BART Determination Report:

Georgia Power Company
Plant Bowen

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for Georgia Power Company

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1.0 Executive Summary

Under the regional haze regulations, determinations of best available retrofit technology (BART) for sources that are BART-eligible and subject to BART must be submitted by the states to EPA no later than December 17, 2007. Coal-fired electric generating units 1, 2, 3, and 4 at Plant Bowen, owned and operated by Georgia Power Company (GPC), are BART-eligible units that are subject to BART. The Georgia Environmental Protection Division (GEPD) is responsible for determining BART for each of the electric generating units (EGUs) at Plant Bowen. With respect to sulfur dioxide (SO_2) and nitrogen oxides (NO_x), GEPD has indicated that it plans to adopt EPA's regional haze rule that allows the cap-and-trade program of the Clean Air Interstate Rule (CAIR) to satisfy BART for SO_2 and NO_x at EGUs. Thus, no BART determination is required for SO_2 and NO_x emissions from Plant Bowen's EGUs. For particulate matter (PM) emissions from Plant Bowen's EGUs, GEPD has requested that GPC provide a proposed BART determination.

The PM emissions from Plant Bowen's EGUs are currently controlled by electrostatic precipitators (ESPs). Wet flue gas desulfurization (WFGD) scrubbers for SO_2 control, which also further reduce PM emissions, have been permitted for Plant Bowen's EGUs and are under construction. Therefore, the PM BART determination analysis for Plant Bowen's EGUs begins with the assumption that each EGU's PM emissions are controlled with both an ESP and a scrubber.

GPC, with the assistance of Southern Company Services (SCS) and RMB Consulting and Research, Inc. (RMB), has identified an additional six feasible PM control options for Units 1 and 2, and five feasible PM control options for Units 3 and 4. The cost of each option, the option's potential for further reducing PM emissions, the resulting dollar-per-ton removed cost-effectiveness, and the energy and non-air environmental impacts of each option have also been analyzed. Using the least-cost-envelope curve approach recommended by EPA, GPC narrowed down the possible BART options for each of the units to the following four: (1) high voltage power conditioners (Juice Cans), (2) a particle agglomerator, (3) the combination of Juice Cans and an agglomerator, and (4) a wet electrostatic precipitator (WESP). To assess visibility improvement, two of those options (WESP and the Juice Can/agglomerator combination) have been modeled using CALPUFF. Table 1-1 contains a summary of the cost, expected PM emissions reduction, cost-effectiveness (average dollars-per-ton removed), and modeled visibility improvement (delta-delta-deciviews), for the control options at each of the Bowen EGUs.

Based on this information, GPC proposes that PM BART for the Plant Bowen EGUs be no additional controls. Each unit at Plant Bowen is already extremely well controlled for PM emissions. With regard to the WESP control option, although the modeling predicts a small improvement in visibility at the Cohutta Class I area associated with use of that option, the cost-effectiveness of that option is well above any threshold for cost-effectiveness that could be considered reasonable for BART. In addition, the WESP would consume additional energy and would create adverse non-air quality environmental impacts.

Table 1-1 Summary of Bowen BART Determination Results[1]

Upgrade Option	Annualized Cost [$/yr]	PM_{10} Reduction [tpy]	Average Cost [$/ton]	Visibility Improvement from Baseline[2] [delta-delta-dv]
Bowen Unit 1 Results				
Juice Can	$76,860	11.3	$6,815	-
Agglomerator	$1,163,529	62.0	$18,759	-
Agglomerator/Juice Cans	$1,240,389	73.1	$16,921	-0.01
Wet ESP	$12,474,580	261.0	$47,804	-0.14
Bowen Unit 2 Results				
Juice Can	$76,860	15.6	$4,923	-
Agglomerator	$1,163,529	85.9	$13,550	-
Agglomerator/Juice Cans	$1,240,389	101.5	$12,222	-0.01
Wet ESP	$12,474,580	336.2	$37,107	-0.14
Bowen Unit 3 Results				
Juice Can	$98,820	21.1	$4,677	-
Agglomerator	$1,495,965	51.6	$28,965	-
Agglomerator/Juice Can	$1,594,785	72.8	$21,914	-0.01
Wet ESP	$16,038,745	334.8	$47,909	-0.15
Bowen Unit 4 Results				
Juice Can	$98,820	24.0	$4,110	-
Agglomerator	$1,495,965	58.8	$25,452	-
Agglomerator/Juice Cans	$1,594,785	82.8	$19,256	-0.01
Wet ESP	$16,038,745	360.5	$44,492	-0.16

Notes:
1. Visibility improvement results represent new IMPROVE equation and virtual stack temperature.
2. Incremental change is the "Highest of 8^{th} Highest delta-delta-dv for the 3-years."

With regard to the agglomerator option and the Juice Can/agglomerator combination, the cost-effectiveness values exceed levels that have been considered reasonable even in the context of New Source Review (NSR) "Best Available Control Technology" (BACT) assessments and the BART-like determination conducted by Tampa Electric Company for evaluation of ESP-upgrade options at Big Bend Station. (The exception is for Unit 2, where the cost-effectiveness of these options falls within the upper range of values that could be considered reasonable for BACT.) Moreover, the CALPUFF modeling predicts virtually no visibility improvement would occur with use of those options.

Finally, although the Juice Can option could be deemed by GEPD to have a relatively moderate dollar-per-ton removed cost-effectiveness, that option reduces only a few tons of PM and is not expected to improve visibility at all.

For these reasons, GPC proposes that PM BART for Units 1-4 at Plant Bowen be no additional controls.

2.0 Introduction

The regional haze regulations require a BART determination for each BART-eligible source that emits any air pollutant which may reasonably be anticipated to cause or contribute to any impairment of visibility in a mandatory Federal Class I area.[1] The determination of BART for fossil-fuel fired power plants having a total generating capacity greater than 750 megawatts must be made pursuant to EPA's "BART Guidelines" found in Appendix Y to 40 C.F.R. Part 51.[2]

GPC owns and operates coal-fired EGUs 1, 2, 3, and 4 at Plant Bowen, near Cartersville, Georgia. To be BART-eligible, a source must fall within one of the 26 BART-eligible source categories identified in the Clean Air Act (for example, "fossil-fuel fired steam electric plants of more than 250 million Btu per hour heat input"), the source must have been in existence on August 7, 1977 and have begun operation after August 7, 1962, and the source must have potential emissions of a visibility-impairing pollutant of 250 tons per year or more. All four EGUs at Plant Bowen satisfy these criteria and thus are BART-eligible. The visibility-impairing pollutants emitted by Plant Bowen's EGUs are SO_2, NO_x, and PM. GEPD has determined that volatile organic compounds (VOCs) and, except in limited cases not applicable here, ammonia will not be considered visibility-impairing pollutants in Georgia.

GEPD has announced its intention to participate in the CAIR cap-and-trade program and to use that program to satisfy BART for SO_2 and NO_x at BART-eligible EGUs, pursuant to 40 C.F.R. Section 51.308(e)(4). Based on guidance from EPA, if a state opts to allow CAIR to satisfy SO_2 and NO_x BART for an EGU, then a modeling analysis may be conducted to determine whether PM emissions from that EGU, by themselves, cause or contribute to visibility impairment in a Class I area (i.e., are subject to BART). As a result, GPC undertook CALPUFF modeling to assess whether the PM emissions from Plant Bowen's EGUs are subject to BART.

The Plant Bowen CALPUFF modeling was conducted pursuant to a modeling protocol submitted by GPC to GEPD in May 2006, *see* "BART Modeling Protocol: Plant Bowen" (May 2006), with revisions to the procedures based on later discussions with GEPD.[3] The results of that modeling indicate that the PM emissions from Plant Bowen's EGUs are subject to BART. Specifically, using GEPD's 0.5 delta-deciview threshold (8^{th} highest impact each year; 22^{nd} highest impact over three years) for assessing whether a source contributes to visibility impairment in a Class I area, the visibility impact from Plant Bowen's PM emissions exceed that threshold in one Class I area, the Cohutta wilderness area in North Georgia. Table 3-1, as presented later in Section 3.0 of this BART Determination Report, shows the results of the CALPUFF exemption modeling performed for Plant Bowen. Therefore, pursuant to EPA's BART Guidelines, a BART determination is required for PM emissions from each Plant Bowen EGU.[4]

[1] 40 C.F.R. Section 51.308(e)

[2] 40 C.F.R. Section 51.308(e)(1)(ii)(B); BART Guidelines, Section I.F.1

[3] The revised procedures are reflected in the "BART Determination Modeling Protocol" (December 2006) that was submitted to GEPD. *See* Section 4.6 of this report.

[4] BART Guidelines, Section IV.B

BART is defined in the regional haze regulations as an emission limitation based on the degree of reduction achievable through the application of the best system of continuous emission reduction for a pollutant emitted by a BART-eligible source. A BART emission limitation must be established on a case-by-case basis taking into consideration the technology available, the costs of compliance, the energy and non-air quality environmental impacts of compliance, any pollution control equipment in use or in existence at the source, the remaining useful life of the source, and the degree of improvement in visibility which may reasonably be anticipated to result from the use of such technology.[5]

This document contains the analysis of these factors for determining BART for PM emitted from each of Plant Bowen's EGUs. Section 3.0 summarizes the exemption modeling performed using the baseline conditions. Section 4.0 identifies and provides an analysis of the feasible PM control technology options, as well as a discussion of the considerations that must be examined for determining BART. Section 5.0 discusses GPC's proposal that PM BART for Plant Bowen's EGUs be no additional controls.

[5] BART Guidelines, Section IV.A

3.0 BART Exemption Modeling Results

One factor in evaluating whether a source is subject to BART and which control options should be evaluated as BART is consideration of any existing pollution control technology in use at the source. Currently, PM emissions from Plant Bowen's EGUs are controlled with ESPs. However, SO_2 scrubbers, which also remove additional PM emissions, have been permitted and are under construction for Plant Bowen's EGUs. Because the scrubbers will be in operation well before the expected implementation date for any additional BART PM control option that may be required, GPC has used the PM emissions from the scrubbed EGUs as the baseline for the PM BART modeling. The baseline condition also includes the stack parameters associated with the new stacks that will be constructed for the new scrubbers. ("Good engineering practice" (GEP) stack height assumptions have been used for the modeling.)

The procedures contained in the "BART Modeling Protocol: Plant Bowen," submitted to EPD on May 1, 2006, were used to conduct the BART exemption modeling. Based on discussions with EPD, it was agreed that the exemption modeling would be done for the units as scrubbed (the May 2006 Protocol as submitted discusses only unscrubbed emissions), and the results would be presented using both the new and old IMPROVE equations.[6]

One issue that was not addressed in the modeling protocols was the stack temperature to use in the modeling. In the May 2006 and December 2006 Protocols (Tables 2-1 and 2-2, respectively), the stack temperature is reported as 327 K. This is the actual temperature. However, the virtual temperature of 349 K should have been reported and was, in fact, used in the modeling. The plume rise equations in the existing EPA-approved air quality models describe the behavior of dry plumes. Since a scrubber plume is saturated and thus has greater buoyancy than dry flue gas, the virtual temperature of the stack gas is appropriate for modeling of scrubbed plumes. Virtual temperature is the temperature that a dry plume would need to have to provide the same buoyancy as the wet gas. Research engineers at Southern Company's Research and Environmental Affairs Department created a calculation tool which determines the virtual temperature of a moist plume based on fuel, operational, ambient and physical stack parameter inputs. This tool was used to calculate the virtual temperature at the stack exit of both of the new scrubber stacks. A description of the calculation tool is provided in Appendix A. Since the temperature does have a small effect on the results, the results using both the virtual and actual temperatures are presented below. However, the results representing the use of virtual temperature and the new IMPROVE equation are considered the primary basis for the BART exemption (Section 3.0) analysis.

The exemption modeling results are provided in Table 3-1, and Appendix B lists delta-deciview results for the top 20 days for each year modeled and the top 25 days for the overall three years at each Class I area for the primary results (i.e., the virtual temperature, new IMPROVE equation case). The table indicates that both the 8th highest day's impacts for each year and the 22nd highest day's impacts over all three years are below 0.5 delta-dv for four of the five Class I areas within 300 km. However, the impacts are greater than 0.5 delta-dv at Cohutta. These results demonstrate

[6] Revisions to the modeling procedures (including estimates of PM emission reductions due to the scrubbers) are reflected in the "BART Determination Modeling Protocol" (December 2006), which is discussed in section 4.6 of this report.

Table 3-1 Summary of Results – Plant Bowen Refined BART Exemption Modeling

		2001			2002			2003				
Class I area	Distance from source to Class I area boundary	# of days and receptors beyond 98th percentile with impact > 0.5 delta-dv		8th Highest delta-dv	# of days and receptors beyond 98th percentile with impact > 0.5 delta-dv		8th Highest delta-dv	# of days and receptors beyond 98th percentile with impact > 0.5 delta-dv		8th Highest delta-dv	Highest of 8th Highest delta-dv for the 3-years	22nd Highest delta-dv over 3-year period
	km	Days	Rec	delta-dv	Days	Rec	delta-dv	Days	Rec	delta-dv	delta-dv	delta-dv
Cohutta												
New Improve Virtual Temp	84.8	6	5	0.74	12	6	0.94	6	4	0.59	0.94	0.74
New Improve Actual Temp	84.8	10	6	0.78	15	7	1.05	13	5	0.73	1.05	0.82
Old Improve Virtual Temp	84.8	13	8	0.91	20	6	1.15	16	7	0.73	1.15	0.91
Old Improve Actual Temp	84.8	16	8	0.97	22	7	1.28	23	6	0.90	1.28	1.00
Great Smoky Mountains												
New Improve Virtual Temp	175.9	0	0	0.28	0	0	0.23	0	0	0.23	0.28	0.24
New Improve Actual Temp	175.9	0	0	0.27	0	0	0.28	0	0	0.26	0.28	0.27
Old Improve Virtual Temp	175.9	0	0	0.35	0	0	0.29	0	0	0.28	0.35	0.30
Old Improve Actual Temp	175.9	0	0	0.33	0	0	0.34	0	0	0.34	0.34	0.34
Joyce Kilmer												
New Improve Virtual Temp	162.3	0	0	0.27	0	0	0.31	0	0	0.25	0.31	0.27
New Improve Actual Temp	162.3	0	0	0.28	0	0	0.34	0	0	0.29	0.34	0.30
Old Improve Virtual Temp	162.3	0	0	0.34	0	0	0.39	0	0	0.31	0.39	0.34
Old Improve Actual Temp	162.3	0	0	0.35	0	0	0.43	0	0	0.37	0.43	0.38
Shining Rock												
New Improve Virtual Temp	228.0	0	0	0.17	0	0	0.12	0	0	0.18	0.18	0.16
New Improve Actual Temp	228.0	0	0	0.17	0	0	0.14	0	0	0.19	0.19	0.18
Old Improve Virtual Temp	228.0	0	0	0.21	0	0	0.14	0	0	0.22	0.22	0.20
Old Improve Actual Temp	228.0	0	0	0.20	0	0	0.16	0	0	0.24	0.24	0.22
Sipsey												
New Improve Virtual Temp	223.5	0	0	0.08	0	0	0.12	0	0	0.11	0.12	0.11
New Improve Actual Temp	223.5	0	0	0.08	0	0	0.12	0	0	0.12	0.12	0.11
Old Improve Virtual Temp	223.5	0	0	0.10	0	0	0.15	0	0	0.14	0.15	0.14
Old Improve Actual Temp	223.5	0	0	0.11	0	0	0.16	0	0	0.15	0.16	0.15

that Plant Bowen's PM_{10} emissions contribute to visibility impairment at Cohutta and Plant Bowen's EGUs are therefore subject to PM BART and a PM BART determination analysis for Cohutta is required.

An external hard drive is being provided separately that contains all of the electronic data related to this application (i.e., the virtual temperature, new IMPROVE equation case). This drive contains all of the input and output files used in the modeling. A ***readme.txt*** file is also included on the hard drive that lists all of the files on the drive.

