underestimates can be attributed to limitations in the model formulation and to input emissions and meteorological data. We suggest that one major reason for this underestimation is that most organic material appears to be directly emitted and that it is underestimated by several fold in the inventories used in the 812 Prospective Study and the national emission trends inventories.

The AQMS has another concern with the PM emissions estimates that has a direct impact on the quality of the air quality modeling results to be used in the cost/benefit analysis. The comparison of the PM 10 estimates in the Regulatory Modeling System for Aerosols and Deposition (REMSAD) with measured values in the western United States show a pattern of substantial underestimation. Because this pattern is much more prevalent for PM 10 than for PM 2.5, it suggests that the sources are more localized in their effects on airborne concentrations than the size of the modeling grid cells. Thus, averaging over the whole volume of the modeling grid cell leads to consistent underestimation in the PM concentrations. This raises a problem for the estimation of concentrations at the census tract level. If the effects of the PM are linear with no threshold, then there should not be a problem with the assumptions in the analysis. However, if there is a threshold and a non-uniform distribution of population across the grid cell, there could be substantial under or overestimation of effects. It is not feasible to eliminate this problem in the current Prospective Study, but it needs to be recognized as a potentially large source of uncertainty in the outcome.

Charge Question 5: The Project Team has used an expanded array of air quality model-derived adjustment factors to estimate changes relative to baseline air quality concentrations. Specifically, rather than a single adjustment factor applied in the Retrospective Study to estimate concentration changes across the entire range of initial ambient concentrations for a given pollutant, ten separate adjustment factors were calculated and applied based on decile midpoints generated by the relevant air quality model. Do the Council and AQMS consider this methodological change to reflect an improvement in the validity and reliability of projected concentration changes?

Response. The proposal to derive separate adjustment factors for different concentration ranges from results of the model and then to apply the factors to observations to obtain future changes in air quality seems reasonable. The choice of percentile values at which to make the changes in an adjustment factor also seems to be justifiable. To demonstrate the validity of the approach, we recommend that the Agency show illustrations of the observed distributions and the simulated distributions so that the two distributions can be easily compared.

Charge Question 6: The Project Team has used an alternative spatial inte rpolation method to estimate baseline air quality concentrations in locations that do not have adequate local monitoring data. In the Retrospective Study, complete representation of initial air quality conditions in the 48 contiguous states for each pollutant was obtained by simple spatial interpolation to each unmonitored or under monitored location from the closest relevant, sufficiently operated monitor. Based on advice from the AQMS and Council pursuant to the January - February 1998 review meetings, the Project Team sought to develop an enhanced methodology based on a space-time continuum concept described by the AQMS. The homology mapping technique subsequently developed by the Project Team proved promising in initial validation tests; however the Project Team concluded that additional development and validation work should be completed before using the tool in the context of the section 812 studies. As an alternative, an enhanced version of the traditional spatial interpolation method was developed which relies on inverse distance-weighted interpolation from multiple surrounding monitors. This technique is referred to as Voronoi Neighbor Averaging (VNA). The Project Team requests advice from the Council and AQMS on the two sub-questions:

Charge Question 6.1. Do the Council and AQMS consider the homology mapping technique a reasonable adaptation of the space-time continuum concept previously advanced? If so, what specific additional development, testing, and validation steps do the Council and AQMS recommend be undertaken by the Project Team to facilitate potential use of this technique in future assessments?

Charge Question 6.2. Do the Council and AQMS consider the change to the VNA approach to reflect an improvement in the validity and reliability of projected initial air quality concentration estimates relative to the previous, single monitor spatial interpolation method?

Responses. The use of the VNA method is reasonable and justifiable for interpolating within the bounds of a region surrounded by monitors. It is much less certain that it can be used to extrapolate over substantial distances where no data are available. The homology mapping technique appears promising, but it would be premature to employ it in this Prospective Study without further refinement of the input data and testing.

The need for a technique like VNA arises from the basic approach as shown in Figure II-1, p. 2-4 of the Technical Report. Because model-derived adjustment factors are applied to measurement data, the approach is limited to those locations that have observatories. Due to the request from the Council to provide complete coverage of forty-eight states and because only 81% of the population live in counties within 50 kilometers of a monitor, there arises a need to estimate ozone and PM distributions for the non-monitored counties. In the Retrospective Study, these estimated counties were assigned the same values as the nearest monitored location.

