Georgia Department of Natural Resources

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Noel Holcomb, Commissioner
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August 19, 2008

Mr. J. I. Palmer, Regional Administrator
U.S. EPA, Region IV
Atlanta Federal Center
61 Forsyth Street, SW
Atlanta, Georgia 30303-8909

Subject: Request for Approval to Use New IMPROVE Equation for BART Modeling

Dear Mr. Palmer:

The Georgia Environmental Protection Division (GA EPD) has been working with the Visibility Improvement States and Tribal Association of the Southeast (VISTAS) and the U.S. Environmental Protection Agency (EPA) Region IV staff to implement the Best Available Retrofit Technology (BART) requirements of the Regional Haze Rule. As part of this process, the need for a methodology to post-process CALPUFF/CALPOST modeling data to implement the new IMPROVE equation was identified. VISTAS tasked Dr. Ivar Tombach to develop such a methodology. The resulting spreadsheet and supporting information was submitted by the State of North Carolina to EPA and the Federal Land Managers (FLMs) for review. EPA Region 4 staff commented that they consider this post-processing methodology a non-regulatory modeling application requiring compliance with Section 3.2 of Appendix W Part 51: *Guideline on Air Quality Models* and that NCDAQ must obtain approval for its use from the EPA Regional Administrator. On the basis of these comments and for the reasons discussed below, GA EPD is providing the following additional information and requests a formal approval of use of this alternative by the affected sources for BART exemption and BART determination modeling.

Rationale for Use of New IMPROVE Equation

The new IMPROVE equation, which is a much better representation of the effects of particulate matter on light extinction than the old equation, takes into account the latest scientific understanding of several parameters:

1. The new algorithm overcomes biases of the old algorithm on the haziest days and the clearest days as demonstrated by comparing the measured light extinction from nephelometers at Class I areas to light extinction calculated using each of the equations.

2. The new algorithm recognizes spatial and temporal variation in light extinction as size distribution of the aerosol changes by increasing extinction efficiency as sulfate, nitrate and organic concentrations increase.

3. The new algorithm incorporates a term to reflect the contribution of fine sea salt and its hygroscopic growth with increasing relative humidity recognizing research findings showing that fine sea salt can be an important contributor to light extinction in coastal areas.

4. The new algorithm reflects research finding that the mass concentration of particulate organic matter in rural areas is greater than represented by the old equation.

5. The new algorithm includes a NO_2 term to represent times when light absorption by NO_2 is a meaningful contributor to light extinction.

6. The new algorithm incorporates site-specific Rayleigh scattering values to better represent sites close to sea level or with very hot or cold climates.

With this combination of revisions to the IMPROVE equation, the resulting apportionment of extinction to various components is more accurate on the haziest and clearest days. This is important for development of emission control strategies since the benefits of control of concentrations of each species will be represented more correctly with the new algorithm. Further discussion of these reasons is included in Enclosure 1.

Two of Georgia's BART eligible sources, Georgia Pacific Cedar Springs and Georgia Power Company-Plant Bowen, have requested the use of the new IMPROVE equation. Specifically, the new IMPROVE equation will more accurately represent the spatial and temporal variation in light extinction caused by sulfate, nitrate, and organic carbon concentrations. As a result, these sources can better determine their contribution to haze and more accurately evaluate the benefits of potential control strategies.

A spreadsheet was developed for VISTAS by Dr. Tombach to implement the entire new IMPROVE equation for use with CALPUFF and contains a modification of CALPOST that calculates the light extinction from the CALPUFF output. In the review of the spreadsheet and supporting documentation, EPA Region IV staff commented that the VISTAS methodology contained in the spreadsheet appropriately implements the features of the new IMPROVE equation, with the exception of the nitrogen dioxide term. EPA Region 4 further stated that it would be acceptable to use the total NO_x concentration from the CALPOST output as a conservative surrogate for NO_2 in order to address the NO_2 term in the new IMPROVE equation. EPA Region IV indicated that the

VISTAS methodology to incorporate the new IMPROVE equation would be acceptable on a case-by-case basis upon consultation with the EPA Regional Office once the NO_2 term was addressed. Since the initial EPA review of the methodology, Dr. Tombach has modified the spreadsheet to address the NO_2 contribution. A copy of the modified spreadsheet and instructions is provided as Enclosure 3 for your review.

Evaluation Performance versus Measured Values

Comparison of the old versus new IMPROVE equation and nephelometer data at several Class I areas, including Okefenokee and Cohutta, are included in Enclosure 2. The old IMPROVE equation tends to show a low bias on high extinction days. The new equation shows a better match on high extinction days with a slight high bias. The correlation coefficients are often slightly lower for the new equation than the old equation because there is slightly more scatter at the low end of the equation. Overall, this data indicates that the new equation is overall a much better tool for converting mass data into visibility data than the old equation.

We look forward to your response to this request for approval to use the VISTAS methodology for purposes of BART exemption modeling and BART determination modeling. Should you have any questions regarding this matter, please contact James Boylan at (404) 362-4851.

Sincerely,

Carol A. Couch
Director

CC:HA:JJ:JK:TV:klc

Enclosures

c: Jimmy Johnson, GA EPD
Jim Boylan, GA EPD
Jim Kelly, GA EPD
Dick Schutt, EPA Region 4
Michele Notarianni, EPA Region 4
Brenda Johnson, EPA Region 4

Enclosure 1.

DRAFT 10/26/06

Why Use the New IMPROVE Algorithm?

The new IMPROVE algorithm, which has been approved by the IMPROVE Steering Committee, is a much better representation of the effects of particulate matter on light extinction than the old IMPROVE algorithm. Excellent justification of this conclusion is provided in the November 2005 report of the IMPROVE Steering Committee, "Revised IMPROVE Algorithm for Estimating Light Extinction from Particle Speciation Data."

The new algorithm incorporates changes that represent much of what has been learned about the relationship between particulate matter component concentrations and light extinction in the more than a decade since the old algorithm was developed. The main reasons that justify using the new algorithm instead of the old one are the following:

1. The new algorithm overcomes the biases of the old algorithm on the haziest days (when the old algorithm underestimates light extinction) and on the clearest days (when the old algorithm overestimates extinction).