4.0 BART Determination Analysis for PM

4.1 Overview of PM Species

The size of particulate resulting from coal-fired combustion will vary depending on coal type, boiler design, and mill grind. At the boiler exit, particles may range up to 200 microns[7] for a typical pulverized coal boiler.[8] Particle size distribution of flue gas particulate may be altered by control device type and operation, as certain types of PM controls (such as ESPs) have different size-specific collection efficiencies. For an ESP-equipped boiler, PM sizes in the stack may range up to 100 microns, although 50-80% of the total mass is represented by particles less than 10 um.[9]

There are two distinct particle size ranges that are currently regulated by EPA. These are particles less than 10 microns in diameter (PM_{10}) and particles less than 2.5 microns in diameter ($PM_{2.5}$). EPA classifies PM between 10 and 2.5 microns as coarse PM and PM at or below 2.5 microns as fine PM.

PM emissions from fossil fuel fired boilers are generally characterized as 'filterable' and 'condensable' particulate. PM_{10} coarse is essentially all filterable and $PM_{2.5}$ includes both filterable and condensable species.

Filterable PM Species

Filterable particulate refers to particulate that is measured using standard filter-based measurement techniques.[10] The particulate is captured from the flue gas on a filter and weighed for a direct mass measurement. Filterable PM is usually solid-phase material consisting of unburned carbon, ash, and other inorganic material.[11] Filterable PM measurement techniques do not catch vapors or some particles less than 0.3 microns.[12]

Condensable PM Species

Condensable PM refers to particulate that forms either by condensation of vapor-phase species or by chemical reaction between gases. Primary condensable particulate forms either in the stack or shortly after discharge from the stack, as hot flue gases are cooled by ambient air. Secondary particulate is formed in the atmosphere through chemical reaction between ambient constituents.

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[7] A 'micron' is one millionth of a meter: 1 μm = 1×10^{-6} m

[8] Applied Electrostatic Precipitation, Parker, K.R., 1997.

[9] RMB analysis of SRI impactor data for a variety of coals and boiler types.

[10] EPA Reference Method (RM) 5 (out of stack sampling) and RM-17 (in stack sampling)

[11] While technically considered "condensable", filterable measurements may occasionally include suspended droplets and aerosols, such as scrubber carryover and condensed sulfuric acid, which are large enough to be captured on the filter.

[12] AP-42

Virtually all condensable particulate is less than one micron, and therefore may constitute a significant fraction of $PM_{2.5}$.

Primary Condensable Species
Primary condensable PM includes organic[13] compounds, sometimes referred to as primary organic aerosols (POA), and inorganic compounds. For coal-fired applications, most primary condensable PM species is inorganic, representing roughly 80% of the total condensable PM_{10}.[14]

The primary organic components include a broad range of compounds known as polycyclic organic matter (POM). The most commonly tested and reported subset of POM are polycyclic aromatic hydrocarbons (PAH), which are compounds containing only carbon and hydrogen.

POM are products of incomplete combustion that are most often associated with complex fuels that have a high carbon to hydrogen content and staged combustion, such as coal.[15] POM compounds exist in the solid phase under ambient conditions and may be emitted from the stack in either vapor form or solid form, depending on flue gas temperature. At typical flue gas temperatures (> 300°F), most POM is emitted in the vapor phase. However, for scrubbed stacks where temperatures are often below the melting point of most POM (~ 200°F), POM compounds readily condense onto existing particulate. In this case, only a small portion of POM is emitted from the stack in vapor-phase.

Primary inorganic compounds are typically condensed acids. For coal-fired applications, sulfuric acid (H_2SO_4) and the sulfuric acid precursor SO_3 are most significant. During the combustion of fossil fuels, fuel-bound sulfur is oxidized to form SO_2. A small fraction of SO_2 (< 1%) is further oxidized to form SO_3 in the convective regions of the furnace, depending on coal sulfur content and excess air level. Additional SO_2 is oxidized in the economizer region of the boiler in a catalytic reaction that depends on SO_2 concentration, ash and boiler tube compositions, excess air level, and gas/tube surface temperature and surface area. This additional oxidation may range up to 2%.[16] Upstream of the air pre-heater, SO_3 exists in the flue gas in the gaseous phase. However, as the gas passes through the air heater and cools, the hygroscopic SO_3 combines with flue gas moisture to form vapor-phase sulfuric acid (H_2SO_4).

Units equipped with SCR for NO_x control, particularly those firing high-sulfur coals, have a higher susceptibility to acid gas formation, as SCR catalysts are known to cause additional oxidation of flue gas SO_2. The SCR catalyst reduces NO_x (predominately NO) to molecular nitrogen, which provides additional oxygen for further SO_2 to SO_3 conversion. Test data have shown that this additional conversion may be as high as 3% depending on the operating parameters, system design

[13] Carbon containing

[14] AP-42

[15] U.S. Environmental Protection Agency. *Locating and Estimating Air Emissions from Sources of Polycyclic Organic Matter*. EPA-454/R-98-014. Office of Air Quality Planning and Standards, Research Triangle Park, NC. 1998.

[16] *Emissions of Sulfur Trioxide from Coal-Fired Power Plants*, Srivastava, R.K., Miller, C.A., Erickson, C., Jambhekar, R.

and catalyst formulation. This increase can effectively double the existing SO_3 flue gas concentration.[17]

Measurement of primary condensable PM has become a more recent regulatory issue. The current version of the EPA reference method[18] for measuring condensable PM is known to have a measurement bias for flue gas containing SO_2, NO_x, or soluble semi-volatile organic compounds. A portion of these gases dissolve in the impinger solutions and oxidize to form artifacts that artificially inflate measured particulate. EPA is presently considering modification of RM-202 to reduce artifact formation.

Secondary Condensable Species
Secondary condensable PM also includes both organic ("secondary organic aerosols", SOA) and inorganic components. SOA are formed when the oxidation products of certain volatile organic compounds[19] (VOCs) condense on pre-existing aerosols (usually POA). The atmospheric behavior of SOA is currently not well understood and ambient SOA concentration is difficult to measure.

The most notable secondary inorganic particulates associated with visibility impairment are ammonium sulfate, ammonium bisulfate, and ammonium nitrate, each formed in the atmosphere through photochemical reactions. Unlike SOA, the mechanisms of sulfate and nitrate formation and their contribution to atmospheric fine particles are well documented.[20]

<u>Applicable PM Species for BART</u>

Only direct PM emissions, including filterable and primary condensable PM species, are considered in the BART evaluation. Secondary inorganic species are not considered PM emissions under the Clean Air Act, and thus are not considered for the purposes of the BART PM evaluation. These species are analyzed separately as part of BART evaluations for SO_2 and NO_x, which Plant Bowen is not required to undertake because SO_2 and NO_x BART are being satisfied through the State of Georgia's implementation of the Clean Air Interstate Rule (CAIR). Secondary organic species (SOA), although considered PM in ambient air, is also not subject to this analysis since it is not considered to be direct PM emissions from a stack and is not included in the current VISTAS modeling protocol.[21]

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[17] *Current Work on the Impacts of SO_3 Emissions from Selective Catalytic Reduction Systems,* Erickson, C, Jambhekar, R.

[18] EPA RM-202, *Determination of Condensable Particulate Emissions from Stationary Sources*

[19] Organic species include volatile, semi-volatile, and (primary) condensable organic compounds. VOCs refers to those volatile and semi-volatile components that are emitted to the atmosphere in a gaseous phase.

[20] EPA, ibid.

[21] CALPUFF provides SOA modeling capability. However, the model was adapted from SOA formation from biogenic organic emissions, and, therefore, is not suited for modeling combustion-related SOA formation. The VISTAS protocol acknowledges that the application for combustion-related SOA formation requires additional investigation. Note that the organic carbon model input parameter refers to POA, not SOA.

Filterable Species
The initial selection of BART options for filterable PM emissions is independent of particle size. Separate evaluations are not required for PM_{10} and $PM_{2.5}$. However, as part of the BART evaluation, the impact analysis requires a source to evaluate the visibility improvement of competing BART alternatives. Since fine particles have a greater effect on visibility, this suggests that any changes in the "baseline" particle size distribution should be considered when comparing BART alternatives.

Condensable Species
The BART evaluation for primary condensable PM species will be based on sulfuric acid emissions. Plant Bowen Units 1-4 are currently equipped with SCRs and Units 3 and 4 have flue gas conditioning. Also, all four units have permits for wet scrubbers and these scrubbers are currently under construction. Therefore, stack conditions may be favorable for relatively high concentrations of condensed sulfuric acid.

POA (POM) will not be considered in the selection of BART alternatives. SCS is unaware of any post-combustion controls that are specifically designed for POA reduction for coal-fired applications. Furthermore, for those control scenarios where some theoretical reduction in POA may be possible (i.e. WESP, wet scrubber), SCS was unable to locate any additional information on removal efficiency. Given the relatively low concentrations of POA in the flue gas, if any such data were available, it would likely be meaningless because of measurement uncertainty.

4.2 Potentially Available PM Controls

The first step in the BART evaluation is to identify all available retrofit control technologies. "Available" refers to technologies "*with a practical potential for application to the emissions unit and the regulated pollutant under evaluation*."[22] This limits the potential retrofit options to only those technologies that are field-proven and commercially available.

Based on the preceding discussion, this effort is limited to the control technologies for filterable PM and sulfuric acid gas emissions. Many of the control technologies available for filterable PM removal have little or no removal of sulfuric acid emissions and vice-versa. In fact, while some controls may improve collection of one species, they may increase emissions of the other (e.g. sorbent injection removes sulfuric acid gas but increases filterable PM).[23] Therefore, in selecting the appropriate BART option, which could include one or more retrofit technologies, consideration will be given to the overall net PM removal and the net effects on visibility.

The following section includes a general discussion of the various potentially available control options for filterable PM and sulfuric acid emissions. Some of these options may not be applicable to certain affected units. A case-by-case analysis is discussed in Section 4.3 as part of the BART evaluation to eliminate technically infeasible options for each unit.

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[22] BART Guidelines, Section IV.D.1.1.

[23] The "appropriate" BART determination may include a combination of one or more PM control devices/upgrades (e.g. ESP upgrade and sorbent injection). Note that the appropriate BART determination could also be a single control technology that does not provide removal capability of both PM species.

Filterable PM Controls

For coal-fired applications, all conventional PM controls are designed to remove primary, filterable particulate. In determining the initial list of appropriate control technologies, SCS considered all field-proven, commercially available upgrade options listed in the EPRI ESP upgrade guidelines manual.[24] These technologies have been applied at multiple coal-fired plants and the suppliers provide performance guarantees. Two additional technologies are included, because they have reached some degree of maturity in the period of time since the original guidelines documents were prepared: the Indigo Technologies' particle agglomerator and the BHA "Juice Can" filter.

Wet ESP
Wet ESPs ("WESPs") use the same basic operating principles as conventional, cold-side or hot-side ESPs. However, instead of a plate rapping system, a flowing sheet of water covering each collecting plate is used to remove the collected ash. Collected material flows down the plate with the water film and is collected in a drain system. WESPs virtually eliminate reentrainment and back corona problems found in conventional precipitators.

A WESP system can be installed either as a separate unit downstream of the existing ESP or, as a retrofit, in the outlet field of the existing ESP casing. WESPs can be constructed in either a tubular or plate (similar to conventional ESPs) configuration. Tubular WESPs are suitable for vertical flow applications only. This design is slightly more compact, but more complicated to build than a flat plate design.

One of the critical design issues is the material used in the collection system. WESP internals must be made of a conductive material that will resist corrosion due to the acid mist that might be present in the gas. Common materials include conductive fiberglass, carbon steel, stainless steels, and various high-end alloys. For most multi-pollutant applications, an acid-gas scrubber is used to pre-treat the gas entering the WESP.

WESP technology has received particular interest as a multi-pollutant emissions control device capable of reducing emissions of acid fumes, fine particulate, mercury, and other metals. WESPs have also been considered a performance enhancement option for installations with either high ash resistivity or excessive reentrainment.

Although WESPs have been used successfully in some smaller-scale industrial applications and widely used in the sulfuric acid industry to control SO_3 mist, historically, they have not been used in utility applications because of the high costs associated with the corrosion-resistant metals used in their manufacture. Disposal of wastewater is also an issue.

Pulse Energization
A conventional power supply for an ESP consists of a high voltage step up transformer to provide either a full wave or, in some older installations, half wave rectified electrical power input to the corona-generating electrode system. The complete system includes a control system with an appropriate operating control algorithm. The conventional power supply provides input to the ESP system with a sinusoidal shaped varying voltage to transfer energy to the ESP. Electrical energy

[24] *Guidelines for Upgrading Electrostatic Precipitators: Volume 2,* EPRI Report Number TR-113582.

flows to the collector when the applied voltage from the power supply exceeds the residual voltage on the ESP electrode system. This conventional power supply is appropriate for most ESP installations.

Pulse energization is a technology that is useful for increasing the ESP collection efficiency for high resistivity fly ash particles. The advantage of pulse energization is that the voltage applied to the corona electrode is increased at such a fast rate that the process of individual tuft formation does not have time to develop before the entire corona electrode is brought into corona. It takes several microseconds of time for the individual tufts to form so the entire corona electrode is generating corona before the shielding of individual tufts can occur. This pulse corona process leads to the entire surface of the corona electrode supplying carrier ions and a much more nearly uniform current distribution over the surface of the dust layer.

In order to implement pulsed energization, it is necessary to purchase and install the new power supplies. In some cases, portions of the existing power supplies can be reused, but in most cases, they are scrapped or installed on another unit. If the ESP is operating with heavy back corona, the emissions can be significantly reduced with the addition of pulsers.

COHPAC

COHPAC, an acronym for *Compact Hybrid Particulate Collector*, is a technology that includes a small pulse jet fabric filter downstream of the existing ESP. There are two methods of installing COHPAC. The first method ("COHPAC I") places the fabric filter downstream of the ESP in a new casing. The second method ("COHPAC II") requires the last mechanical field of the ESP to be replaced with the fabric filter.[25] The pulse jet collector can be designed with a much higher gas to cloth ratio than a conventional collector because of two factors. First, the fly ash loading into the filter is much less than in a stand-alone filter because the ESP has removed more than 90% of the ash. Second, the ash suspended in the gas stream is electrically charged by the ESP and will form a much more porous dust cake than uncharged ash. PM removal efficiency ($PM_{2.5}$ and total PM) for COHPAC is consistent with the typical efficiency of pulse jet fabric filter installations (~99% of existing emissions levels).

Particle Agglomerator

The collection efficiency of an ESP varies as a function of the particle size of the material to be collected. This is because of a combination of factors related to the electrical charging mechanisms and the ease with which particles of different sizes are able to move through the molecules in the gas stream. The collection efficiency for an ESP is high for large particles, decreases to a minimum for particles in the half micron diameter range, and then increases somewhat for the even smaller particles. The minimum collecting efficiency just coincides with the wavelength of light that causes the greatest opacity of particles in the atmosphere.

The particle agglomerator is a technology that causes the smaller particles to contact and adhere to the larger particles so that they will be removed with the large particles that are collected more

[25] COHPAC II is not commercially available, and, therefore, does not meet the selection criteria as a viable retrofit technology.

efficiently than they would have been if remaining as individual particles. The principles used for particle coagulation are a combination of electrical and turbulent gas flow mechanisms that bring the oppositely charged particles into close proximity and allow them to adhere together.

The system consists of a number of individual corona discharge systems operating in parallel, with one channel operated with negative corona and the next with positive corona. This provides a gas stream with approximately half of the particles charged positively, with the remainder negative. When these gas streams are mixed, the oppositely charged particles are attracted together, then, upon contact, they adhere to each other and behave as one larger particle.

This device is installed in the ductwork leading to the ESP inlet plenum, where the gas velocity is relatively high – on the order of 20 to 40 feet per second. This region is designed to be highly turbulent to cause these gas streams to mix and bring the oppositely charged particles together. The gas stream is next brought into a conventional ESP for particle collection.

The specific agglomerator considered in this study is the Indigo Technologies system. There have been other types of agglomerators evaluated in the past; acoustic, electrical and sonic. The Indigo unit, using a combination of oppositely charged particles together with a highly turbulent mixing region, has provided the best performance in operating systems.

Vendor guarantees suggest a 50% reduction in particles less than five microns. The resulting improvement in ESP collection efficiency will depend on the existing particle size distribution upstream of the agglomerator.