In response to advice from the AQMS, the Agency sought to improve upon this process and has produced two techniques, the VNA method and the homology mapping technique. While the VNA method does a better job of interpolation than simply assigning the nearest monitor, interpolation of a sparse, highly variable field may not be appropriate. This is because no process

or cause-and-effect information that spans the non-monitored area was used in the VNA algorithm and the VNA method merely computes a surface at the average height of the nearest monitors (effectively VNA interpolates the results, not the causes). When nearest monitors are located in different causal regions linearly interpolating between those regions may produce very serious errors. For example, between Columbia, South Carolina; Atlanta, Georgia; Jacksonville, Florida; and Tampa Florida, the VNA method produces a nearly uniform field of ozone at the average value of the monitors in these four cities, more than 120 ppb, yet the air quality model shows that there is an ozone minimum between Atlanta and Jacksonville that is 60 ppb for one case and 40 ppb (the model's background) on other days. This type of problem happens in Texas and between Portland, Oregon and Seattle, Washington. The Agency also developed another methodology, the homology mapping technique which assumes that similar features or characteristics result in similar ozone or PM. This is not an interpolation method; it is a substitution method. It assumes that the monitored data set has a set of conditions that are sufficiently similar to those in the non-monitored regions and that there is a set of discriminating features available for both the monitored and non-monitored areas. This method is more causally dependent than the VNA method and potentially more accurate than the VNA method. Successful application of the method depends on the selection of a feature set that is truly causal for the phenomenon being estimated.

The AQMS concurs with the Agency that application of the homology mapping technique is premature given its stage of development and testing. The AQMS believes that this method has sufficient promise that it should be further developed and evaluated. This includes exploring alternative feature sets such as, for example, adding terrain (e.g., valley floor, mountain side), use of neural-net techniques, and extensive testing within the data set.

As presently formulated, neither the VNA nor the homology mapping technique takes advantage of the best cause and effect relationships available to the Agency, the air quality model simulations themselves. A lot of effort was expended to produce 48-state model coverage, but the choice of model scaling technique, which requires monitored data, results in the loss of important information contained in the model output. The AQMS gave the Agency oral advice in May to develop a method that would take advantage of the air quality modeling simulation results in estimating concentrations at the non-monitored counties.

The Subcommittee received a proposal for just such a method immediately before the June 3, 1999 teleconference call.Although the proposed method is not tested, the Subcommittee finds it an acceptable approach for the current Prospective Study, provided the Agency acknowledges that the modified VNA method depends in part on simulation models. As a result, it will be subject to the uncertainties associated with them. Acknowledgment of these model-related uncertainties needs to appear both in the discussion of the VNA approach. It also needs to be reflected in the discussion of overall sources of possible error in the estimated health and ecological effects which are based on the air quality analysis results.

The AQMS also suggests that the Agency develop a testing protocol that compares the VNA method for two different sets of locations, those near monitors and those more distant from

monitors. The results from this test will help guide the design of future Prospective Studies. In future studies, the homology mapping technique should be further developed and alternative feature sets should be explored, perhaps including county-averaged emission density.

Conclusion

In summary, the AQMS commends the study team on the progress since the last review. The remaining limitations (particularly those associated with the PM emissions and air quality simulations), if captured in concise discussions and tables, should strengthen the acceptability of the overall report. We also want to emphasize that future prospective studies could benefit greatly from our recommended Agency-wide analysis of representativeness and reliability of emissions modeling, use of the same, high quality air quality modeling system platform (such as Models-3) across the entire United States, and further exploration of a wider range of techniques for dealing with uncertainties in complex assessments. The AQMS is ready to help support the emissions review and reconciliation of emissions inventories and modeling results with observations. This issue cuts across many activities of the Agency and deserves careful consideration.

We thank the Agency for the opportunity to be of service in review of the building blocks that will lead to the forthcoming Prospective Study and to the review of the draft Study itself. We look forward to the response to this Advisory from the Assistant Administrator of the Office of Air and Radiation.

Sincerely,

Dr. Maureen L. Cropper, Chair
Advisory Council on Clean Air
Compliance Analysis

Dr. Paulette Middleton, Chair
Air Quality Models Subcommittee
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GLOSSARY OF TERMS AND ACRONYMS

ADV	Advisory
AQMS	Air Quality Models Subcommittee (of the Council)
CAAA	Clean Air Act Amendments
C-R	Concentration-Response
EPA	U.S. Environmental Protection Agency (U.S. EPA)
GIS	Geographic Information System
HAP	Hazardous Air Pollutant
HEES	Health and Ecological Effects Subcommittee (of the Council)
LTR	Letter Report
N	Nitrogen
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter (2.5 microns in diameter)
PM10	Particulate Matter (10 microns in diameter)
ppb	Parts per billion
RADM-RPM	Regional Acid Deposition Model-Regional Particulate Matter
REMSAD	Regulatory Modeling System for Aerosols and Deposition
VNA	Voronoi Neighbor Averaging