2. The new algorithm recognizes that light extinction efficiencies vary from location to location and time to time as the size distribution of the aerosol changes, and it reflects this variation by increasing the extinction efficiency as the concentrations of sulfates, nitrates, and organics increase. It also recognizes that the humidity-related growth rates of particles differ depending on their sizes. As a result, the new algorithm generally does a better job of representing light extinction at individual sites than does the old algorithm, as indicated by the reduced fractional biases in each RPO region

3. The new algorithm recognizes research findings that show that fine sea salt can be an important contributor to light extinction in coastal areas, and thus includes a new term that reflects its contribution and its hygroscopic growth with increasing relative humidity. The old algorithm ignores sea salt, probably because it was originally developed mainly for inland Class I areas in the inter-mountain West (although incorporating sea salt into the calculation was already considered in a University of California at Davis memo in 1995).

4. The new algorithm acknowledges that substantial recent research has shown that the mass concentration of particulate organic matter (often denoted by OMC in IMPROVE publications) in rural areas is a greater multiple of the measured OC concentration than the 1.4 value used in the old algorithm. The new algorithm updates the factor to a more-appropriate1.8.

5. The new algorithm recognizes that there may be times (near urban areas or in some source emission plumes) when light absorption by NO_2 gas is a meaningful contributor to light extinction, and thus includes a new term based on the NO_2 concentration.

6. The new algorithm recognizes that the assumption of constant Rayleigh scattering of 10 Mm^{-1} (representative of an elevation of about 5000 feet) may have been adequate when only inter-mountain West sites were considered, but is a distortion for sites close to sea level or with very hot or cold climates. It thus allows for site-specific values of the Rayleigh scattering.

At any given location, the net result of all these changes is typically small on average because some changes result in increases in extinction and some in decreases, but the apportionment of that extinction to the various components is more accurate with the new algorithm, especially on the haziest and clearest days. This is particularly important for the development of emission management strategies, because the benefits of control of concentrations of each species will be represented more correctly with the new algorithm.

Enclosure 2.

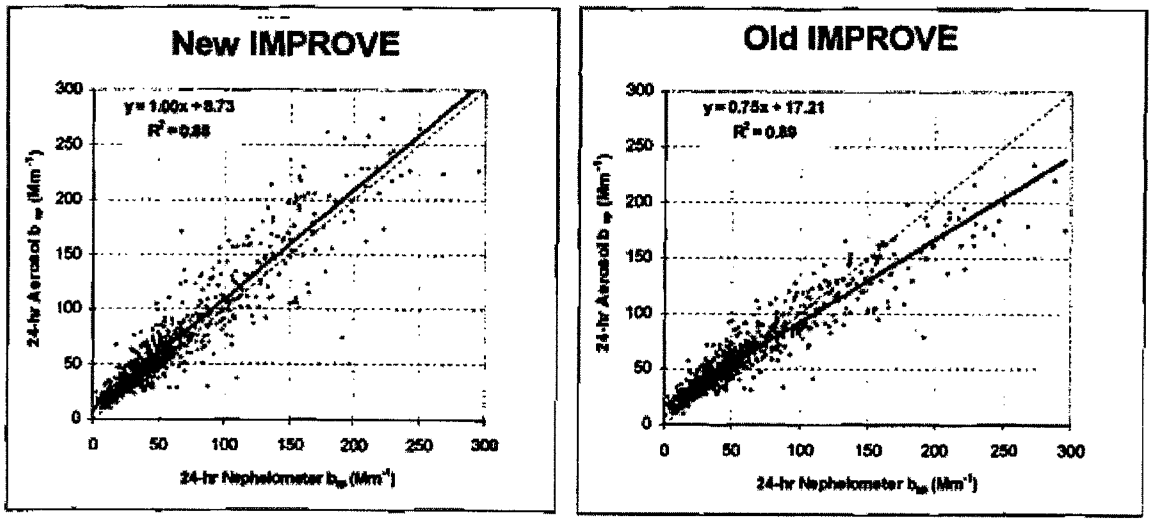

Figure 1. Aerosol Scattering vs Nephelometer Scattering Comparing New and Old IMPROVE Algorithm and Daily f(RH), Great Smoky Mountains National Park, 1995-2004

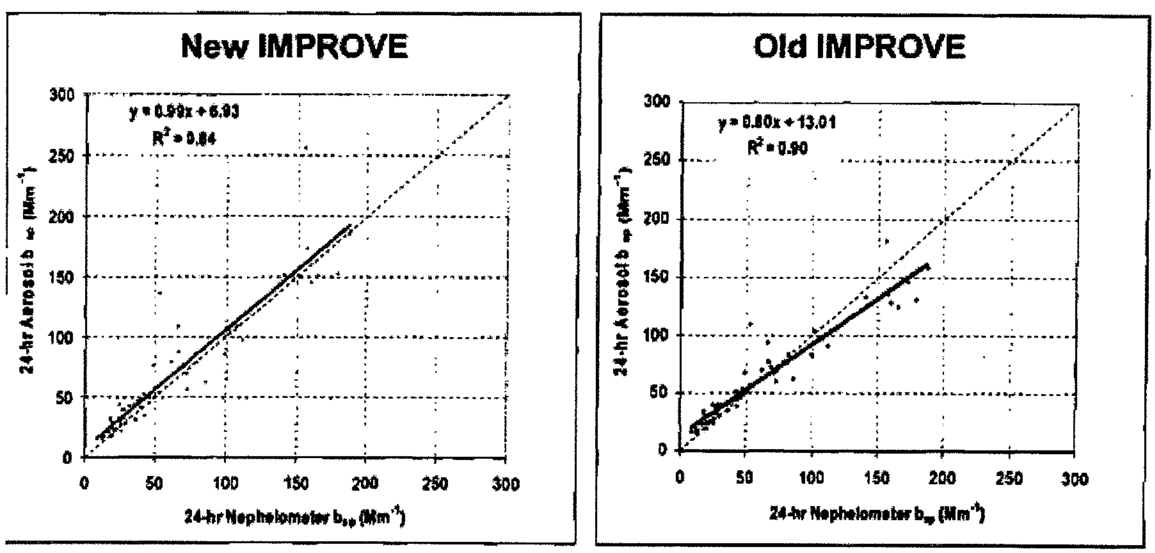

Figure 2. Aerosol Scattering vs Nephelometer Scattering Comparing New and Old IMPROVE Algorithm and Daily f(RH), Cohutta Wilderness Area, 2004