Gas Flow Optimization

The gas velocity distribution in an ESP influences the overall removal efficiency in two ways. First, the ESP is an exponential type of collector; from collection considerations alone, the more nearly uniform the gas velocity distribution, the higher the primary collection efficiency. The removal process for a dry collector, however, consists of the primary removal coupled with the removal of the collected dust layer and deposition of this material into the ash hopper collection system. The optimization process depends on optimizing the combination of collection and removal to the hopper.

When the ash deposit is removed from the collecting electrodes, the ash falls into the hopper by gravity. As the material falls, the layer will break up to some degree, with some of the material carried away by the gas stream while the remainder falls into the hopper. When this material falls into the hopper, the ash tends to break up and re-entrain into the gas stream. This reentrainment is referred to as hopper "boil up."

The amount of previously collected ash that is reentrained into the gas stream is a function of the gas velocity where reentrainment occurs. The material collected on the top of the collecting electrode falls a greater distance in traveling to the hoppers than that collected on the bottom. Hopper boil up occurs in the region just above the collecting electrode. Therefore, there is a trend for more reentrainment to occur near the lower portion of the ESP than from the top. These considerations favor a gas velocity distribution with higher velocities in the top, minimizing the amount of material that must fall through the gas stream with lower gas velocities near the bottom, where higher collecting and lower reentrainment should occur. These considerations suggest that the gas velocity distribution for optimized collection will not necessarily be one that is uniform, but one that is somewhat skewed towards higher velocities in the top of the ESP.

To optimize the gas flow in an ESP, the existing gas flow distribution must be measured and analyzed. The analysis is usually accomplished with a smaller scale model of the ESP system. When the desired gas velocity distribution is produced in the model study, the gas flow distribution baffles, turning vanes, etc. are designed and installed in the full scale unit. Of course, the resultant gas velocity distribution must be verified in the full scale ESP installation. The estimated improvement in ESP performance will depend on the quality of the existing flow distribution and the existing amount of hopper reentrainment.

Juice Can

Modern ESP power supply controls are programmed to maintain the electrical energization as high as possible to the point where some characteristic of the ESP- particle combination limits the applied voltage or current. The two primary limitations on the ESP operating level are the mechanical spacing of the ESP components and the electrical characteristics of the ash being collected. The applied voltage can increase until one of the following occurs: (1) spark-over between the electrodes, (2) the current or voltage limit is reached on the power supplies, or (3) electrical breakdown occurs in the collected dust layer.

In conventional industrial negative corona ESPs, spark-over is initiated at the positive or collecting electrode. If the applied voltage is raised, corona begins to flow at an applied voltage of about 20 kilovolts and increases somewhat exponentially until spark-over occurs or either the voltage or current reaches the power supply limits. If the collecting electrodes are clean, spark-over will occur when the local value of the electric field adjacent to some location on the collecting electrode system reaches a value on the order of 10 kilovolts per centimeter, where sparking is initiated.

Sparking that is initiated by geometrical constraints is limited by the instantaneous value of the applied voltage. The formation of the flare on the electrically positive surface occurs in a few microseconds. Therefore, any modification to the ESP system that can maintain the peak value of the applied voltage just below sparking voltage while increasing the average value of the voltage will increase the collecting efficiency of the ESP. This condition applies whenever the ESP is collecting low resistivity particles. This is the condition where the “Juice Can” is an appropriate technology.[26]

The “Juice Can” consists of a capacitor connected in parallel with the distributed capacitance of the ESP electrode system. The normal ESP electrode system has an equivalent electrical circuit of a parallel resistor-capacitor combination with a time constant on the order of 15 milliseconds. Since capacitances in parallel add, the addition of the Juice Can increases the electrode system capacitance, while the equivalent resistance remains nearly constant. This causes the electrical time constant of the electrode system to increase. If the Juice Can capacitance is equal to that of the ESP electrode system, the time constant is approximately doubled. Since the charging current flows from the power supply every 8.33 milliseconds, while the time constant of the ESP-Juice Can combination is doubled to 30 milliseconds, the ESP voltage will decay less, perhaps leading to

[26] The Juice Can may actually be detrimental to the performance of an ESP collecting high resistivity fly ash (unless the ash is conditioned).

a peak to average voltage ratio of only 1.15. This would raise the average operating voltage to 87% of the peak value. This simple change will increase the migration velocity for individual particles by perhaps 15%. It increases the average operating current density as well. The estimated performance improvement of Juice Can technology is unit-specific and depends on existing ash resistivity and field power levels.

Add Extra Collecting Field
Adding an extra field merely increases the size of the ESP and, thus, increases the overall collecting efficiency. This option can be considered for any ESP provided adequate space exists. The estimated performance improvement varies depending on the performance of the existing ESP, the size of the additional field, and gas velocity through the ESP.

Moisture Injection
It is well known that cooling a gas stream in a cold side ESP results in a reduction of gas volume and the electrical resistivity of the ash, which improves the overall performance of the ESP. While moisture conditioning is based on sound theory, the drawback is the difficulty with which the water must be injected into the flue gas without forming heavy deposits in the ductwork. Field experience with moisture conditioning systems has shown that the problems with the routine operation of these systems far outweigh the advantages.

Moisture conditioning was not seriously considered for use as a retrofit. It is only included in the discussion of potential retrofit technologies because it is usually mentioned as a low cost option.

Sulfuric Acid Gas Controls

Several methods are used to control emissions of condensed sulfuric acid and SO_3, a sulfuric acid precursor. These methods are described briefly as follows:

Sorbent Injection
Acid gas formation can be controlled by the use of sorbent materials that are either injected directly into the boiler during the combustion process or into the flue gas stream upstream of the air heater. These sorbent materials are alkaline (basic) in nature and combine with the acid gas as particulate that is removed by the ESP or baghouse.

For furnace-injection technologies, alkaline sorbents are injected directly into the boiler. Known sorbent materials for this methodology include limestone and calcium or magnesium-based slurries. For units with SCR, furnace injection technologies offer the potential benefit of allowing lower load operation and reduced SCR inlet temperatures. However, preliminary data suggest that furnace-injected sorbents do not provide significant control of SCR generated SO_3.

For post-furnace sorbent injection, alkaline sorbents can be injected upstream or downstream of the SCR, if so equipped, or upstream or downstream of the air heater. Pre-air heater injection offers the potential benefit of reducing the SO_3 generated by the SCR and lowering the acid dewpoint temperature, which allows for lower air heater outlet temperatures and the potential of increased plant efficiency. Known sorbents used for pre-air heater injection include ammonia, hydrated lime, limestone, magnesium oxide powder, and various sodium compounds.

Relatively high removal efficiencies (+80%) of SO_3 have been reported using sorbent-based control techniques. However, the injection of sorbent material can cause a reduction in ESP performance and in some cases may be the limiting factor in SO_3 reduction. This has been confirmed, to some extent, by existing field studies by EPRI, DOE, and others. The potential effects on ESP inlet flue gas characteristics include increased mass loading at the ESP inlet, a reduction in particle size distribution, increased particulate resistivity, and changes in particulate adhesion and cohesion properties. The combined effect of these issues suggests decreased ESP performance and an increase in outlet emissions. In addition, the collection of sorbent-containing ash may adversely affect the quality of salable flyash.

Flue Gas Humidification
Another method of sulfuric acid emissions control is to cool the flue gas below the acid dew point temperature by injecting water into the ductwork upstream of a cold-side ESP. The theory is to intentionally condense the sulfuric acid from the flue gas.

Again, moisture conditioning was not seriously considered for use as a retrofit option. It is only included in the discussion of potential retrofit technologies because it is usually mentioned as a low cost option. While testing conducted by DOE has shown some incremental improvement in sulfuric acid removal, there is insufficient data to assess the long-term feasibility of this option. Previous studies using humidification for improving ESP performance have shown sludge buildup in flue gas ductwork to be a significant problem. For sulfuric acid control, corrosion of internal ESP components is another significant concern.

SCR Catalyst Replacement
Units equipped with SCR for NO_x control, particularly those firing high-sulfur coals, have a higher susceptibility to acid gas formation, as SCR catalysts are known to cause additional oxidation of flue gas SO_2. The SCR catalyst reduces NO_x (predominately NO) to molecular nitrogen, which provides additional oxygen for further SO_2 to SO_3 conversion. Test data have shown that this additional conversion may be as high as 3% depending on the operating parameters, system design and catalyst formulation. This increase can effectively double the existing SO_3 flue gas concentration.[27]

SO_3 formation can also be controlled by reducing the additional SO_2 conversion that takes place across the SCR. Catalysts are currently available from manufacturers that produce lower levels of SCR-formed SO_3, in some cases, less than 0.5%.

Wet ESP
WESPs are widely used in the sulfuric acid industry to control SO_3 mist. WESPs capture sulfuric acid by passing the flue gas through an electrostatic precipitator after it has been cooled to saturation. By combining the electrostatic forces with low temperature and water saturation, sulfuric acid can be captured at relatively high efficiencies (80+%).

[27] *Current Work on the Impacts of SO_3 Emissions from Selective Catalytic Reduction Systems,* Erickson, C, Jambhekar, R.

4.3 Feasibility Analysis of Potential Controls

GPC may eliminate potential upgrade options from the BART determination analysis if such options are considered technically infeasible.[28] Technical feasibility depends on whether each technology is commercially available and whether the technology can be applied to the affected source. Site-specific issues, such as space limitations and flue gas properties, may preclude the application of certain commercially available technologies. Upgrade options that are eliminated due to technical feasibility are exempt from subsequent analysis in the BART determination. The following is a summary of the feasibility of the various potential upgrade options included in the previous section.

<u>Wet ESP</u>

WESP is considered a technically feasible option for all four Bowen units. Each boiler could be retrofitted with a WESP to reduce filterable particulate matter as well as condensable particulate matter. Depending on the available space, the WESP would need to be integrated within the WFGD scrubber vessel or downstream of the WFGD as a grade-mounted installation. Additional analysis would be required to determine the available space, although a preliminary investigation suggests that an integrated design may be applicable to Units 3 and 4 due to the confined layout.

<u>Pulse Energization</u>

Pulse energization is a technology that is useful for increasing the ESP collection efficiency for high resistivity fly ash particles. However, this is not an issue on any of the Bowen units because each unit is equipped with a flue gas conditioning system which controls fly ash resistivity. As a result, pulse energization is not considered a technically feasible option for any of the Bowen units.

<u>COHPAC</u>

COHPAC is available in two configurations: COHPAC I and COHPAC II. COHPAC I requires the installation of a fabric filter in a separate casing downstream of the existing ESP. COHPAC II is a retrofit of the outlet field of an existing ESP with a fabric filter. Of the two configurations, only COHPAC I is commercially available and therefore COHPAC II is not considered as part of this analysis.

COHPAC I retrofit would be very difficult if not impossible due to the limited space existing between the ESPs and ID fans, especially on Units 3 and 4. Therefore, this option is considered technically infeasible.

<u>Particle Agglomerator</u>

The particle agglomerator is a technically feasible option for all four of the Bowen units. The addition of an agglomerator should improve the performance of the existing ESPs. Units 3 and 4 should benefit the most from this technology due to the relatively smaller size of the ESPs. Some

[28] BART Guidelines, Section IV.D.2.

caution should be taken with this option due to the lack of experience in installing agglomerators on boilers of this size.

Gas Flow Optimization

Gas flow optimization is considered a technical feasible option on all of the Bowen units. However, since GPC has already conducted gas flow improvements, it is uncertain how much additional improvement can be made on these units. The excellent performance of the existing ESPs brings to question the overall benefit possible with this option.

Juice Can

Juice Can technology is considered a technically feasible option on all of the Bowen units. Juice Cans have already been installed on some transformer/rectifier sets on Units 3 and 4 and have shown to improve the performance of the ESPs. Installation on Units 1 and 2 may show similar levels of performance improvement. However, further improvement on Units 3 and 4 is uncertain due to the existing performance of these units.

Add Extra Collecting Field

Adding collection surface to any ESP will improve performance. This option was evaluated for Plant Bowen for Units 3 and 4 but was determined to be technically infeasible due to inadequate space. Space is available for Units 1 and 2, and, therefore, addition of an extra collecting field is considered technically feasible for these two units.

Moisture Injection (for PM and/or SO_3 control)

Field experience with moisture conditioning/flue gas humidification has shown this to be an infeasible technology due to the associated maintenance problems. Moisture injection has repeatedly been shown to cause heavy deposits of sludge in the ductwork. On the Bowen units, moisture injection would also cause additional sulfuric acid condensation, which would create corrosion problems in the ESP ductwork and casing.

Sorbent Injection

Sorbent injection for SO_3 control is considered a technically feasible option for all of the Bowen units. However, while sorbent injection can provide a significant reduction in flue gas SO_3 concentration, it produces collateral PM emissions due to the added particulate. In addition, since sorbent is typically injected upstream of the ESP, it can create a reduction in ESP performance due to the increased loading and adverse changes in flue gas properties. Because of these issues, SCS has assumed the sorbent would be injected downstream of the ESP between the ESP and the WFGD. SCS has also assumed that lime would be used as the sorbent material.

SCR Catalyst Replacement

Catalyst replacement may be considered a feasible option for units with a high SO_3 conversion across the SCR. However, the SO_3 conversion across the SCRs on the Bowen units is already relatively low (~1%). Switching to an ultra-low conversion catalyst (~0.5%) is not considered technically feasible at this time because such catalysts are not well demonstrated in the field. Furthermore, since SO_3 conversion is related to mercury oxidation, SCS is evaluating the potential co-benefit of the additional mercury oxidation across the SCR (and subsequent removal in the WFGD) as part of the long-term compliance strategy for CAMR.

Summary of Feasible Upgrade Options

Table 4-1 summarizes the feasible upgrade options for all four units. All other options are considered technically infeasible and have been excluded from the remainder of the BART determination analysis.

Table 4-1 Technically Feasible Upgrade Options for Plant Bowen

Upgrade Option	Applicable Unit
WESP	Units 1-4
Particle Agglomerator	Units 1-4
Gas Flow Optimization	Units 1-4
Juice Can	Units 1-4
New Collection Field	Units 1 and 2
Sorbent (Lime) Injection	Units 1-4

Combinations of Feasible Upgrade Options

The EPA BART Guidelines suggest that combinations of upgrade options should be considered as part of the feasibility analysis. EPA allows affected sources to determine the extent to which upgrade combinations are included but does not expect every possible control combination to be investigated. The selection of control combinations should be based on a reasonable consideration of estimated emissions reductions, the cost of the various alternatives, and other plant impacts.

For Plant Bowen, any combination of the feasible upgrade options listed in Table 4-1 is technically possible since the effects on particulate removal are independent of each other. As EPA suggests, analysis of all possible control combinations is unreasonable. As part of the cost impact analysis, GPC will evaluate one or more combinations of the lower cost control technologies and/or control technologies that provide lower levels of emissions reduction.

4.4 Control Effectiveness of Feasible Options

The evaluation of the various upgrade options requires a comparison of total PM_{10} (filterable and condensable) reduction of each option. The estimated total PM_{10} reduction is determined by using an assumption of the incremental speciated removal efficiencies of filterable PM_{10}, filterable $PM_{2.5}$, and sulfuric acid for each upgrade option. For WESP and lime injection, speciated removal efficiencies reflect typical removal efficiencies that have been demonstrated in practice. For ESP upgrade options, speciated removal efficiencies are based on ESP computer model results. Once the incremental removal efficiencies were determined, they were then applied to the baseline emissions data to determine the overall emissions reduction, expressed in terms of ‘tons per year’, for each upgrade option.

The following section summarizes the assumptions used to determine the control effectiveness and the expected emissions reduction of each feasible option:

Wet ESP

WESPs are capable of removing both filterable and condensable PM (sulfuric acid) species, although they are primarily considered for sulfuric acid removal on units equipped with SCR and WFGD. Like conventional ESPs, WESP removal efficiency depends on a number of factors including size, gas velocity, and various flue gas properties. WESPs may be designed to achieve a specific emissions limit and/or they may be used to achieve the same emissions level as pre-SCR conditions. Since this analysis does not require a target emissions rate for sulfuric acid or filterable PM emissions, SCS has assumed that the WESP would be used to limit sulfuric acid emissions to pre-SCR level. The estimated collection efficiency for this target emission rate is 80% removal of sulfuric acid at the WESP inlet. This removal rate also represents the maximum, sustained removal efficiency, accounting for normal unit downtime, that can be expected using WESP technology. SCS has assumed the corresponding filterable PM_{10} and filterable $PM_{2.5}$ collection efficiency to be 90%.