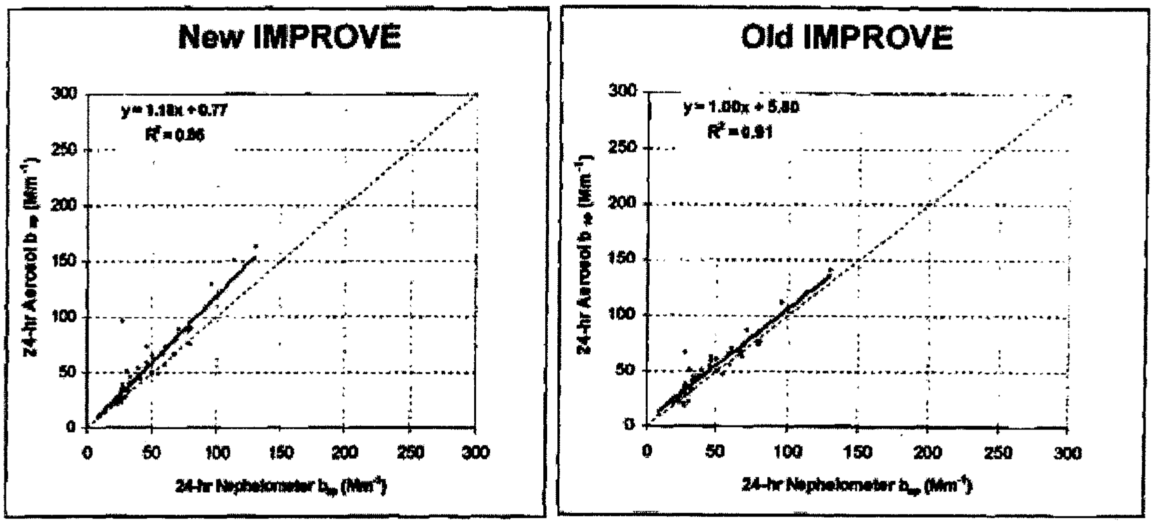

Figure 3. Aerosol Scattering vs Nephelometer Scattering Comparing New and Old IMPROVE Algorithm and Daily f(RH), Cape Romain Wildlife Refuge, 2004

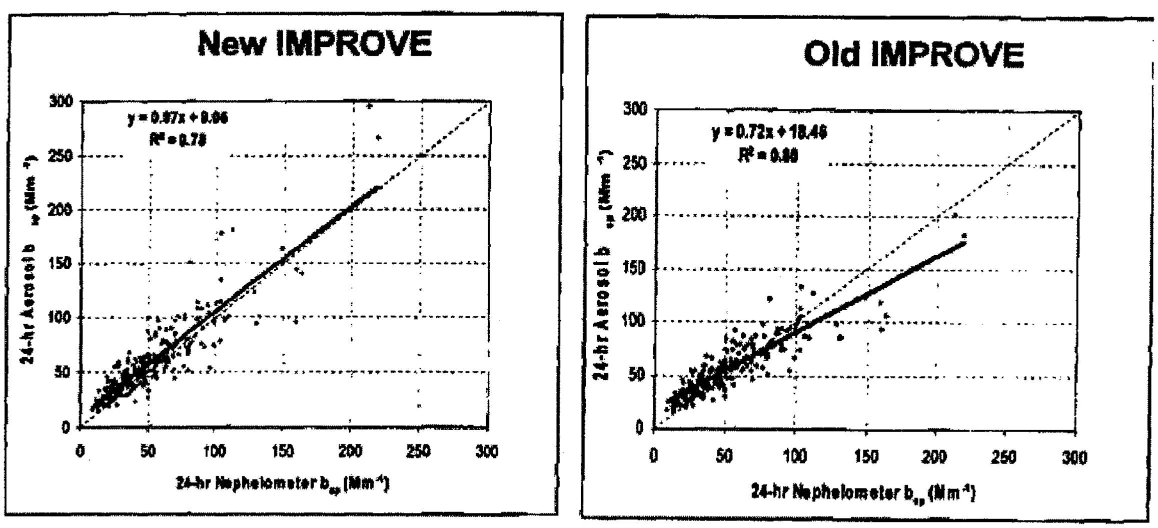

Figure 4. Aerosol Scattering vs Nephelometer Scattering Comparing New and Old IMPROVE Algorithm and Daily f(RH), Okefenokee Wilderness Area, 1993-1997

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Instructions: A Postprocessor for Recalculating CALPOST Visibility Outputs with the New IMPROVE Algorithm

Version 2
14 October 2006

Introduction

CALPOST can be used to processes outputs from CALPUFF modeling of a source's emissions to calculate the 24-hr average visibility impairments caused by primary and secondary particulate matter attributable to emissions from the modeled source. Those increments are presented in two tables, both labeled "Ranked Daily Visibility Change", in the CALPOST output (.LST) file. The table of interest to us has the subtitle "Modeled Extinction by Species" and lists the dates and locations of such incremental impacts in light extinction (b_{ext}) in ranked order, starting with the one that represents the largest percentage change in light extinction.[1]

In addition, with a different setup of the control file CALPOST.INP, the CALPOST postprocessor can be used to calculate 24-hr averages of NO_x concentrations. As described below, the outputs from that additional CALPOST run can be used to assess the visibility impact of the NO_2 gas in the source plume.

Visibility effects due to particulate matter are calculated in CALPOST from CALPUFF-modeled particulate matter component concentrations using effectively the "traditional" IMPROVE algorithm. CALPOST allows for choice of the humidity scattering enhancement function (f(RH)) to be used with the IMPROVE algorithm; for modeling in connection with the US EPA's Regional Haze Regulations (RHR), the appropriate form of f(RH) is the one described and tabulated in the EPA's 2003 guidance for tracking progress under the RHR. Visibility effects due to NO_2 are not considered in the CALPOST visibility calculation.

Recently, the IMPROVE Steering Committee developed a new algorithm for estimating light extinction from particulate matter component concentrations. This algorithm (the "new IMPROVE algorithm") provides a better correspondence between the measured visibility and

[1] The other table in the CALPOST visibility output file, with the subtitle "% of Modeled Extinction by Species", provides equivalent results in terms of changes in the haze index, in deciviews. The two tables represent the same results, with identical ranking of events, while just using different (but mathematically related) metrics.

that calculated from particulate matter component concentrations. The new algorithm differs in several substantive ways from the traditional one:

- The extinction efficiencies of sulfates, nitrates, and organics have been changed and are now functions of their concentrations. The extinction efficiencies of sulfate and nitrate are no longer identical, although the new hygroscopic scattering enhancement factors applied to them are the same.

- The concentration of particulate organic matter (POM; variously also labeled OCM or OMC, and sometimes just called "organics") is now taken to be 1.8 times that of the measured organic carbon (OC) concentration. (Confusingly, CALPOST labels the organics concentration as OC.)

- The contribution of fine sea salt to light extinction has been added, and is accompanied by its own hygroscopic scattering enhancement factor, $f_{ss}(RH)$.

- The light scattering by air itself (Rayleigh scattering) now varies with site elevation and mean temperature. It is to be rounded off to the nearest one Mm^{-1} when used with the new algorithm.

- The light absorption by NO_2 gas has been added.

The new IMPROVE algorithm is represented by the following formula:[2]

$$
\begin{aligned}
b_{ext} = \; & 2.2 \bullet f_S(RH) \bullet [small\ sulfate] + 4.8 \bullet f_L(RH) \bullet [large\ sulfate] \\
& + 2.4 \bullet f_S(RH) \bullet [small\ nitrate] + 5.1 \bullet f_L(RH) \bullet [large\ nitrate] \\
& + 2.8 \bullet [small\ organics] + 6.1 \bullet [large\ organics] \\
& + 10 \bullet [elemental\ carbon] \\
& + 1 \bullet [fine\ soil] \\
& + 1.7 \bullet f_{SS}(RH) \bullet [sea\ salt] \\
& + 0.6 \bullet [coarse\ matter] \\
& + Rayleigh\ scattering\ (site\ specific) \\
& + 0.33 \bullet [NO_2(ppb)]
\end{aligned}
\qquad \text{(Eq. 1)}
$$

The concentrations of "large" and "small" sulfate particles are calculated as follows:

$$[large\ sulfate] = \{[total\ sulfate]/20\} \bullet [total\ sulfate]\ if\ [total\ sulfate] < 20\ \mu g^3$$

$$[large\ sulfate] = [total\ sulfate]\ if\ [total\ sulfate] \geq 20\ \mu g/m^3 \qquad \text{(Eqs. 2)}$$

$$[small\ sulfate] = [total\ sulfate] - [large\ sulfate].$$

Identical formulas, with changes in component names, are used for nitrate and organics. In effect, these formulas conclude that low concentrations of these components are mainly in the form of "small" particles with their own extinction efficiency and $f_S(RH)$, while high

[2] Square brackets denote concentrations.

concentrations (approaching 20 μg/m^3) are mainly in the form of "large" particles with a different extinction efficiency and $f_L(RH)$. The scaling factor [total sulfate]/20 sets the fraction of total sulfate that is small.

The sea salt concentration is taken to be 1.8•[Cl^-] or, if chloride ion measurements are not available, the chlorine concentration can be used in its place. Site specific Rayleigh scattering values have been calculated for all IMPROVE sites.[3] Nitrogen dioxide concentrations are not measured at IMPROVE sites, but the ambient NO_2 concentrations under natural conditions can be expected to be negligibly small. The higher NO_2 concentration in a source plume may be great enough to cause a change in visibility, however.

In order to enable CALPOST to calculate CALPUFF-modeled source impacts on visibility using the new IMPROVE algorithm, it would have to be extensively reprogrammed. As an alternative, such a calculation could be done "off line" by adding another layer of post processing after CALPOST. To this end, I have developed a processor, in the form of an Excel workbook, that takes the CALPOST "Ranked Daily Visibility Change: Modeled Extinction by Species" output table, referenced against default annual average natural conditions concentrations, and creates an equivalent table of results based on the new algorithm. It can also incorporate the visibility impact due to light absorption by NO_2 in the plume.

The following describes the science behind the processor (which we'll call the CALPOST-IMPROVE Processor) and provides instructions for using it.

Concepts

In addition to the mechanical changes imposed by all the new terms in the new IMPROVE formula, applying the new algorithm also requires some conceptual changes. The biggest of these is that the extinction efficiencies of sulfates, nitrates, and organics now depend on the concentrations of those species. The practical implication of this is that extinction is no longer linearly additive. To calculate total extinction, you cannot take a background level of extinction and add to it CALPOST's calculation of extinction caused by the particulate matter coming from a source, because when the two aerosols mix in the atmosphere their combined mass concentration results in increases in the extinction efficiencies of both the background and the source contribution. This means that combining background particulate matter with the particulate matter from a source gives an extinction result that is greater than the sum of the two separate extinctions.

With the nonlinear behavior resulting from applying the new IMPROVE algorithm, the extinction impact of the source (i.e., the increase in extinction resulting from introducing source emissions into the atmosphere) is the sum of three parts:

1. The source impact calculated by the new IMPROVE algorithm using the CALPOST outputs for a plume in isolation;

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[3] *Revised IMPROVE Algorithm for estimating Light Extinction from Particle Speciation Data.* Report to IMPROVE Steering Committee, November 2005.

2. An increase in that source impact because the extinction efficiency increases when the source's aerosol combines with the background aerosol; and correspondingly,

3. An increase in the extinction of the background aerosol because of that same mixing.

The total new extinction is the sum of the above three components plus the original background extinction. The original background extinction is just that calculated by the new IMPROVE algorithm from background concentrations of the various components, without any consideration of the effects of the plume. For this application, the background is taken to be that described by EPA's default natural conditions. The difference between the total extinction and the background is the impact of the source.

More details about the calculation are given in the appendix.

Description of Processor

The CALPOST-IMPROVE Processor is a Microsoft Excel workbook that consists of four worksheets. In Version 2 the worksheets are the following.

1. Input & Output – The output table from CALPOST is imported to here and user entries are made for the Rayleigh scattering coefficient and, if desired, for a sea salt concentration at the Class I area of interest. The NO_x concentration on each day attributable to the emissions from the source can also be entered together with an assumption of what fraction of the NO_x is in the form of NO_2. A revised table, with extinction based on the new IMPROVE algorithm is then presented on the same page. This is the only page on which user input takes place, and the results of the calculations appear on this page.

2. Calculations -- The calculations themselves are all done on this worksheet. There is no user input to this page. The variables are explained on the worksheet itself, so the user can find intermediate values if so inclined.

3. F(RH) – This worksheet tabulates the traditional IMPROVE f(RH) against RH, and then also lists values for the three new humidity growth functions, $f_S(RH)$, $f_L(RH)$, and $f_{SS}(RH)$. It serves as a lookup table for the "Calculations" worksheet.