Lime Injection

Lime injection has shown to be an effective method of reducing flue gas SO_3. However, the injection of lime causes an increase in filterable particulate emissions because the added particulate is not completely removed in the downstream PM control device. Since the assumed injection point is upstream of the WFGD, the WFGD represents the downstream PM control device. Emissions of total PM_{10} (filterable and condensables) may increase or decrease depending on the speciation of the flue gas prior to the lime addition, injection rate, and the filterable PM removal efficiency of the downstream control device. As with WESP design, lime injection rate can be adjusted to achieve a specific target SO_3 emission limit or to maintain SO_3 emissions to pre-SCR levels.

SCS calculated lime injection rates for each unit based on achieving pre-SCR levels of SO_3. These injection rates translate to an estimated combined sulfuric acid collection efficiency of both the WFGD scrubber and lime injection of 75%.[29] SCS assumed that the added particulate was collected in the WFGD with a collection efficiency of 90% for both filterable PM_{10} and filterable $PM_{2.5}$. This removal efficiency is slightly higher than the removal efficiency of 80% used in the baseline scrubber emissions estimates due to the larger particle size distribution of the lime and the higher collection efficiency of the larger particulate in the scrubber.

ESP Upgrade Options

ESP upgrade options include those options that result in an improvement in ESP performance - Juice Can, new collection field, gas flow optimization, particle agglomerator. Since ESPs remove filterable PM species, estimated performance effects are considered only for filterable PM for these options. Generalized emissions reduction factors are not appropriate for analysis of these options

[29] Based on testing conducted at Plant Yates in 2006.

because the effects of the various upgrade options on ESP removal efficiency are unit-specific and depend on a number of factors, including ESP size and configuration, inlet loading, particle size distribution, gas flow rate, and other flue gas properties.

In order to improve the accuracy of the estimated emissions reduction, SCS conducted computer modeling[30] of each upgrade option for each ESP design. ESP computer models calculate performance from first principles and, therefore, have the capability to account for variations in flue gas properties. The output of the computer model was used to determine an estimated percent emissions reduction for each option. Given the similarity in ESP design and flue gas characteristics between Units 1 and 2 (identical units) and Units 3 and 4 (identical units), modeling was conducted on a representative model for each set of units and the results were applied to the baseline emissions data for each unit. Certain upgrade options may affect particle-size specific collection efficiency more than others. Therefore, results were generated for both filterable PM_{10} and filterable $PM_{2.5}$ species.

Particle Agglomerator

The particle agglomerator improves overall filterable PM removal by exploiting the site-specific collection efficiency of the ESP. It is well known that fine PM collection efficiency in an ESP is lower than the overall PM collection efficiency. The particle agglomerator combines some of the fine particulate into larger particulate, which is more readily collected in the ESP. This increases overall collection efficiency and reduces fine particle concentration at the ESP exit.

Vendor guarantees suggest a 50% reduction in PM_5 at the ESP inlets due to the particle agglomeration. This roughly translates to a 20% increase in the particle size distribution mass mean diameter at the ESP inlet on each unit. SCS adjusted the inlet particle size distributions accordingly in each baseline model. For Units 1 and 2, the modeling results suggest a 33% reduction in filterable PM_{10} and a 34% reduction in filterable $PM_{2.5}$. For Units 3 and 4, the results suggest a 22% reduction in filterable PM_{10} and a 34% reduction in filterable $PM_{2.5}$.

Gas Flow Optimization

One of the primary benefits of gas flow optimization is a reduction in rapping and steady reeentrainment losses from ESP hoppers. The degree of improvement is directly related to the existing flow profile within each ESP. Since SCS has already conducted previous flow studies on the Bowen units, it is not expected that this option will provide a significant performance improvement. As a conservative estimate, SCS assumed that gas flow optimization would produce a 15% reduction in reentrainment losses from the ESP.

For Units 1 and 2, the modeling results suggest a 3% reduction in filterable PM_{10} and a 1% reduction in filterable $PM_{2.5}$ at the ESP outlet. For Units 3 and 4, the results suggest a 6% reduction in filterable PM_{10} and a 2% reduction in filterable $PM_{2.5}$.

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[30] All modeling was conducted using EPRI's *ESPM Version 3* software using baseline models that were calibrated using measured emissions test data.

Juice Can
The addition of Juice Can technology to the existing transformer-rectifier sets will increase the average operating voltages and currents within the ESP. EPRI research suggests an increase in the average voltage to ~90% of the peak operating voltage and an increase in the operating current density of approximately 10%.[31] SCS adjusted the operating voltages of each calibrated model accordingly. For Units 1 and 2, operating currents were increased by 10%. For Units 3 and 4, operating currents were only increased by 5%, as a more conservative assumption, given the relatively high existing current levels.[32]

For Units 1 and 2, modeling results suggest a 6% reduction in both filterable PM_{10} and $PM_{2.5}$. For Units 3 and 4, the results suggest a 9% reduction in both filterable PM_{10} and $PM_{2.5}$.

New Collection Field
Units 1 and 2 are each equipped with two ESPs arranged in a parallel configuration. Box 'A' is equipped with four fields in the direction of gas flow and Box 'B' is equipped with six fields in the direction of gas flow. For the purpose of this analysis, SCS has assumed that the additional field would be added in a separate casing to the outlet of Box 'A' because it would provide a greater performance improvement over the addition to the outlet of Box 'B'. SCS has also assumed that the mechanical and electrical characteristics of the new field would be identical to those in the immediate upstream field in Box 'A'.

For Units 1 and 2, modeling results suggest a 35% reduction in filterable PM_{10} and a 32% reduction in filterable $PM_{2.5}$. Modeling was not conducted for Units 3 and 4 because the addition of a new field was considered technically infeasible on these units.

4.5 Impacts Analysis for Feasible Options

A BART determination requires consideration of certain statutory factors for each feasible control option. Among these are the costs of compliance and the energy and non-air quality environmental impacts of compliance. The following discussion analyzes these factors for the previously-identified feasible options.

4.5.1 Energy Impacts

Energy impacts may occur due to increased station service requirements and/or forced or extended unit outages that may be required to install a particular upgrade technology. Energy impacts are considered to be negligible for all feasible upgrade options, except the WESP, provided the upgrades can be conducted during a scheduled outage. Upgrades such as installation of the Juice Cans and gas flow optimization may be conducted during a one to two week outage. Installation of the particle agglomerator, lime injection, and the addition of a new ESP field may require four to six weeks, which could be coordinated with the plant's major outage schedule.

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[31] Nichols, G. (1999), *Guidelines for Upgrading Electrostatic Precipitator Performance: Volume 2: Electrostatic Precipitator Upgrade Guidelines*, Electric Power Research Institute.

[32] Some of the existing T/R sets are already equipped with Juice Can technology.

WESP Energy Impacts
WESP systems require additional station service to power the electrical fields and the various pumps associated with the water recycle and water treatment systems. Station service requirements are estimated at 0.5% of the gross turbine generating capacity (MW).[33]

WESP installations may require an extended unit outage depending on the WESP configuration. Grade-mounted installations minimize unit downtime. Virtually all construction can be conducted with the unit online and the WESP may be tied-into the flue gas ductwork during a scheduled outage. The WESP tie-in could take four to six weeks, depending on complexity of the additional ductwork. Retrofit installations where the WESP is integrated into the WFGD vessel are more complicated than grade-mounted installations because additional custom field work (less modularization) is required. In addition, the integrated design may require reinforcement of the scrubber foundation as the WFGD may not support the additional weight of the WESP. Integrated retrofits require the unit to be offline for the duration of the installation, which can result in extended unit outages. A more detailed evaluation would be necessary to determine the potential unit downtime, but it is likely that such an installation would extend beyond the four weeks of a typical major outage at Bowen.[34] A preliminary analysis suggests that an integrated design may be needed on the Bowen units due to the available space.

4.5.2 Non-Air Quality Environmental Impacts

Non-air quality related environmental impacts are considered to be negligible for all upgrade options except the WESP. WESP operation is a water intensive process that requires an adequate supply of make-up water and disposal and/or treatment of ash-laden byproducts.

WESP water systems are site-specific and may vary considerably in complexity. The basic configuration may be either a once-through or closed-loop design. In a once-through design, fresh makeup water supplies 100% of the water used in the WESP. Make-up water may come from a nearby lake or stream or from other plant processes such as the condenser cooling water. While once-through systems typically provide better performance and cleaning than closed-loop systems, water requirements are much higher. Water consumption on a once-though system is estimated at 10 gpm/MW for adequate plate washing.[35]

Make-up water requirements can be minimized by using a closed-loop design, which recycles most of the water in the WESP. This may be suited for plants with a limited supply of fresh makeup water. Some makeup water is still required in order to replace water lost through evaporation, leakage, and blow-down of recycled effluent. Make-up water requirements in closed-loop systems depend largely on flue gas ash concentration and recycle water chemistry. Water consumption in a

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[33] L. Monroe (SCS). Estimate is supported by DOE estimates of 0.5% (*Economic Comparison of SO_3 Control Options for Coal-Fired Power Plants*, presented at Air Quality IV Conference, Arlington, VA September 23, 2003).

[34] Major scheduled outages occur 18-24 months and are typically 30 days in duration.

[35] Harrison, W, et al. (1999), *Field Pilot Test Results for a Utility Wet Electrostatic Precipitator: Water Treatment and Performance*, Electric Power Research Institute.

closed-loop system may range from 1 to 2 gpm/MW for a typical bituminous coal application with WFGD.[36]

WESP ash disposal may represent a more significant environmental concern for many plants. WESP effluent may either be sluiced to the plant's existing ash pond or filtered and shipped for landfill disposal. Unlike dry ESP flyash, where the ash can be sold for various commercial applications, the market for recycled WESP ash is likely to be limited because of the various substances in the ash.

4.5.3 Cost Impacts

SCS determined the cost effectiveness of each competing upgrade alternative. The cost components used in this analysis are consistent with those found in the *EPA Air Pollution Control Cost Manual.* For the purpose of this analysis, SCS has assumed a baseline generation rate of 700 MW for Units 1 and 2 and 900 MW for Units 3 and 4. Baseline emissions and unit capacity factors are based on historical data for the period 2003-2005. Baseline emissions data have been adjusted to account for future WFGD operation.

<u>Total Capital Costs</u>

The following section discusses the total capital costs associated with each of the upgrade options, including direct and indirect capital costs. Direct capital costs consist of basic equipment and installation costs, ductwork modifications (if applicable), various infrastructure costs incurred to accommodate the new equipment, design and engineering costs, and typical vendor contingencies. Indirect capital costs include the loss of investment interest incurred during the construction period.

Direct Capital Costs
The direct capital cost information provided represents the latest cost information available from industry sources. Direct capital cost estimates for retrofits are highly site-specific. The generalized estimates used in this analysis, expressed in terms of dollars per kilowatt ($/kW) of net generation capacity, are assumed to be accurate within 25% - 50%.[37] Considerable effort would be required to develop more accurate cost estimates. However, this level of accuracy should be sufficient to evaluate the cost-effectiveness of various upgrade options since the cost uncertainties affect all of the proposed upgrade options.

WESP. Capital costs for a WESP installation depend on a number of factors, including the configuration and size of the unit (based on required efficiency and gas flow rate), the cost of corrosion resistant materials used in construction, the required level of water treatment, and market conditions. These factors may result in as much as an order of magnitude variation in capital costs. In addition, capital costs for retrofit applications may be significantly higher, depending on the difficulty of the retrofit. For this analysis, SCS has assumed that an integrated retrofit configuration would be required for all units. Capital cost for the WESP has been estimated at

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[36] Harrison, W., Ibid.

[37] Nichols, G., Ibid.

$115/kW.[38] It should be noted that material costs can vary significantly depending on market conditions. As demand for new power plant construction and pollution control devices increases, particularly for new WFGD systems, market prices for materials and construction will also increase.

Lime Injection. Lime injection requires the installation of an injection manifold, ductwork modifications, various storage tanks, silos, blowers, and piping. SCS has assumed a capital cost of $10/kW for the addition of lime injection.[39]

ESP Upgrade Options. Capital costs for gas flow optimization and Juice Cans were assumed to be $1.5/kW and $1.0/kW, respectively.[40] Capital costs for the installation of a new collection field were assumed to be $40/kW. Capital costs for the particle agglomerator were assumed to be $13.3/kW.[41]

Indirect Capital Costs

Indirect capital costs include the loss of investment interest incurred during the construction period of the upgrade option. While indirect capital costs can be a significant cost component for some construction projects, SCS has excluded them from this cost analysis. Almost all of the upgrade options can be completed within a four to six week timeframe and, therefore, the indirect capital costs associated with these upgrade options are considered minor. For the WESP option, while the installation may likely take longer than six weeks, SCS can not provide a reasonable estimate of the construction timeframe for the purpose of estimating indirect capital costs. Therefore, in order to provide a conservative cost estimate, SCS has excluded this cost component from the analysis.

Capital Cost Summary

The total capital investment (TCI) normally includes both the direct and indirect capital costs associated with upgrade option. Since indirect capital costs have been excluded from this analysis, TCI is based solely on direct capital costs. The TCI for each applicable upgrade option is summarized in Tables 4-2 and 4-3 for each unit.

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[38] Estimate is consistent with EPA data for WESP of $40/kW to $400/kW (EPA Air Pollution Technology Fact Sheet EPA-452/F-03-029). Higher cost estimate is justified due to complexity of integrated retrofit.

[39] Data is consistent with DOE estimates for lime injection (upstream of A/H) of $9/kWh (Blythe, G. (2004). *Furnace Injection of Alkaline Sorbents for Sulfuric Acid Removal,* DOE Report).

[40] Nichols, G., Ibid. Estimates are based on a model 300MW boiler equipped with 200 SCA (cold-side) ESP.

[41] Based on vendor estimates provided by Indigo Technologies, Inc. for a 235 MW boiler equipped with a 110 SCA (cold-side) ESP (Appendix C). SCS has included an additional 20% cost adjustment to reflect in house facilities and engineering costs.

Table 4-2 Total Capital Cost Estimates, Units 1/2

Upgrade Option	TCI
Agglomerator	$9,310,000
Optimize Gas Flow	$1,068,065
Juice Cans	$700,000
Add New Collection Field	$28,000,000
WESP	$80,500,000
Lime Injection	$7,000,000

Table 4-3 Total Capital Cost Estimates, Units 3/4

Upgrade Option	TCI
Agglomerator	$11,970,000
Optimize Gas Flow	$1,373,226
Juice Cans	$900,000
WESP	$103,500,000
Lime Injection	$9,000,000

Annualized Costs

The cost impact analysis requires the determination of the annualized cost of each upgrade option. Annualized costs include operating and maintenance (O&M) costs, annualized TCI costs and station service penalties associated with certain upgrade options. Annualized costs are based on average capacity factor for the 2003 – 2005 historical baseline timeframe (see discussion below). The following section discusses the annualized costs associated with each upgrade option.

Operation and Maintenance Costs
O&M costs include the additional man-power and other resources (i.e. water requirements, sorbent materials, etc.) required to operate and maintain the equipment.[42] O&M costs for most of the upgrades are considered negligible except for the WESP and lime injection options. O&M costs for the WESP have been estimated at $0.47/MWh[43]. O&M costs for the lime injection system consist primarily of the added sorbent cost. SCS has assumed the O&M costs for lime injection to be $0.40/MWh.

Annualized TCI Costs
Total capital costs (TCI) for major utility construction projects are typically referred to as "capital recovery costs" and are expressed on an annualized basis. Annual capital recovery costs are equivalent to an annual payment that is sufficient to finance the investment over the expected life of the equipment. Capital recovery costs are determined by applying a capital recovery factor to the TCI cost. The capital recovery factor used in this analysis (0.1098) is derived from a simple interest formula assuming a "real"[44] interest rate of 7% and an equipment life of 15 years. The

[42] Station service requirements for WESP and lime injection are not included in O&M cost estimates. These costs are accounted for separately as station service penalties.

[43] Estimate is below EPA data for WESP O&M costs of $1.6/MWh to $2.6/MWh (EPA Air Pollution Technology Fact Sheet EPA-452/F-03-029).

[44] A "real" interest rate does not take into account the effects of inflation.

capital recovery cost approach does not include all revenues necessary to support an investment item such as administrative costs, property taxes, and insurance expenses.