4. Rayleigh & Sea Salt – This page tabulates the IMPROVE-recommended Rayleigh scattering coefficients for all VISTAS Class I areas and for Class I areas in adjacent states. It also lists the average sea salt concentrations for the same locations, as tabulated on the VIEWS web site, based on chloride or chlorine measurements by IMPROVE monitors between 2000 and 2004. This sheet just provides information for the user; it is not linked to the rest of the workbook. The user can obtain Rayleigh and sea salt numbers for the Class I area of interest from this table and then manually enter them in the designated spaces in worksheet 1.

Instructions for Using the CALPOST-IMPROVE Processor

These instructions apply to Version 2 of the processor. Version 2 includes the ability to calculate the light extinction effects of NO_2 resulting from the source's emissions.

Step 1. Begin by opening the output (.LST) file from a CALPOST visibility calculation run in a text editor or word processing program.[4] In the second half of the file, locate the table "Ranked Daily Visibility Change" with the subheading "Modeled Extinction by Species".[5]

Step 2. Copy this table and paste it onto a new page. Save it as a text (.txt) file, not as a formatted (e.g., MS Word .doc or .rtf) file. The final table should contain only the column headings and the data. Delete all other captions, any additional data summaries at the end, and blank lines before or after the table. The processor can handle a maximum of 22 lines of data (i.e., the highest rank in the last, unlabeled, column should be 22) plus a row of column captions. Delete any data that exceed this limit. (Fewer than 22 lines of data are OK.) The result should look like the example in Figure 1, although the line wrapping may differ.

Step 3. Open the CALPOST-IMPROVE Processor in Microsoft Excel. Save the open file under a new name so that the original empty processor will remain available for future use. The front worksheet, labeled "Input & Output" looks like Figure 2. There is a large empty box, surrounded by double lines, into which the table created above will be imported, as described below.[6] On the right is a box into which NO_x concentrations may be entered manually, and a small box below this box is provided for entry of the user's assumption of what fraction of that NO_s is in the form of NO_2. Two smaller boxes provide for user input of the Rayleigh scattering coefficient and, optionally, sea salt concentration for the Class I area, as described below. Results of the new IMPROVE algorithm calculations appear in blue in the lower half of the worksheet and some additional results, that are also useful for quality control, appear in green to the right of the large box. At the moment, many results cells will display nonsensical numbers and error messages, such as shown in Figure 2.

Step 4. Select the upper left cell (A7) in the large box. On the Excel menu bar, go to *Data>Get External Data* and click on *Import Text File*.[7] (If the large box is not empty, click on *Edit Text Import* instead.) Select the file that contains the table created in Step 2 and click on the *Get Data* button. Go through the Text Import Wizard steps, checking that all values appear correctly in separate columns. (The label "COORDINATES (km)" will be split over two columns; this is OK.) When everything appears in order, click *Finish*.

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[4] The background concentrations that were entered into CALPOST must be the EPA-prescribed default annual average natural conditions concentrations for the East. The processor will not give correct answers if other concentrations were used in CALPOST.

[5] For future reference in Step 7, this may also be a good time to locate the table with the same title but with the subtitle "% of Modeled Extinction by Species", which appears later in the output file.

[6] If the workbook has already been used, the boxes may not be empty. This does not matter.

[7] The exact wording may vary slightly between different versions of Microsoft Excel. The terminology used here is from Excel 2004 for Macintosh.

```
YEAR DAY HR  RECEPTOR    COORDINATES (km)  TYPE BEXT(Model) BEXT(BKG)
BEXT(Total) %CHANGE  F(RH)  bxSO4  bxNO3   bxOC   bxEC  bxPMC  bxPMF
2002 175  0  1027        1479.069     24.683    D       5.495      21.650       27.145
25.38    3.500  5.401  0.045  0.042  0.002  0.001  0.004    1
2002 172  0  1021        1479.244     23.778    D       4.923      21.650       26.573
22.74    3.500  4.475  0.404  0.038  0.001  0.001  0.004    2
2002 284  0  1045        1484.348     27.580    D       3.150      21.470       24.620
14.67    3.300  2.684  0.428  0.033  0.001  0.001  0.003    3
2002 353  0  1026        1482.762     24.457    D       2.594      21.290       23.884
12.18    3.100  2.017  0.557  0.018  0.001  0.000  0.002    4
2002 283  0  1026        1482.762     24.457    D       2.502      21.470       23.972
11.65    3.300  2.269  0.201  0.028  0.001  0.001  0.003    5
2002 195  0  1045        1484.348     27.580    D       2.011      21.830       23.841
9.21    3.700  1.963  0.031  0.015  0.001  0.000  0.001    6
2002  20  0  1117        1486.636     34.592    D       1.872      21.200       23.072
8.83    3.000  1.542  0.320  0.009  0.000  0.000  0.001    7
2002 173  0  1128        1479.259     35.042    D       1.649      21.650       23.299
7.62    3.500  1.625  0.012  0.010  0.000  0.000  0.001    8
2002 234  0  1021        1479.244     23.778    D       1.524      22.190       23.714
6.87    4.100  1.482  0.029  0.011  0.000  0.000  0.001    9
2002 298  0  1021        1479.244     23.778    D       1.459      21.470       22.929
6.80    3.300  1.284  0.160  0.014  0.001  0.000  0.001   10
2002 299  0  1021        1479.244     23.778    D       1.436      21.470       22.906
6.69    3.300  1.281  0.140  0.013  0.000  0.000  0.001   11
2002 275  0  1026        1482.762     24.457    D       1.270      21.470       22.740
5.92    3.300  1.202  0.058  0.009  0.000  0.000  0.001   12
2002 263  0  1045        1484.348     27.580    D       1.237      22.100       23.337
5.60    4.000  1.223  0.008  0.005  0.000  0.000  0.001   13
2002 252  0  1026        1482.762     24.457    D       1.189      22.100       23.289
5.38    4.000  1.166  0.013  0.009  0.000  0.000  0.001   14
2002 285  0  1021        1479.244     23.778    D       0.992      21.470       22.462
4.62    3.300  0.813  0.179  0.001  0.000  0.000  0.000   15
2002 161  0  1026        1482.762     24.457    D       0.873      21.650       22.523
4.03    3.500  0.842  0.020  0.009  0.000  0.000  0.001   16
2002 150  0  1026        1482.762     24.457    D       0.857      21.380       22.237
4.01    3.200  0.822  0.026  0.007  0.000  0.000  0.001   17
2002 340  0  1140        1481.017     37.258    D       0.817      21.290       22.107
3.84    3.100  0.663  0.153  0.001  0.000  0.000  0.000   18
2002 151  0  1117        1486.636     34.592    D       0.745      21.380       22.125
3.49    3.200  0.704  0.033  0.007  0.000  0.000  0.001   19
2002 160  0  1021        1479.244     23.778    D       0.735      21.650       22.385
3.40    3.500  0.710  0.014  0.010  0.000  0.000  0.001   20
2002 346  0  1021        1479.244     23.778    D       0.703      21.290       21.993
3.30    3.100  0.620  0.080  0.002  0.000  0.000  0.000   21
2002 247  0  1021        1479.244     23.778    D       0.661      22.100       22.761
2.99    4.000  0.654  0.004  0.002  0.000  0.000  0.000   22
```

Figure 1. Example of CALPOST Output Table, in Proper Format for Importing into the CALPOST-IMPROVE Processor.