Capacity and Energy Penalties
This analysis also includes the calculation of indirect capacity and energy penalties associated with the increased station service requirements of certain upgrade options. Station service requirements for Units 1/2 were assumed to be 350 kW for both the agglomerator retrofit and the addition of a new collection field and 3,500 kW for the WESP. Station service requirements for Units 3/4 were assumed to be 450 kW for the agglomerator retrofit and 4,500 kW for the WESP. Station service requirements for all other upgrade were assumed to be negligible.

SCS assumed that the incremental capacity reduction would be made up by additional capacity constructed to offset the reduction. It is estimated that the cost of this capacity would be about $600/kW and that this capital would be recovered under the same financial assumptions as the control technologies being evaluated. In addition, the analysis includes an additional cost penalty associated with the energy production capability lost from the capacity reduction. It is reasonable to assume that this energy will be made up by purchasing makeup power at an average cost of $0.05/kWh.

Annualized Cost Summary
A breakdown of the total, annualized costs (in 2006 dollars) associated with each upgrade option is provided in Tables 4-4 and 4-5 for each unit.

Table 4-4 Annualized Upgrade Cost Summary (2006 Dollars), Units 1/2

			Capacity and Energy Penalties			
Upgrade Option	O&M Costs	TCI Capital Recovery	Capital Cost of Additional Capacity	Capital Recovery of Additional Capacity	Cost of Makeup Energy	Annualized Cost
Agglomerator		$1,022,238	$210,000	$23,058	$118,233	$1,163,529
Optimize Gas Flow		$117,273				$117,273
Juice Cans		$76,860				$76,860
Add New Collection Field		$3,074,400	$210,000	$23,058	$118,233	$3,215,691
WESP	$2,222,773	$8,838,900	$2,100,000	$230,580	$1,182,326	$12,474,580
Lime Injection	$1,891,722	$768,600				$2,660,322

Table 4-5 Annualized Upgrade Cost Summary (2006 Dollars), Units 3/4

			Capacity and Energy Penalties			
Upgrade Option	O&M Costs	TCI Capital Recovery	Capital Cost of Additional Capacity	Capital Recovery of Additional Capacity	Cost of Makeup Energy	Annualized Cost
Agglomerator		$1,314,306	$270,000	$29,646	$152,013	$1,495,965
Optimize Gas Flow		$150,780				$150,780
Juice Cans		$98,820				$98,820
WESP	$2,857,851	$11,364,300	$2,700,000	$296,460	$1,520,134	$16,038,745
Lime Injection	$2,432,214	$988,200				$3,420,414

Other Cost Factors

There are a number of important factors that were not specifically included in the economic analysis. The most important of these relates to the reduced reliability that results from the add-on of sulfuric acid control options. Reduced reliability means these generating units would potentially be available for power generation less often. To make up for this unavailability, additional capacity would have to be installed or energy purchases made in order to adequately serve the customer demand for electricity.

Cost Analysis

SCS performed the cost analysis of the various upgrade options in accordance with EPA's BART Guidelines and the *EPA Air Pollution Control Cost Manual*. The objective of the cost analysis is to eliminate upgrade options from further evaluation that are not considered cost effective. This analysis considers both average and incremental cost effectiveness using the annualized installed capital, operating, and other indirect annualized costs and the estimated total PM_{10} emissions reduction of each upgrade option. Estimated emissions reduction for each option are determined using baseline emissions with scrubber operation and the incremental improvement in collection efficiency identified in the previous section.

Baseline Emissions

Baseline emissions for the cost analysis are derived from historical emissions for the three-year period 2003 through 2005 and have been adjusted to account for future scrubber operation. First, total filterable PM emissions were calculated using emissions test results for total, filterable PM from 2002 and 2004[45] and actual heat input data as reported in the Acid Rain Program quarterly EDR files. The resulting estimate for total, filterable PM emissions, in tons per year, along with corresponding NO_x and SO_2 emissions, is summarized in Tables 4-6 through 4-9 for the baseline historical period.

Table 4-6 2003 – 2005 Historical Emissions, Unit 1

Year	Capacity Factor	Boiler Heat Input	PM Test Results	Total, Filterable PM Emissions	SO_2 Emissions	NO_x Emissions
2003	70.9%	42,878,960	0.029	622	34,644	4,695
2004	71.5%	43,260,104	0.081	1,752	34,447	5,129
2005	74.8%	45,277,146	0.081	1,834	39.451	5,344
Average	72.4%	43,805,403	0.064	1,403	36,181	5,056

45 SCS conducts biannual PM compliance testing for total, filterable PM. Emissions test results, expressed in terms of 'lb/mmBtu' from 2002 were applied to historical heat input data for 2003 to determine total, filterable PM emissions for 2003 in terms of 'tons per year'. Emissions test results from 2004 were applied to historical heat input data for 2004 – 2005 to determine total, filterable PM emissions for 2004 – 2005.

Table 4-7 2003 – 2005 Historical Emissions, Unit 2

Year	Capacity Factor	Boiler Heat Input	PM Test Results	Total, Filterable PM Emissions	SO_2 Emissions	NO_x Emissions
2003	70.6%	42,723,636	0.071	1,517	34,063	4,760
2004	76.9%	46,546,493	0.084	1,955	38,494	5,364
2005	92.6%	56,039,764	0.084	2,354	48,000	7,153
Average	80.1%	48,436,631	0.080	1,942	40,186	5,759

Table 4-8 2003 – 2005 Historical Emissions, Unit 3

Year	Capacity Factor	Boiler Heat Input	PM Test Results	Total, Filterable PM Emissions	SO_2 Emissions	NO_x Emissions
2003	81.8%	59,294,767	0.086	2,550	46,724	7,308
2004	85.8%	62,211,838	0.046	1,431	50,603	7,979
2005	76.5%	55,427,706	0.046	1,275	48,714	6,597
Average	81.4%	58,978,104	0.059	1,752	48,680	7,295

Table 4-9 2003 – 2005 Historical Emissions, Unit 4

Year	Capacity Factor	Boiler Heat Input	PM Test Results	Total, Filterable PM Emissions	SO_2 Emissions	NO_x Emissions
2003	85.9%	63,231,404	0.099	3,130	49,453	8,197
2004	71.5%	52,604,828	0.051	1,342	42,370	6,298
2005	80.4%	59,201,659	0.051	1,510	50,306	7,151
Average	79.3%	58,345,964	0.067	1,994	47,376	7,216

The average total, historical filterable PM estimate for the baseline historical period was combined with AP-42 emissions factors to calculate estimated historical emissions for the various PM species, including filterable PM_{10}, fine PM, and organic carbon.[46] Baseline sulfuric acid emissions were calculated using the baseline SO_2 emissions (unadjusted for WFGD operation) and the assumption of 0.8% conversion of flue gas SO_2 to SO_3 in the boiler, a 51% reduction in boiler-generated SO_3 across both the air pre-heater and ESP, and an additional 0.99% oxidation of flue gas SO_2 to SO_3 across the SCR.[47] Finally, the speciated PM emissions data were adjusted to account for future WFGD operation.[48] The resulting baseline emissions for each unit are summarized in Table 4-10.

[46] The emissions factor used in the analysis for filterable PM_{10} (0.67) was applied to the baseline estimate of total, filterable PM emissions. The emissions factor for filterable, fine PM (0.444) was applied to the calculated estimate of filterable PM_{10} emissions. The emissions factor for organic carbon (0.0032) was applied to the baseline SO_2 emissions (unadjusted for WFGD operation).

[47] The estimate of SCR-formed SO_3 has been adjusted to account for reaction with ammonia, assuming an ammonia slip of 0.75 ppm at 6% O_2.

[48] Baseline emissions estimates with WFGD operation assume an additional 80% removal of PM_{10} and an additional 40% removal of sulfuric acid emissions across the scrubber.

Table 4-10 Baseline Emissions [tons per year], Units 1–4

		Filterable Species			Condensable Species		
Unit	Total PM_{10}	Tot Filt PM_{10}	Coarse PM	Fine PM	Tot Cond PM_{10}	Sulfuric Acid	OC
1	418.5	188.0	104.5	83.5	230.5	114.7	115.8
2	516.3	260.2	144.7	115.5	256.1	127.5	128.6
3	544.9	234.8	130.6	104.2	310.1	154.4	155.8
4	568.8	267.2	148.6	118.6	301.6	150.0	151.6

Estimated Post-Retrofit Emissions

The estimated PM_{10} emissions for each upgrade option were calculated by applying the incremental removal efficiencies for filterable PM_{10}, filterable fine PM, and sulfuric acid emissions (see *Control Effectiveness of Feasible Options*) to the baseline emissions for each unit. Tables 4-11 through 4-14 summarize the estimated emissions for the various PM species for each unit.

Table 4-11 Estimated Post-Retrofit Emissions [tons per year], Unit 1

		Filterable Species			Condensable Species		
Upgrade Option	Total PM_{10}	Tot Filt PM_{10}	Coarse PM	Fine PM	Tot Cond PM_{10}	Sulfuric Acid	OC
Agglomerator Retrofit	356.4	125.9	70.8	55.1	230.5	114.7	115.8
Optimize Gas Flow	412.8	182.3	99.7	82.6	230.5	114.7	115.8
Juice Can Retrofit	407.2	176.7	98.3	78.4	230.5	114.7	115.8
Add New Collection Field	352.7	122.2	65.5	56.7	230.5	114.7	115.8
WESP	157.5	18.8	10.5	8.3	138.7	22.9	115.8
Lime Injection	385.4	221.8	123.3	98.5	163.6	47.8	115.8

Table 4-12 Estimated Post-Retrofit Emissions [tons per year], Unit 2

		Filterable Species			Condensable Species		
Upgrade Option	Total PM_{10}	Tot Filt PM_{10}	Coarse PM	Fine PM	Tot Cond PM_{10}	Sulfuric Acid	OC
Agglomerator Retrofit	430.4	174.3	76.2	98.1	256.1	127.5	128.6
Optimize Gas Flow	508.5	252.4	114.4	138.0	256.1	127.5	128.6
Juice Can Retrofit	500.7	244.6	108.6	136.0	256.1	127.5	128.6
Add New Collection Field	425.2	169.1	78.5	90.6	256.1	127.5	128.6
WESP	180.1	26.0	11.5	14.5	154.1	25.5	128.6
Lime Injection	478.2	296.5	131.6	164.9	181.7	53.1	128.6

Table 4-13 Estimated Post-Retrofit Emissions [tons per year], Unit 3

		Filterable Species			Condensable Species		
Upgrade Option	Total PM_{10}	Tot Filt PM_{10}	Coarse PM	Fine PM	Tot Cond PM_{10}	Sulfuric Acid	OC
Agglomerator Retrofit	493.3	183.1	114.3	68.8	310.1	154.4	155.8
Optimize Gas Flow	530.8	220.7	118.6	102.1	310.1	154.4	155.8
Juice Can Retrofit	523.8	213.6	118.7	94.9	310.1	154.4	155.8
WESP	210.1	23.5	13.1	10.4	186.7	30.9	155.8
Lime Injection	500.3	280.2	155.8	124.4	220.1	64.3	155.8

Table 4-14 Estimated Post-Retrofit Emissions [tons per year], Unit 4

		Filterable Species			Condensable Species		
Upgrade Option	Total PM_{10}	Tot Filt PM_{10}	Coarse PM	Fine PM	Tot Cond PM_{10}	Sulfuric Acid	OC
Agglomerator Retrofit	510.0	208.4	130.1	78.3	301.6	150.0	151.6
Optimize Gas Flow	552.8	251.1	134.8	116.3	301.6	150.0	151.6
Juice Can Retrofit	544.8	243.1	135.2	107.9	301.6	150.0	151.6
WESP	208.3	26.7	14.8	11.9	181.6	30.0	151.6
Lime Injection	525.6	311.5	173.2	138.3	214.1	62.5	151.6

Average Cost Effectiveness

Average cost effectiveness refers to the total annualized costs of a control upgrade option, in dollars per year, divided by the estimated annual emissions reduction associated with the upgrade option, in tons per year. Average cost effectiveness is expressed in terms of (annualized) dollars per ton of pollutant removed ($/ton).

In addition to the initial list of technically feasible upgrade options, SCS evaluated the cost effectiveness of combining multiple options.[49] In evaluating which upgrade options to combine, SCS considered the combination of the two options that would provide the maximum expected visibility improvement (WESP and lime injection) and the combination of the two most cost effective options on an individual basis (agglomerator retrofit and Juice Cans).

Tables 4-15 through 4-18 summarize the average cost effectiveness of each upgrade option and upgrade combination. The results show that the most cost effective control option for all four units is the addition of Juice Cans. The average cost for this option ranges from $4,100/ton to $6,800/ton. The results also show that the least cost effective control option for all four units is the addition of lime injection. The average cost for the addition of lime injection ranges from $70,000/ton to $80,000/ton.

[49] EPA's BART Guidelines allow (Section IV.D.2) discretion in selecting the number of control combinations and the methodology used to determine these combinations.

Table 4-15 Average Cost Effectiveness of Upgrade Options, Unit 1

Upgrade Option	Annualized Cost [$/yr]	PM_{10} Reduction [tpy]	Average Cost [$/ton]
Agglomerator	$1,163,529	62.0	$18,759
Optimize Gas Flow	$117,273	5.6	$20,798
Juice Cans	$76,860	11.3	$6,815
Add New Collection Field	$3,215,691	65.8	$48,881
WESP	$12,474,580	261.0	$47,804
Lime Injection	$2,660,322	33.1	$80,377
Agglomerator/Juice Cans	$1,240,389	73.1	$16,921
WESP/Lime Injection	$15,134,902	271.0	$55,857

Table 4-16 Average Cost Effectiveness of Upgrade Options, Unit 2

Upgrade Option	Annualized Cost [$/yr]	PM_{10} Reduction [tpy]	Average Cost [$/ton]
Agglomerator	$1,163,529	85.9	$13,550
Optimize Gas Flow	$117,273	7.8	$15,023
Juice Cans	$76,860	15.6	$4,923
Add New Collection Field	$3,215,691	91.1	$35,308
WESP	$12,474,580	336.2	$37,107
Lime Injection	$2,660,322	38.1	$69,889
Agglomerator/Juice Cans	$1,240,389	101.5	$12,222
WESP/Lime Injection	$15,134,902	347.4	$43,563

Table 4-17 Average Cost Effectiveness of Upgrade Options, Unit 3

Upgrade Option	Annualized Cost [$/yr]	PM_{10} Reduction [tpy]	Average Cost [$/ton]
Agglomerator Retrofit	$1,495,965	51.6	$28,965
Optimize Gas Flow	$150,780	14.1	$10,705
Juice Can Retrofit	$98,820	21.1	$4,677
WESP	$16,038,745	334.8	$47,909
Lime Injection	$3,420,414	44.6	$76,652
Agglomerator/Juice Can	$1,594,785	72.8	$21,914
WESP/Lime Injection	$19,459,159	348.2	$55,878

Table 4-18 Average Cost Effectiveness of Upgrade Options, Unit 4

Upgrade Option	Annualized Cost [$/yr]	PM_{10} Reduction [tpy]	Average Cost [$/ton]
Agglomerator	$1,495,965	58.8	$25,452
Optimize Gas Flow	$150,780	16.0	$9,406
Juice Cans	$98,820	24.0	$4,110
WESP	$16,038,745	360.5	$44,492
Lime Injection	$3,420,414	43.2	$79,225
Agglomerator/Juice Cans	$1,594,785	82.8	$19,256
WESP/Lime Injection	$19,459,159	373.6	$52,092

EPA does not provide a "bright line" in determining acceptable control costs for BART. The average cost effectiveness should be compared to the cost effectiveness of other similar BART determinations. However, such information is currently unavailable. SCS relies instead on the cost effectiveness of another "BART-like" determination in EPA Region 4 for this comparison. The PM BACT determination conducted by Tampa Electric Company (TECO) for ESP upgrades at Big Bend Station[50] showed an average cost effectiveness for upgrade options ranging from \$2,800/ton to \$5,100/ton[51]. The only upgrade option with similar cost effectiveness for Bowen is the installation of Juice Can technology. The data suggests that all other upgrade options are not cost effective.