Step 5.[8] The "Import Data" window will appear, with cell A7 indicated as the location at which data will be entered. Click on the *Properties* button. In the window that appears, select "Overwrite existing cells with new data, clear unused cells" and uncheck "Adjust column width", then click on *OK*. Now click on the *OK* button in the "Import Data" window.

Step 6. Assuming that your Excel application is set up to automatically recalculate whenever any entries are changed, you should now have filled the cells in the large box on the first worksheet,

[8] If the processor already had data in it and *Edit Text Import* was clicked in Step 4, then the "Import Data" window will not appear and Step 5 can be skipped.

1. At cell A7, import "Ranked Daily Visibility Change" (bext) table, including column headings, from CALPOST (22 days, max)

YEAR	DAY	HR	RECEPTOR	COORDINATES (km)	TYPE	BEXT(Model)	BEXT(BKG)	BEXT(Total)	%CHANGE	F(RH)	bxSO4	bxNO3	bxOC	bxEC	bxPMC	bxPMF	Rank

2. Check calculated values below against CALPOST's "Ranked Daily Visibility Change" (dv) table

dv(total)	dv(bkg)	Δdv
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!
#NUM!	#NUM!	#NUM!

5. (Optional) Enter 24hr NOx conc.

NOx(ppb)

3. Enter value of site-specific Rayleigh scattering coefficient, from "Rayleigh & Sea Salt" worksheet

4. (Optional) Insert annual average sea salt concentration, from "Rayleigh & Sea Salt" worksheet. Leave blank if not used, i.e. default is 0.

6. Enter desired NO2/NOx ratio (default is 0)

---------------------------------- OUTPUT (based on new IMPROVE algorithm) ----------------------------------

YEAR	DAY	HR	RECEPTOR	COORDINATES (km)		TYPE	BEXT(Source)	BEXT(BKG)	BEXT(Total)	%CHANGE	RH(%)	bsSO4	bsNO3	bsOC	bsEC	bsPMC	bsPMF	baNO2	New Rank	dv(total)	dv(bkg)	Δdv
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00
0	0	0	0	0	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0	0	0	1	#N/A	#N/A	0.00

Figure 2. Example of Appearance of Input & Output Worksheet before Data Entry.

numbers should have appeared in the green columns to the right, and some numbers will have appeared in the output table in blue on the lower half of the worksheet. If the data import worked properly, none of the imported data should have spilled out of the large box. Check that all the column captions in bold outside the large box are now duplicated on the first line in the box. (There won't be a caption for Rank.)

Step 7. As a further check on whether everything is correct so far, the dv information in the three columns to the right of the large box should be the same as that in the second CALPOST table "Ranked Daily Visibility Change: % of Modeled Extinction by Species", which was mentioned in Footnote 1.

Step 8. Beneath the large box that was just filled with imported data, enter the Rayleigh scattering coefficient for the Class I area of interest into the top small box after red instruction 3. Also, if you wish, fill in the other small box, the one after red instruction 4, with the annual average sea salt concentration. (The sea salt box may be left blank, but the Rayleigh scattering coefficient box must be filled in.) To help with filling in these two boxes, the fourth worksheet, "Rayleigh & Sea Salt", provides IMPROVE-calculated values of the Rayleigh coefficients for Class I areas in the VISTAS region and in adjacent states. Also, average sea salt concentrations for 2000-2004, calculated in accordance with the new IMPROVE procedures, can be found there.

Step 9.[9] If the impact due to NO_2 is to be considered, a second CALPOST run will be needed to provide the 24-hr average NO_x concentrations estimated by CALPUFF. For this purpose, run CALPOST using the ASPEC = NOX option in Input Group 1 of the CALPOST.INP control file. The NO_x values to insert in the NO_x input box on the Input & Output page of the processor have to be extracted manually from the CALPOST output file for each date and receptor listed in the file that was imported in Steps 1 through 5 above and are displayed in the left hand columns in the large box.

Step 10. Select a value between 0 and 1 to represent what fraction of NO_x is in the form of NO_2. Enter this value into the small box at red instruction 6 below the column where the NO_x concentrations were entered.[10]

Step 11. The blue data table at the bottom of the page represents the new IMPROVE algorithm outputs. An example is shown in Figure 3. This table can be compared with the original CALPOST table at the top of the page. All of the columns in both tables show exactly the same variables, except that the F(RH) column in the top table is replaced by just the RH in the lower table (since the new procedure has three different f(RH) functions) and a new $baNO_2$ column has been added to the bottom table to show the light absorption due to NO_2 (in Mm^{-1}). Although the events are listed in the same order in both tables, note that their rankings may have changed, as is the case for many of the lines in the blue output table in Figure 3.

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[9] Steps 8 and 9 are optional. If the impact due to NO_2 is not of interest, just leave the entry fields mentioned in these steps blank.

[10] An easy way to see the effect of the NO_2 on the source's impact in the output table in the lower half of the page is to toggle this NO_2/NO_x value between the selected value and zero.

For those who are interested in more detail concerning the calculations that take place, values of the three f(RH) functions appear in columns M through O on the second, "Calculations" spreadsheet. The extinction impact of the source, including enhancement of the extinction efficiencies for sulfates, nitrates, and organics because of greater total mass concentrations, appears in columns V through AC. Extinction due to the annual average natural background appears in Columns AJ through AN; natural background extinctions for those components that are enhanced by greater total mass concentrations appear in columns AU through AX.