Incremental Cost Effectiveness

Incremental cost effectiveness (ICE) is used to compare the cost and performance of a particular upgrade option to the next most stringent upgrade option. Incremental cost effectiveness is calculated according to the following formula:

$$ICE = \frac{(Cost_{Option} - Cost_{NextMostStringentOption})}{(Emissions_{Option} - Emissions_{NextMostStringentOption})}$$

EPA recommends that both incremental and average cost effectiveness be used in combination when considering whether to eliminate potential upgrade options. The incremental cost effectiveness may be used to justify the elimination of a more stringent alternative that may have comparable average cost effectiveness to the next most stringent option, but the incremental cost of the additional emissions reduction is excessive.

EPA recommends evaluating incremental cost effectiveness based on dominant control alternatives.[52] A dominant control alternative is a control option that has an average cost effectiveness that is consistent with the general relationship between cost and emissions reduction for all competing control options. Dominant control alternatives can be identified by graphing the average cost effectiveness of each upgrade option. Dominant alternatives will form a smooth, non-linear curve known as the "least-cost envelope". Control options that lie inside of the least-cost envelope are considered inferior options because the cost per ton of particulate removed is inconsistent with other competing alternatives.

SCS determined the least-cost envelope for the technically feasible upgrade options by creating a graphical plot of the total annualized cost and total PM_{10} emissions reductions for each upgrade option. An iterative procedure was then used to select the dominant options by including various combinations of upgrade options to achieve a least-cost envelope with the best curve fit.

[50] TECO's PM BACT analysis was conducted as a requirement of a consent decree that was issued in 2000. TECO applied BACT procedures to evaluate potential upgrade technologies for their existing ESPs on Units 1 - 3.

[51] The BACT determination for all three units was a combination of upgrades including the installation of PC-based controls, improvements in ESP flow and temperature distribution, and upgrades to the ash handling system.

[52] BART Guidelines, Section IV.D.4.e.2.

As shown in Figures 1 through 4, the dominant control choices for all four units include WESP, the addition of Juice Can technology on existing transformer/rectifier (T/R) sets, the particle agglomerator, and the combination of Juice Can/particle agglomerator. Gas flow optimization, lime injection, the addition of a new electrical field (on Units 1 and 2), and the combination of WESP/lime injection have been eliminated because they fall inside of the least-cost envelope. These options are considered inferior based on cost and emissions reduction and, therefore, have been eliminated from further analysis.

SCS calculated the incremental cost effectiveness of the dominant control options, as shown in Tables 4-19 thru 4-22, sorted in ascending order by annualized cost. The results suggest that the WESP has both high average costs ($37,000/ton - $48,000/ton and high incremental costs ($47,000/ton - $60,000/ton) and should be eliminated due to the excessive cost. The results suggest that, while the incremental cost of the agglomerator/Juice Can combination is moderate ($4,100/ton - $6,800/ton), the average cost of this option in also relatively high ($12,000/ton - $22,000/ton) and should be eliminated. Comparing the lowest cost option (Juice Cans) with the next most stringent option (agglomerator retrofit) shows incremental costs ranging from $15,000/ton to $46,000/ton. These incremental costs are also excessive – the incremental cost is approximately three to ten times higher than the average cost of the Juice Cans.

Cost Analysis Summary
The cost analysis suggests that the gas flow optimization, the addition of a new collection field (Units 1 and 2), lime injection, and the combination of WESP and lime injection should be eliminated from further consideration. These options were identified as inferior because they fall inside the least-cost envelope for each unit. Of the dominant upgrade options (Juice Cans, agglomerator retrofit, WESP, combination of Juice Cans/agglomerator), the Juice Can retrofit is the most cost-effective for all four units at Bowen. Average costs for this option range from $4,100/ton to $6,800/ton, which is somewhat higher but comparable to the average costs shown in TECO's BACT evaluation. Average and incremental costs for the remaining dominant alternatives appear to be excessive.

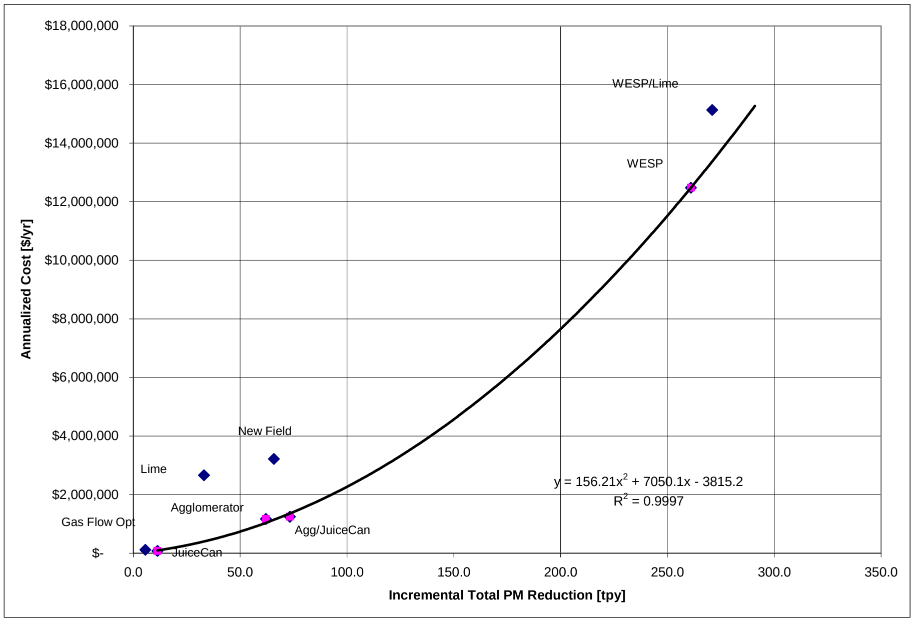

Figure 4-1. Least Cost Envelope, Unit 1

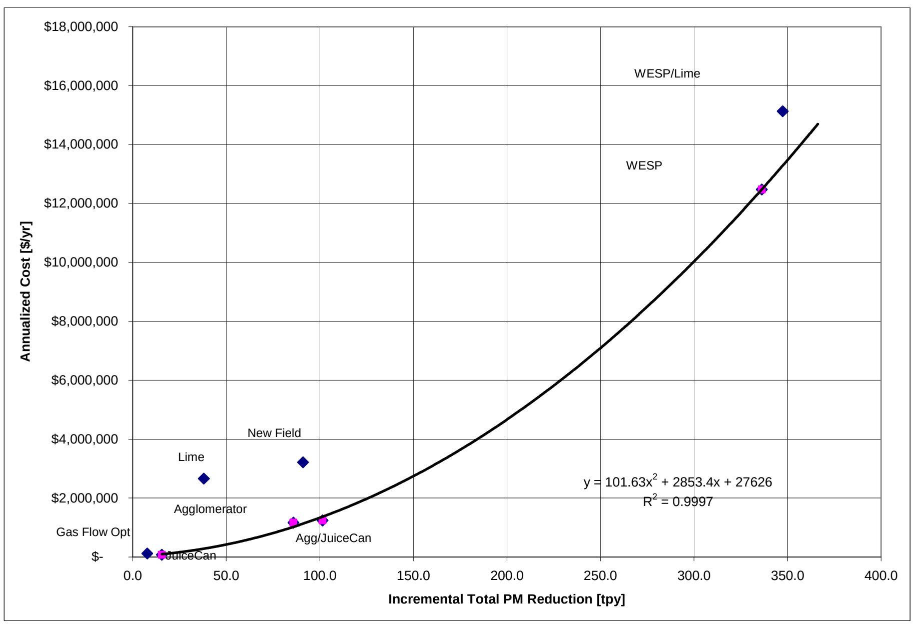

Figure 4-2. Least Cost Envelope, Unit 2

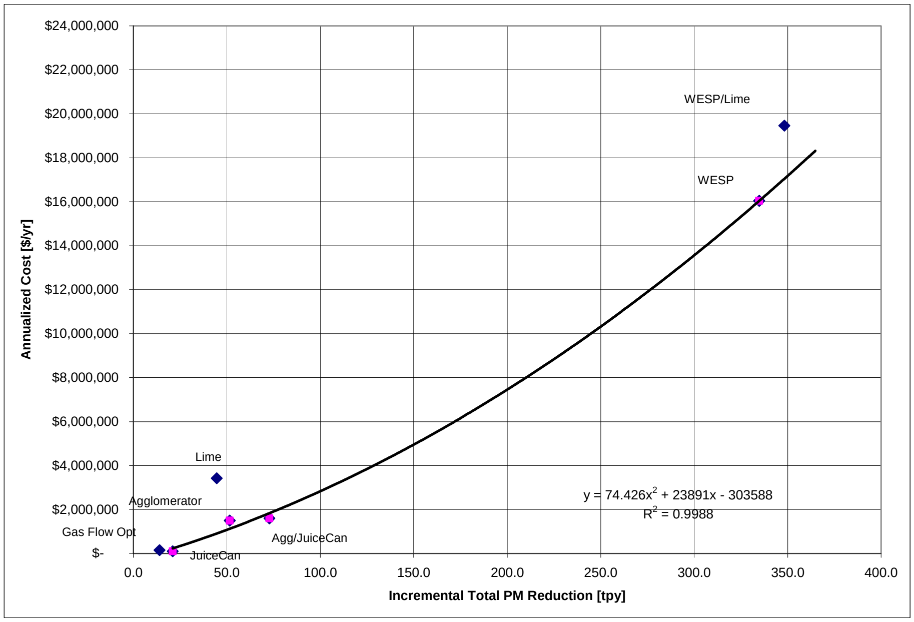

Figure 4-3. Least Cost Envelope, Unit 3

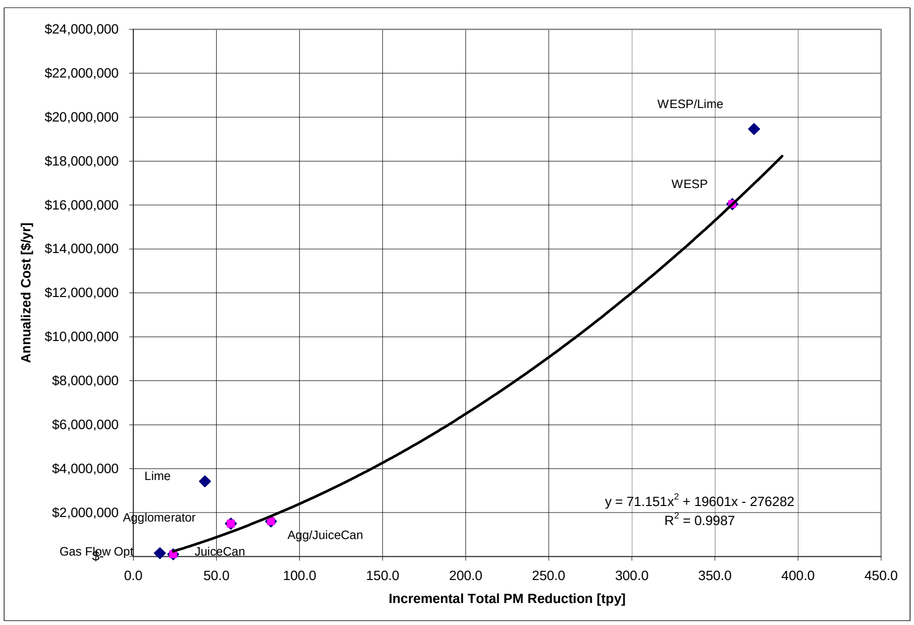

Figure 4-4. Least Cost Envelope, Unit 4

Table 4-19 Incremental Cost Effectiveness, Unit 1

Upgrade Option	Annualized Cost [$/yr]	Total PM_{10} Reduction [tpy]	Average Cost [$/ton]	Incremental Cost [$/ton]
Juice Cans	$76,860	11.3	$6,815	NA
Agglomerator	$1,163,529	62.0	$18,759	$21,413
Agglomerator/Juice Cans	$1,240,389	73.3	$16,921	$6,815
WESP	$12,474,580	261.0	$47,804	$59,868

Table 4-20 Incremental Cost Effectiveness, Unit 2

Upgrade Option	Annualized Cost [$/yr]	Total PM_{10} Reduction [tpy]	Average Cost [$/ton]	Incremental Cost [$/ton]
Juice Cans	$76,860	15.6	$4,923	NA
Agglomerator	$1,163,529	85.9	$13,550	$15,467
Agglomerator/Juice Cans	$1,240,389	101.5	$12,222	$4,923
WESP	$12,474,580	336.2	$37,107	$47,867

Table 4-21 Incremental Cost Effectiveness, Unit 3

Upgrade Option	Annualized Cost [$/yr]	Total PM_{10} Reduction [tpy]	Average Cost [$/ton]	Incremental Cost [$/ton]
Juice Cans	$98,820	21.1	$4,677	NA
Agglomerator	$1,495,965	51.6	$28,965	$45,780
Agglomerator/Juice Cans	$1,594,785	72.8	$21,914	$4,677
WESP	$16,038,745	334.8	$47,909	$55,129

Table 4-22 Incremental Cost Effectiveness, Unit 4

Upgrade Option	Annualized Cost [$/yr]	Total PM_{10} Reduction [tpy]	Average Cost [$/ton]	Incremental Cost [$/ton]
Juice Cans	$98,820	24.0	$4,110	NA
Agglomerator	$1,495,965	58.8	$25,452	$40,227
Agglomerator/Juice Cans	$1,594,785	82.8	$19,256	$4,110
WESP	$16,038,745	360.5	$44,492	$52,020

4.5.4 Remaining Useful Life

One of the factors that is considered in determining BART is the remaining useful life of the emissions unit.[53] In situations in which the unit will retire before BART compliance is required, the "remaining useful life" factor would allow a state to determine that no control of that unit is required as BART. Similarly, in situations in which the unit will retire before conclusion of the assumed 15-year equipment life used for the capital recovery factor in annualizing the cost of the control options, the state would consider the "remaining useful life" factor in determining the cost-effectiveness of the control options being evaluated.

For each of the EGUs at Plant Bowen, neither situation exists. None of the units will be retired before BART compliance would be required, and none of the units will be retired before conclusion of the 15-year equipment life for annualizing the cost of control options. Thus, there is no basis for considering the "remaining useful life" factor in determining PM BART for any of Plant Bowen's EGUs.

4.6 Visibility Impacts Modeling for Feasible Options

In determining BART, states must consider the visibility improvement that would result from the potential control options under evaluation.[54] The visibility improvement modeling for Plant Bowen's EGUs was conducted pursuant to the "BART Determination Modeling Protocol" submitted to EPD on December 4, 2006 (Appendix D). (As was the case for the exemption modeling discussed in section 3.0 above, the stack temperature used in the determination modeling has been adjusted from actual to virtual temperature.) Although each possible control option could be modeled and that option's visibility improvement could then be compared to the baseline visibility impact, the previous discussion suggests that the visibility improvement analysis for the Plant Bowen PM BART determination could be simplified by limiting the required modeling to a subset of the dominant control options for each unit. Specifically, modeling was conducted for the following two upgrade options for each unit: (1) the combination of the particle agglomerator and Juice Cans, which has the highest PM removal rate of the set of relatively lower cost controls; and (2) the WESP, the option with the highest total PM_{10} removal. The December 2006 Modeling Protocol further explains this approach. As discussed below, this approach provides adequate information to evaluate the visibility improvement associated with each of the feasible control options.

Tables 4-23 and 4-24 summarize the results of the visibility improvement modeling. For the agglomerator/Juice Can combination, the results show that there is virtually no visibility improvement associated with that option. For each of the units, the delta-delta-deciview improvement compared to the baseline is -0.01 dv (out to two decimal places, using the new IMPROVE equation and virtual temperature, 8^{th} highest high). Given these results, it is clear that,

[53] BART Guidelines, Section IV.D.4.k

[54] BART Guidelines, Section IV.D.5.