CALPOST Recalculation with New IMPROVE Algorithm

--------------------------- INPUT from CALPOST (based on old IMPROVE algorithm) -------------------

1. At cell A7, import "Ranked Daily Visibility Change" (bext) table, including column headings, from CALPOST (22 days, max)

2. Check calculated values below against CALPOST's "Ranked Daily Visibility Change" (dv) table

5. (Optional) Enter 24hr NOx conc. NOx(ppb)

YEAR	DAY	HR	RECEPTOR	COORDINATES (km)		TYPE	BEXT(Model)	BEXT(BKG)	BEXT(Total)	%CHANGE	F(RH)	bxSO4	bxNO3	bxOC	bxEC	bxPMC	bxPMF	Rank				
YEAR	DAY	HR	RECEPTOR	COORDINA	TES (km)	TYPE	BEXT(Model)	BEXT(BKG)	BEXT(Total)	%CHANGE	F(RH)	bxSO4	bxNO3	bxOC	bxEC	bxPMC	bxPMF		dv(total)	dv(bkg)	Δdv	
2002	175	0	1027	1479.069	24.683	D	5.495	21.65	27.145	25.38	3.5	5.401	0.045	0.042	0.002	0.001	0.004	1	9.99	7.72	2.26	2
2002	172	0	1021	1479.244	23.778	D	4.923	21.65	26.573	22.74	3.5	4.475	0.404	0.038	0.001	0.001	0.004	2	9.77	7.72	2.05	0.5
2002	284	0	1045	1484.348	27.58	D	3.15	21.47	24.62	14.67	3.3	2.684	0.428	0.033	0.001	0.001	0.003	3	9.01	7.64	1.37	0.4
2002	353	0	1026	1482.762	24.457	D	2.594	21.29	23.884	12.18	3.1	2.017	0.557	0.018	0.001	0	0.002	4	8.71	7.56	1.15	0.7
2002	283	0	1026	1482.762	24.457	D	2.502	21.47	23.972	11.65	3.3	2.269	0.201	0.028	0.001	0.001	0.003	5	8.74	7.64	1.10	1.4
2002	195	0	1045	1484.348	27.58	D	2.011	21.83	23.841	9.21	3.7	1.963	0.031	0.015	0.001	0	0.001	6	8.69	7.81	0.88	0.4
2002	20	0	1117	1486.636	34.592	D	1.872	21.2	23.072	8.83	3	1.542	0.32	0.009	0	0	0.001	7	8.36	7.51	0.85	0.8
2002	173	0	1128	1479.259	35.042	D	1.649	21.65	23.299	7.62	3.5	1.625	0.012	0.01	0	0	0.001	8	8.46	7.72	0.73	1.2
2002	234	0	1021	1479.244	23.778	D	1.524	22.19	23.714	6.87	4.1	1.482	0.029	0.011	0	0	0.001	9	8.63	7.97	0.66	1.2
2002	298	0	1021	1479.244	23.778	D	1.459	21.47	22.929	6.8	3.3	1.284	0.16	0.014	0.001	0	0.001	10	8.30	7.64	0.66	0.3
2002	299	0	1021	1479.244	23.778	D	1.436	21.47	22.906	6.69	3.3	1.281	0.14	0.013	0	0	0.001	11	8.29	7.64	0.65	0.5
2002	275	0	1026	1482.762	24.457	D	1.27	21.47	22.74	5.92	3.3	1.202	0.058	0.009	0	0	0.001	12	8.22	7.64	0.57	0.7
2002	263	0	1045	1484.348	27.58	D	1.237	22.1	23.337	5.6	4	1.223	0.008	0.005	0	0	0.001	13	8.47	7.93	0.54	0.4
2002	252	0	1026	1482.762	24.457	D	1.189	22.1	23.289	5.38	4	1.166	0.013	0.009	0	0	0.001	14	8.45	7.93	0.52	1.5
2002	285	0	1021	1479.244	23.778	D	0.992	21.47	22.462	4.62	3.3	0.813	0.179	0.001	0	0	0	15	8.09	7.64	0.45	1.9
2002	161	0	1026	1482.762	24.457	D	0.873	21.65	22.523	4.03	3.5	0.842	0.02	0.009	0	0	0.001	16	8.12	7.72	0.40	1.7
2002	150	0	1026	1482.762	24.457	D	0.857	21.38	22.237	4.01	3.2	0.822	0.026	0.007	0	0	0.001	17	7.99	7.60	0.39	1.4
2002	340	0	1140	1481.017	37.258	D	0.817	21.29	22.107	3.84	3.1	0.663	0.153	0.001	0	0	0	18	7.93	7.56	0.38	1.8
2002	151	0	1117	1486.636	34.592	D	0.745	21.38	22.125	3.49	3.2	0.704	0.033	0.007	0	0	0.001	19	7.94	7.60	0.34	1.4
2002	160	0	1021	1479.244	23.778	D	0.735	21.65	22.385	3.4	3.5	0.71	0.014	0.01	0	0	0.001	20	8.06	7.72	0.33	1.4
2002	346	0	1021	1479.244	23.778	D	0.703	21.29	21.993	3.3	3.1	0.62	0.08	0.002	0	0	0	21	7.88	7.56	0.32	0.4
2002	247	0	1021	1479.244	23.778	D	0.661	22.1	22.761	2.99	4	0.654	0.004	0.002	0	0	0	22	8.22	7.93	0.29	0

3. Enter value of site-specific Rayleigh scattering coefficient, from "Rayleigh & Sea Salt" worksheet: **11**

4. (Optional) Insert annual average sea salt concentration, from "Rayleigh & Sea Salt" worksheet. Leave blank if not used, i.e. default is 0.: **0.02**

6. Enter desired NO2/NOx ratio (default is 0): **0.75**

--------------------------------- OUTPUT (based on new IMPROVE algorithm) --------------------------------