Table 4-23
Summary of Results - Plant Bowen BART Determination Modeling for Cohutta

	2001	2002	2003	Highest of 8th Highest delta-dv for the 3-years	22nd Highest delta-dv over 3-year period
	8th Highest delta-dv	8th Highest delta-dv	8th Highest delta-dv		
Baseline - Scrubbed					
Bowen 1-4 Result					
New Improve Virtual Temp	0.74	0.94	0.59	0.94	0.74
New Improve Actual Temp	0.78	1.05	0.73	1.05	0.82
Old Improve Virtual Temp	0.91	1.15	0.73	1.15	0.91
Old Improve Actual Temp	0.97	1.28	0.90	1.28	1.00
Agglomerator/Juice Can					
Bowen 1-4 Results - Unit 1 Controlled					
New Improve Virtual Temp	0.73	0.94	0.58	0.94	0.73
New Improve Actual Temp	0.78	1.04	0.72	1.04	0.81
Old Improve Virtual Temp	0.91	1.14	0.73	1.14	0.91
Old Improve Actual Temp	0.96	1.27	0.89	1.27	0.99
Bowen 1-4 Results - Unit 2 Controlled					
New Improve Virtual Temp	0.73	0.94	0.58	0.94	0.73
New Improve Actual Temp	0.78	1.04	0.72	1.04	0.81
Old Improve Virtual Temp	0.91	1.14	0.73	1.14	0.91
Old Improve Actual Temp	0.96	1.27	0.89	1.27	0.99
Bowen 1-4 Results - Unit 3 Controlled					
New Improve Virtual Temp	0.73	0.94	0.59	0.94	0.73
New Improve Actual Temp	0.78	1.05	0.72	1.05	0.81
Old Improve Virtual Temp	0.91	1.15	0.73	1.15	0.91
Old Improve Actual Temp	0.96	1.28	0.90	1.28	1.00
Bowen 1-4 Results - Unit 4 Controlled					
New Improve Virtual Temp	0.73	0.94	0.59	0.94	0.73
New Improve Actual Temp	0.78	1.05	0.72	1.05	0.81
Old Improve Virtual Temp	0.91	1.15	0.73	1.15	0.91
Old Improve Actual Temp	0.96	1.28	0.90	1.28	1.00

Table 4-23 (Continued)
Summary of Results - Plant Bowen BART Determination Modeling for Cohutta

	2001	2002	2003	Highest of 8th Highest delta-dv for the 3-years	22nd Highest delta-dv over 3-year period
	8th Highest delta-dv	8th Highest delta-dv	8th Highest delta-dv		
Wet ESP					
Bowen 1-4 Results - Unit 1 Controlled					
New Improve Virtual Temp	0.64	0.80	0.50	0.80	0.64
New Improve Actual Temp	0.67	0.89	0.61	0.89	0.70
Old Improve Virtual Temp	0.78	0.98	0.62	0.98	0.78
Old Improve Actual Temp	0.83	1.09	0.76	1.09	0.85
Bowen 1-4 Results - Unit 2 Controlled					
New Improve Virtual Temp	0.63	0.80	0.50	0.80	0.63
New Improve Actual Temp	0.67	0.89	0.61	0.89	0.69
Old Improve Virtual Temp	0.77	0.98	0.62	0.98	0.77
Old Improve Actual Temp	0.83	1.08	0.75	1.08	0.85
Bowen 1-4 Results - Unit 3 Controlled					
New Improve Virtual Temp	0.63	0.79	0.50	0.79	0.63
New Improve Actual Temp	0.65	0.88	0.61	0.88	0.68
Old Improve Virtual Temp	0.78	0.96	0.61	0.96	0.78
Old Improve Actual Temp	0.81	1.08	0.77	1.08	0.84
Bowen 1-4 Results - Unit 4 Controlled					
New Improve Virtual Temp	0.62	0.78	0.49	0.78	0.62
New Improve Actual Temp	0.65	0.87	0.61	0.87	0.67
Old Improve Virtual Temp	0.78	0.95	0.61	0.95	0.77
Old Improve Actual Temp	0.78	1.06	0.76	1.06	0.83

Table 4-24
Summary of Results – Visibility Improvement from Baseline
Plant Bowen BART Determination Modeling for Cohutta

	2001	2002	2003		
	8th Highest delta-dv	8th Highest delta-dv	8th Highest delta-dv	Highest of 8th Highest delta-dv for the 3-years	22nd Highest delta-dv over 3-year period
	delta-delta-dv	delta-delta-dv	delta-delta-dv	delta-delta-dv	delta-delta-dv
Agglomerator/Juice Can					
Bowen 1-4 Results - Unit 1 Controlled					
New Improve Virtual Temp	-0.01	0.00	-0.01	-0.01	-0.01
New Improve Actual Temp	0.00	-0.01	-0.01	-0.01	-0.01
Old Improve Virtual Temp	0.00	-0.01	0.00	-0.01	0.00
Old Improve Actual Temp	-0.01	-0.01	-0.01	-0.01	-0.01
Bowen 1-4 Results - Unit 2 Controlled					
New Improve Virtual Temp	-0.01	0.00	-0.01	-0.01	-0.01
New Improve Actual Temp	0.00	-0.01	-0.01	-0.01	-0.01
Old Improve Virtual Temp	0.00	-0.01	0.00	-0.01	0.00
Old Improve Actual Temp	-0.01	-0.01	-0.01	-0.01	-0.01
Bowen 1-4 Results - Unit 3 Controlled					
New Improve Virtual Temp	-0.01	0.00	0.00	-0.01	-0.01
New Improve Actual Temp	0.00	0.00	-0.01	-0.01	-0.01
Old Improve Virtual Temp	0.00	0.00	0.00	0.00	0.00
Old Improve Actual Temp	-0.01	0.00	0.00	-0.01	0.00
Bowen 1-4 Results - Unit 4 Controlled					
New Improve Virtual Temp	-0.01	0.00	0.00	-0.01	-0.01
New Improve Actual Temp	0.00	0.00	-0.01	-0.01	-0.01
Old Improve Virtual Temp	0.00	0.00	0.00	0.00	0.00
Old Improve Actual Temp	-0.01	0.00	0.00	-0.01	0.00

Table 4-24 (Continued)
Summary of Results – Visibility Improvement from Baseline
Plant Bowen BART Determination Modeling for Cohutta

	2001	2002	2003	Highest of 8th Highest delta-dv for the 3-years	22nd Highest delta-dv over 3-year period
	8th Highest delta-dv	8th Highest delta-dv	8th Highest delta-dv		
	delta-delta-dv	delta-delta-dv	delta-delta-dv	delta-delta-dv	delta-delta-dv
Wet ESP					
Bowen 1-4 Results - Unit 1 Controlled					
New Improve Virtual Temp	-0.10	-0.14	-0.09	-0.14	-0.10
New Improve Actual Temp	-0.11	-0.16	-0.12	-0.16	-0.12
Old Improve Virtual Temp	-0.13	-0.17	-0.11	-0.17	-0.13
Old Improve Actual Temp	-0.14	-0.19	-0.14	-0.19	-0.15
Bowen 1-4 Results - Unit 2 Controlled					
New Improve Virtual Temp	-0.11	-0.14	-0.09	-0.14	-0.11
New Improve Actual Temp	-0.11	-0.16	-0.12	-0.16	-0.13
Old Improve Virtual Temp	-0.14	-0.17	-0.11	-0.17	-0.14
Old Improve Actual Temp	-0.14	-0.20	-0.15	-0.20	-0.15
Bowen 1-4 Results - Unit 3 Controlled					
New Improve Virtual Temp	-0.11	-0.15	-0.09	-0.15	-0.11
New Improve Actual Temp	-0.13	-0.17	-0.12	-0.17	-0.14
Old Improve Virtual Temp	-0.13	-0.19	-0.12	-0.19	-0.13
Old Improve Actual Temp	-0.16	-0.20	-0.13	-0.20	-0.16
Bowen 1-4 Results - Unit 4 Controlled					
New Improve Virtual Temp	-0.12	-0.16	-0.10	-0.16	-0.12
New Improve Actual Temp	-0.13	-0.18	-0.12	-0.18	-0.15
Old Improve Virtual Temp	-0.13	-0.20	-0.12	-0.20	-0.14
Old Improve Actual Temp	-0.19	-0.22	-0.14	-0.22	-0.17

for each of the control options that provide fewer tons removed than does the agglomerator/Juice Can combination (i.e., the agglomerator alone and the Juice Cans alone), there also will be no visibility improvement from those options.

For the WESP, the results show a small visibility improvement as compared to baseline visibility impacts. For Units 1 & 2 with a WESP, the model predicts a -0.14 delta-delta-deciview improvement compared to the baseline (8^{th} highest high, new IMPROVE equation and virtual temperature). For Unit 3, the model predicts a -0.15 delta-delta-deciview improvement. Finally, for Unit 4, the model predicts a -0.16 delta-delta-deciview improvement.

Appendix E lists delta-deciview results for the top 20 days for each year modeled and the top 25 days for the overall three years at Cohutta for the primary results (i.e., the virtual temperature, new IMPROVE equation case).

An external hard drive is being provided separately that contains all of the electronic data related to this application (i.e., the virtual temperature, new IMPROVE equation case). This drive contains all of the input and output files used in the modeling. A ***readme.txt*** file is also included on the hard drive that lists all of the files on the drive.

5.0 Proposed PM BART for the Plant Bowen EGUs

EPA's BART Guidelines contain little guidance regarding how to select BART from among the control options under consideration.[55] The Guidelines simply indicate that, for each option, the emissions reduction, costs, energy and non-air quality environmental impacts, and modeled visibility improvement must be considered.

Section 4.0 of this document explains that PM emissions from Plant Bowen's EGUs are already very well controlled. Moreover, the available control options for PM BART span a wide range of costs but provide relatively small additional PM emissions reductions. From a regional haze standpoint, none of the available control options would produce a significant improvement in visibility in the most impacted Class I area, Cohutta. This is not surprising given VISTAS' conclusion that SO_2 emissions, not PM emissions, are primarily responsible for visibility impairment in the VISTAS' Class I areas.

Table 5-1 summarizes the information that is relevant for assessing whether any of the feasible PM control options should be considered BART. The following discussion analyzes this information.

The cost of compliance is one of the considerations that must be taken into account in selecting BART. Because neither EPA nor GEPD has announced any cost threshold for selecting BART and cost information from other PM BART determinations is unavailable, GPC has evaluated the BART options based on its general knowledge of previous NSR BACT cost thresholds that have been applied by regulators. It should be noted that GPC believes that NSR BACT cost evaluations are not directly relevant, and are conservative, for a BART analysis, given that NSR BACT applies to new sources and is part of a nationwide health-and-welfare based air quality program, while BART is focused on retrofits to existing sources and is relevant to a single-component (i.e., visibility), welfare-based air quality program for only Federal Class I areas. Thus, if the cost-effectiveness for a BART option exceeds the cost-effectiveness range that has been deemed reasonable in BACT determinations, then GPC believes that there is no reasonable basis for requiring those technologies under the regional haze program. Under NSR BACT determinations, regulators typically have not required installation of technologies that cost more than about $10,000/ton of pollutant removed.

As discussed previously, GPC has considered the cost information from the BART-like ESP upgrade analysis conducted by TECO for Big Bend Station as part of the consent decree issued in 2000. This is perhaps the most relevant cost information, since the objective of the TECO analysis was to evaluate the cost-effectiveness of various PM control device upgrade technologies, which is very similar to BART. The TECO determination showed upgrade costs ranging from $2,800/ton to $5,100/ton.

The analysis described in section 4.0 above reveals that the average cost-effectiveness of the WESP option ranges from about $37,000/ton (for Unit 2) to about $48,000/ton (for Units 1 and 3). In GPC's view, such cost-effectiveness values cannot be considered reasonable for BART. In addition, the WESP uses additional energy and has negative non-air environmental impacts

[55] BART Guidelines, Section IV.E.

associated with wastewater disposal. Finally, the WESP is estimated to produce less than a -0.2 delta-delta-deciview improvement in visibility in the closest Class I area, Cohutta, for any of the units. This level of improvement is well below the level that EPA considers to be detectable

Table 5-1 Summary of Bowen BART Determination Results[1]

Upgrade Option	Annualized Cost [$/yr]	PM_{10} Reduction [tpy]	Average Cost [$/ton]	Visibility Improvement from Baseline[2] [delta-delta-dv]
Bowen Unit 1 Results				
Juice Can	$76,860	11.3	$6,815	-
Agglomerator	$1,163,529	62.0	$18,759	-
Agglomerator/Juice Cans	$1,240,389	73.1	$16,921	-0.01
Wet ESP	$12,474,580	261.0	$47,804	-0.14
Bowen Unit 2 Results				
Juice Can	$76,860	15.6	$4,923	-
Agglomerator	$1,163,529	85.9	$13,550	-
Agglomerator/Juice Cans	$1,240,389	101.5	$12,222	-0.01
Wet ESP	$12,474,580	336.2	$37,107	-0.14
Bowen Unit 3 Results				
Juice Can	$98,820	21.1	$4,677	-
Agglomerator	$1,495,965	51.6	$28,965	-
Agglomerator/Juice Can	$1,594,785	72.8	$21,914	-0.01
Wet ESP	$16,038,745	334.8	$47,909	-0.15
Bowen Unit 4 Results				
Juice Can	$98,820	24.0	$4,110	-
Agglomerator	$1,495,965	58.8	$25,452	-
Agglomerator/Juice Cans	$1,594,785	82.8	$19,256	-0.01
Wet ESP	$16,038,745	360.5	$44,492	-0.16

Notes:
1. Visibility improvement results represent new IMPROVE equation and virtual stack temperature.
2. Incremental change is the "Highest of 8th Highest delta-delta-dv for the 3-years."

(approximately one deciview), and is also below the level (0.5 deciview) that EPA has recommended be used for visibility contribution analyses in the "subject-to-BART" step. In addition, because VISTAS' modeling shows that the Cohutta Class I area is achieving, by a wide margin, the uniform rate of progress (glide slope goal) in 2018, the small additional fraction of visibility improvement that would be associated with use of the WESP would, in GPC's view, not be worth the significant additional cost.

The agglomerator and the Juice Can/agglomerator combination both have average cost-effectiveness values that exceed (Units 1, 3, & 4) or lie at the upper limit (Unit 2) of cost-effectiveness values considered to be reasonable for BACT and other BART-like determinations. As a result, GPC believes that these technologies are not cost-effective for BART. Moreover, these technologies are estimated to produce virtually no visibility improvement in the Cohutta Class I area. Therefore, these options should also be rejected as BART.

Finally, the Juice Can option has an average cost-effectiveness ($4,110 - $6,815) that a regulator might consider reasonable for BACT, and which is close to the upper range for the TECO determination. However, even if this cost range were to be considered reasonable under the BART program, this option reduces PM emissions by only 11 to 24 tons (depending on the unit), and the CALPUFF modeling of control options that reduce even more PM reveals that this option is not expected to improve visibility in the Cohutta Class I area. The fact that the Juice Can option does not improve visibility in Cohutta should eliminate the option from consideration, regardless of whether GEPD would or would not find the cost-effectiveness values to be reasonable.

Based on the foregoing discussion, GPC believes that none of the PM control options should be selected by EPD as BART for any of Plant Bowen's EGUs.

Appendix A

Description of Virtual Temperature Calculation Tool

Appendix A

Buoyancy of Moist Plumes: Equivalent Dry Effluent Temperature

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Southern Company Services, September 2003

Background

Power plant stack effluent is typically treated in dispersion models as a 'dry' plume and moisture impacts are ignored. In high moisture plumes, such as those exiting a wet scrubber, the added buoyancy of water vapor compared to dry air or combustion product gases should be considered. One method of accounting for added buoyancy of high moisture plumes is to calculate an equivalent dry plume temperature. Simply put, a *virtual temperature* (T_v) can be defined and calculated[1] such that a moist plume of temperature T has the same density as a dry plume with temperature T_v. This paper will describe a calculation tool created to determine T_v of a moist plume based on fuel, operational, ambient and physical stack parameter inputs.

Input Data

In order to calculate actual plume constituents and concentrations, a fuel ultimate analysis (user input or provided selections) is needed along with expected excess combustion air. Local ambient dry bulb temperature and humidity ratio are required in addition to site base elevation, stack height and stack exit diameter. A flue gas temperature must be supplied and specified whether the temperature corresponds to the scrubber inlet or outlet (already saturated) location. The program is equipped with a 'saturator' module to calculate scrubber outlet conditions if unknown. Stack exit velocity will be calculated if a total flue gas flow is supplied. It is assumed that the given gas flow corresponds to the chosen scrubber inlet/outlet location. Required input summary:

Fuel ultimate analysis	% by weight of constituents
Flue gas temperature	ºF
Temperature location	Scrubber inlet or outlet (drop down box)
Excess air	%
Flue gas flow	lb/hr
Ambient temperature	ºF
Ambient humidity ratio	$lb_{water\ vapor}$ / $lb_{dry\ air}$
Site base elevation	ft above sea level
Stack height	ft above site base elevation
Stack exit diameter	ft

[1] Rolland B. Stull, Meteorology for Scientists and Engineers, 2nd Ed. (Pacific Grove, CA: Brooks/Cole, 2000), p. 8.