YEAR	DAY	HR	RECEPTOR	COORDINATES (km)		TYPE	BEXT(Source)	BEXT(BKG)	BEXT(Total)	%CHANGE	RH(%)	bsSO4	bsNO3	bsOC	bsEC	bsPMC	bsPMF	baNO2	New Rank	dv(total)	dv(bkg)	Δdv
2002	175	0	1027	1479.069	24.683	D	4.936	22.04	27.016	22.56	86	4.363	0.039	0.033	0.002	0.001	0.004	0.495	1	9.94	7.90	2.03
2002	172	0	1021	1479.244	23.778	D	4.112	22.04	26.187	18.80	86	3.604	0.349	0.029	0.001	0.001	0.004	0.124	2	9.63	7.90	1.72
2002	284	0	1045	1484.348	27.58	D	2.563	21.78	24.363	11.86	84	2.076	0.357	0.026	0.001	0.001	0.003	0.099	3	8.90	7.78	1.12
2002	353	0	1026	1482.762	24.457	D	2.174	21.57	23.760	10.15	82	1.528	0.455	0.014	0.001	0	0.002	0.173	5	8.65	7.69	0.97
2002	283	0	1026	1482.762	24.457	D	2.293	21.78	24.090	10.61	84	1.753	0.167	0.022	0.001	0.001	0.003	0.347	4	8.79	7.78	1.01
2002	195	0	1045	1484.348	27.58	D	1.708	22.21	23.936	7.75	87	1.569	0.027	0.012	0.001	0	0.001	0.099	6	8.73	7.98	0.75
2002	20	0	1117	1486.636	34.592	D	1.625	21.48	23.114	7.62	81	1.16	0.26	0.007	0	0	0.001	0.198	7	8.38	7.64	0.73
2002	173	0	1128	1479.259	35.042	D	1.613	22.04	23.667	7.37	86	1.297	0.01	0.008	0	0	0.001	0.297	8	8.61	7.90	0.71
2002	234	0	1021	1479.244	23.778	D	1.546	22.64	24.193	6.87	89	1.213	0.026	0.009	0	0	0.001	0.297	9	8.83	8.17	0.66
2002	298	0	1021	1479.244	23.778	D	1.209	21.78	22.998	5.59	84	0.988	0.133	0.011	0.001	0	0.001	0.074	13	8.33	7.78	0.54
2002	299	0	1021	1479.244	23.778	D	1.237	21.78	23.027	5.72	84	0.986	0.117	0.01	0	0	0.001	0.124	12	8.34	7.78	0.56
2002	275	0	1026	1482.762	24.457	D	1.154	21.78	22.943	5.34	84	0.925	0.048	0.007	0	0	0.001	0.173	14	8.30	7.78	0.52
2002	263	0	1045	1484.348	27.58	D	1.137	22.64	23.783	5.06	89	1.026	0.007	0.004	0	0	0.001	0.099	16	8.66	8.17	0.49
2002	252	0	1026	1482.762	24.457	D	1.369	22.64	24.015	6.08	89	0.978	0.012	0.007	0	0	0.001	0.371	10	8.76	8.17	0.59
2002	285	0	1021	1479.244	23.778	D	1.245	21.78	23.031	5.74	84	0.625	0.149	8E-04	0	0	0	0.47	11	8.34	7.78	0.56
2002	161	0	1026	1482.762	24.457	D	1.116	22.04	23.165	5.09	86	0.67	0.017	0.007	0	0	0.001	0.421	15	8.40	7.90	0.50
2002	150	0	1026	1482.762	24.457	D	0.997	21.67	22.668	4.63	83	0.623	0.021	0.005	0	0	0.001	0.347	18	8.18	7.73	0.45
2002	340	0	1140	1481.017	37.258	D	1.071	21.57	22.646	4.99	82	0.5	0.125	8E-04	0	0	0	0.446	17	8.17	7.69	0.49
2002	151	0	1117	1486.636	34.592	D	0.913	21.67	22.584	4.24	83	0.533	0.027	0.005	0	0	0.001	0.347	20	8.15	7.73	0.42
2002	160	0	1021	1479.244	23.778	D	0.932	22.04	22.980	4.25	86	0.565	0.012	0.008	0	0	0.001	0.347	19	8.32	7.90	0.42
2002	346	0	1021	1479.244	23.778	D	0.633	21.57	22.208	2.95	82	0.467	0.065	0.002	0	0	0	0.099	21	7.98	7.69	0.29
2002	247	0	1021	1479.244	23.778	D	0.553	22.64	23.195	2.46	89	0.548	0.004	0.002	0	0	0	0	22	8.41	8.17	0.24

Figure 3. Example of Appearance of Finished Input & Output Worksheet.

Appendix
Details of Calculation Approach

As an example of the calculation steps, assume that the sulfate concentration resulting from emissions from a source is $[S_E]$ and the sulfate in the undisturbed natural background is $[S_N]$, for a total ambient sulfate concentration of $[S_T]$. According to Equations 1 and 2 in the main body of this document, the total extinction due to sulfate for this combination is

$$b_{ext}(sulfate) = 2.2 \bullet f_S(RH) \bullet [small\ sulfate] + 4.8 \bullet f_L(RH) \bullet [large\ sulfate], \quad \text{(Eq. A-1)}$$

where

$$[large\ sulfate_T] = \{[S_T]/20\} \bullet [S_T] \text{ if } [S_T] < 20\ \mu g^3$$

$$[large\ sulfate_T] = [S_T] \text{ if } [S_T] \geq 20\ \mu g/m^3 \quad \text{(Eqs. A-2)}$$

$$[small\ sulfate_T] = [S_T] - [large\ sulfate_T],$$

and the subscript T denotes total sulfate

For the original background, where there is no source impact, the corresponding formulas for the terms in Equations A-2 are

$$[large\ sulfate_N] = \{[S_N]/20\} \bullet [S_N] \text{ if } [S_N] < 20\ \mu g^3$$

$$[large\ sulfate_N] = [S_N] \text{ if } [S_N] \geq 20\ \mu g/m^3 \quad \text{(Eqs. A-3)}$$

$$[small\ sulfate_N] = [S_N] - [large\ sulfate_N],$$

where the subscript N denotes natural sulfate.

Similar calculations need to be carried out for nitrates. Contributions of the other particulate components are linear and can just be calculated according to Equation 1.

If the impact due to NO_2 is also to be considered, then the source impact due to this component is, according to Equation 1,

$$b_{ext}(NO_2) = 0.33 \bullet [NO_2], \quad \text{(Eq. A-4)}$$

where $[NO_2]$ is in ppb. It is reasonable to assume that the ambient NO_2 concentrations under natural conditions would be so small as to cause negligible light absorption, so the corresponding term is not needed in the natural conditions calculation.

The contributions due to the various components are summed together as in Equation 1 to obtain the total extinction $b_{ext,T}$ and the natural background extinction $b_{ext,N}$. The fractional change in extinction is then calculated as the difference, normalized by the natural background extinction

$$(b_{ext,T} - b_{ext,N})/b_{ext,N}, \qquad \text{(Eq. A-5)}$$

a result that can also be expressed in deciviews.

These formulas are used in the CALPOST-IMPROVE Processor. Similar formulas apply for nitrates and organics. There is no nonlinearity in the remaining terms in Equation 1.