Optional Data
There is a provision for indirect reheat of the flue gas. In this case, the number of degrees of reheat (over saturation) is required. Note that reheat is indirect - no moisture or hot gas is added and no supplemental fuel is fired. A reheat limit of 40ºF over saturation is incorporated into the tool.

Output Data
For a scrubber 'inlet' specified input parameter set, the tool will saturate the flue gas and provide the actual stack exit (saturated) gas temperature, stack exit virtual temperature, and average stack exit gas velocity. Given a scrubber 'outlet' parameter set, the tool will return stack exit virtual temperature and average stack exit gas velocity (actual saturated stack exit temperature provided in parameter set).

Methodology
Calculation of T_v can be broken down into four distinct areas or calculation modules: determination of (1) fuel/air specific combustion products, (2) moisture saturation temperature of the combustion gas, (3) moisture properties and absolute pressure at various elevations, and (4) final calculation of virtual temperature.

Data from the provided fuel analysis, along with excess air levels, are used to calculate the wet products of combustion. Complete combustion is assumed and combustion air moisture is incorporated. Flue gas composition is now fully defined and can be expressed on a wet or dry basis.

If gas temperature is specified as scrubber 'inlet', the moisture saturation temperature of the gas will be calculated (otherwise, it is given). Saturation temperature is determined by assuming an adiabatic cooling process with a correction[2] for actual flue gas specific heat as a function of CO_2 content. Added moisture from the 'saturator' is incorporated into the flue gas composition. Saturator calculations are performed at the site elevation pressure. No drop in saturated gas temperature occurs as the gas travels to the stack exit elevation. This assumption is based on vendor modeling of heat transfer from the gas to atmosphere for a fiberglass stack liner inside a concrete shell design[3]. For other stack configurations, this assumption should be reviewed.

Local barometric pressure will affect volumetric flow (exit gas velocity) and moisture properties. Absolute pressure at site and stack exit elevation was calculated from U.S. standard atmosphere lapse rate. Properties of moist air, along with lapse rate information were taken from ASHRAE tables[4] or formulae.

Final calculation of virtual temperature is straightforward and is a function of absolute temperature of the gas and mixture humidity ratio (sometimes known as mixing ratio or specific humidity,

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[2] Sirozi Hatta, "New Humidity Chart Simplifies Combustion Gas Problems," Chemical & Metallurgical Engineering, (March 1930), p. 165.

[3] Hamon Custodis model of 500 ft, 130F stack system with 10F ambient indicated <0.3F temperature drop.

[4] American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1997 ASHRAE Handbook: Fundamentals, Inch Pound Edition, (1997), pp. 6.1-6.6.

depending on the reference source). Humidity ratio is defined as the ratio of mass of water vapor to mass of dry gas. *Tv* is calculated as:

$$Tv = T \times (1 + 0.609 \times \omega)$$

Where: T = absolute gas temperature, ^{o}K
ω = gas humidity ratio, $lb_{water\ vapor} / lb_{dry\ gas}$

Appendix B

Exemption Modeling

Delta-Deciview Values for the Top 20 Days – for Each Year/Each Class I Area and for the Top 25 Days – Over Three Years

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 20 Days Each Year)

						F(RH)			% of Modeled Extinction by Species						
YEAR	**DAY**	**REC**	**DV(Total)**	**DV(BKG)**	**DELTA DV**	**S**	**L**	**SS**	**%_SO4**	**%_NO3**	**%_OC**	**%_EC**	**%_PMC**	**%_PMF**	**Rank**
2001	341	2	9.31	7.94	1.37	3.8	2.9	4.3	73.1	0.0	19.9	1.3	2.4	3.3	1
2001	113	1	8.60	7.60	0.99	2.8	2.3	3.6	67.2	0.0	24.2	1.6	3.0	4.0	2
2001	225	3	9.27	8.33	0.94	4.9	3.5	5.1	77.9	0.0	16.3	1.1	2.0	2.7	3
2001	297	3	8.97	8.10	0.87	4.2	3.2	4.6	75.4	0.0	18.2	1.2	2.1	3.1	4
2001	114	4	8.43	7.60	0.82	2.8	2.3	3.6	67.5	0.0	24.3	1.6	2.6	4.0	5
2001	279	1	8.87	8.10	0.77	4.2	3.2	4.6	75.4	0.0	18.3	1.1	2.2	3.0	6
2001	220	54	9.10	8.33	0.76	4.9	3.5	5.1	77.9	0.0	16.3	1.1	1.9	2.8	7
2001	111	16	8.34	7.60	0.74	2.8	2.3	3.6	67.5	0.0	24.2	1.6	2.7	4.0	8
2001	294	1	8.79	8.10	0.69	4.2	3.2	4.6	75.2	0.0	18.2	1.2	2.3	3.1	9
2001	51	8	8.39	7.72	0.67	3.2	2.5	3.8	69.7	0.0	22.6	1.4	2.5	3.7	10
2001	102	9	8.20	7.60	0.60	2.8	2.3	3.6	67.4	0.0	24.2	1.6	2.7	4.1	11
2001	229	16	8.88	8.33	0.55	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.5	2.7	12
2001	110	3	8.12	7.60	0.52	2.8	2.3	3.6	67.3	0.0	24.2	1.6	2.7	4.1	13
2001	142	3	8.34	7.87	0.47	3.6	2.8	4.1	72.5	0.0	20.7	1.4	1.9	3.6	14
2001	112	35	8.08	7.60	0.47	2.8	2.3	3.6	67.5	0.0	24.2	1.6	2.6	4.1	15
2001	343	97	8.40	7.94	0.46	3.8	2.9	4.3	73.0	0.0	19.9	1.4	2.4	3.4	16
2001	158	25	8.56	8.10	0.46	4.2	3.2	4.6	75.4	0.0	18.3	1.2	2.2	2.9	17
2001	126	3	8.31	7.87	0.44	3.6	2.8	4.1	72.2	0.0	20.6	1.3	2.3	3.5	18
2001	236	25	8.77	8.33	0.43	4.9	3.5	5.1	77.8	0.0	16.3	1.1	2.1	2.7	19
2001	198	9	8.62	8.21	0.42	4.5	3.3	4.9	76.7	0.0	17.3	1.2	1.9	3.0	20
2002	224	3	9.67	8.33	1.33	4.9	3.5	5.1	77.9	0.0	16.3	1.1	2.0	2.7	1
2002	15	16	9.07	7.82	1.26	3.4	2.7	4.0	71.4	0.0	21.4	1.3	2.4	3.5	2
2002	227	8	9.52	8.33	1.19	4.9	3.5	5.1	78.0	0.0	16.3	1.1	1.9	2.7	3
2002	365	16	9.08	7.94	1.15	3.8	2.9	4.3	73.0	0.0	19.9	1.3	2.4	3.4	4
2002	67	3	8.72	7.67	1.05	3.0	2.5	3.7	68.7	0.0	23.2	1.5	2.7	3.9	5
2002	228	97	9.33	8.33	1.00	4.9	3.5	5.1	78.0	0.0	16.3	1.1	1.9	2.7	6
2002	230	3	9.31	8.33	0.98	4.9	3.5	5.1	77.8	0.0	16.3	1.1	2.0	2.8	7
2002	226	97	9.28	8.33	0.94	4.9	3.5	5.1	77.9	0.0	16.3	1.1	2.0	2.7	8
2002	314	2	8.76	7.87	0.89	3.6	2.8	4.1	72.1	0.0	20.6	1.3	2.6	3.5	9
2002	35	9	8.57	7.72	0.85	3.2	2.5	3.8	69.6	0.0	22.6	1.4	2.8	3.6	10
2002	222	16	9.12	8.33	0.79	4.9	3.5	5.1	78.2	0.0	16.4	1.1	1.6	2.7	11
2002	28	3	8.59	7.82	0.77	3.4	2.7	4.0	71.3	0.0	21.3	1.3	2.5	3.6	12
2002	107	97	8.32	7.60	0.72	2.8	2.3	3.6	67.3	0.0	24.2	1.5	2.9	4.1	13
2002	207	9	8.90	8.21	0.69	4.5	3.3	4.9	76.8	0.0	17.4	1.1	1.7	3.0	14
2002	85	97	8.24	7.67	0.57	3.0	2.5	3.7	68.7	0.0	23.2	1.5	2.7	3.9	15
2002	323	3	8.43	7.87	0.55	3.6	2.8	4.1	72.1	0.0	20.6	1.3	2.5	3.4	16
2002	105	8	8.13	7.60	0.53	2.8	2.3	3.6	67.6	0.0	24.3	1.5	2.7	3.9	17
2002	191	16	8.72	8.21	0.51	4.5	3.3	4.9	77.1	0.0	17.4	1.1	1.5	2.9	18
2002	128	3	8.37	7.87	0.50	3.6	2.8	4.1	72.0	0.0	20.6	1.4	2.5	3.5	19
2002	106	8	8.08	7.60	0.48	2.8	2.3	3.6	67.2	0.0	24.2	1.6	3.0	4.1	20
2003	271	3	9.29	8.33	0.96	4.9	3.5	5.1	78.0	0.0	16.3	1.1	1.8	2.7	1
2003	270	1	9.28	8.33	0.95	4.9	3.5	5.1	78.0	0.0	16.3	1.1	1.9	2.8	2
2003	178	3	8.79	8.10	0.69	4.2	3.2	4.6	75.2	0.0	18.2	1.2	2.4	3.1	3
2003	356	16	8.61	7.94	0.67	3.8	2.9	4.3	73.2	0.0	19.9	1.3	2.4	3.3	4
2003	68	3	8.33	7.67	0.66	3.0	2.5	3.7	68.4	0.0	23.1	1.5	3.0	4.0	5
2003	246	3	8.98	8.33	0.65	4.9	3.5	5.1	78.0	0.0	16.3	1.1	1.7	2.9	6
2003	107	1	8.23	7.60	0.63	2.8	2.3	3.6	67.4	0.0	24.3	1.6	2.7	4.1	7
2003	163	3	8.69	8.10	0.59	4.2	3.2	4.6	75.5	0.0	18.2	1.2	2.0	3.1	8
2003	164	97	8.69	8.10	0.58	4.2	3.2	4.6	75.4	0.0	18.3	1.2	2.0	3.1	9
2003	187	3	8.79	8.21	0.58	4.5	3.3	4.9	76.4	0.0	17.3	1.1	2.2	2.9	10
2003	35	10	8.25	7.72	0.53	3.2	2.5	3.8	69.6	0.0	22.6	1.5	2.5	3.8	11
2003	242	16	8.84	8.33	0.51	4.9	3.5	5.1	78.2	0.0	16.3	1.0	1.7	2.7	12
2003	160	3	8.60	8.10	0.50	4.2	3.2	4.6	75.0	0.0	18.1	1.3	2.4	3.1	13
2003	326	1	8.36	7.87	0.49	3.6	2.8	4.1	71.9	0.0	20.6	1.3	2.7	3.5	14
2003	247	97	8.81	8.33	0.48	4.9	3.5	5.1	78.3	0.0	16.4	1.1	1.4	2.8	15
2003	304	1	8.56	8.10	0.46	4.2	3.2	4.6	75.4	0.0	18.3	1.2	2.2	3.0	16
2003	108	3	8.06	7.60	0.45	2.8	2.3	3.6	67.3	0.0	24.2	1.6	2.8	4.1	17
2003	259	3	8.78	8.33	0.45	4.9	3.5	5.1	77.7	0.0	16.3	1.1	2.1	2.8	18
2003	197	9	8.65	8.21	0.44	4.5	3.3	4.9	76.6	0.0	17.4	1.1	2.2	2.8	19
2003	166	46	8.54	8.10	0.44	4.2	3.2	4.6	75.3	0.0	18.2	1.2	2.1	3.1	20

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 25 Days Over 3 Years)

						F(RH)			% of Modeled Extinction by Species						
YEAR	DAY	REC	DV(Total)	DV(BKG)	DELTA DV	S	L	SS	%_SO4	%_NO3	%_OC	%_EC	%_PMC	%_PMF	Rank
2001	341	2	9.31	7.94	1.37	3.8	2.9	4.3	73.1	0.0	19.9	1.3	2.4	3.3	1
2002	224	3	9.67	8.33	1.33	4.9	3.5	5.1	77.9	0.0	16.3	1.1	2.0	2.7	2
2002	15	16	9.07	7.82	1.26	3.4	2.7	4.0	71.4	0.0	21.4	1.3	2.4	3.5	3
2002	227	8	9.52	8.33	1.19	4.9	3.5	5.1	78.0	0.0	16.3	1.1	1.9	2.7	4
2002	365	16	9.08	7.94	1.15	3.8	2.9	4.3	73.0	0.0	19.9	1.3	2.4	3.4	5
2002	67	3	8.72	7.67	1.05	3.0	2.5	3.7	68.7	0.0	23.2	1.5	2.7	3.9	6
2002	228	97	9.33	8.33	1.00	4.9	3.5	5.1	78.0	0.0	16.3	1.1	1.9	2.7	7
2001	113	1	8.60	7.60	0.99	2.8	2.3	3.6	67.2	0.0	24.2	1.6	3.0	4.0	8
2002	230	3	9.31	8.33	0.98	4.9	3.5	5.1	77.8	0.0	16.3	1.1	2.0	2.8	9
2003	271	3	9.29	8.33	0.96	4.9	3.5	5.1	78.0	0.0	16.3	1.1	1.8	2.7	10
2003	270	1	9.28	8.33	0.95	4.9	3.5	5.1	78.0	0.0	16.3	1.1	1.9	2.8	11
2002	226	97	9.28	8.33	0.94	4.9	3.5	5.1	77.9	0.0	16.3	1.1	2.0	2.7	12
2001	225	3	9.27	8.33	0.94	4.9	3.5	5.1	77.9	0.0	16.3	1.1	2.0	2.7	13
2002	314	2	8.76	7.87	0.89	3.6	2.8	4.1	72.1	0.0	20.6	1.3	2.6	3.5	14
2001	297	3	8.97	8.10	0.87	4.2	3.2	4.6	75.4	0.0	18.2	1.2	2.1	3.1	15
2002	35	9	8.57	7.72	0.85	3.2	2.5	3.8	69.6	0.0	22.6	1.4	2.8	3.6	16
2001	114	4	8.43	7.60	0.82	2.8	2.3	3.6	67.5	0.0	24.3	1.6	2.6	4.0	17
2002	222	16	9.12	8.33	0.79	4.9	3.5	5.1	78.2	0.0	16.4	1.1	1.6	2.7	18
2002	28	3	8.59	7.82	0.77	3.4	2.7	4.0	71.3	0.0	21.3	1.3	2.5	3.6	19
2001	279	1	8.87	8.10	0.77	4.2	3.2	4.6	75.4	0.0	18.3	1.1	2.2	3.0	20
2001	220	54	9.10	8.33	0.76	4.9	3.5	5.1	77.9	0.0	16.3	1.1	1.9	2.8	21
2001	111	16	8.34	7.60	0.74	2.8	2.3	3.6	67.5	0.0	24.2	1.6	2.7	4.0	22
2002	107	97	8.32	7.60	0.72	2.8	2.3	3.6	67.3	0.0	24.2	1.5	2.9	4.1	23
2003	178	3	8.79	8.10	0.69	4.2	3.2	4.6	75.2	0.0	18.2	1.2	2.4	3.1	24
2002	207	9	8.90	8.21	0.69	4.5	3.3	4.9	76.8	0.0	17.4	1.1	1.7	3.0	25

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for GSM (Top 20 Days Each Year)

						F(RH)			% of Modeled Extinction by Species						
YEAR	**DAY**	**REC**	**DV(Total)**	**DV(BKG)**	**DELTA DV**	**S**	**L**	**SS**	**%_SO4**	**%_NO3**	**%_OC**	**%_EC**	**%_PMC**	**%_PMF**	**Rank**
2001	112	396	7.97	7.57	0.40	2.8	2.3	3.5	67.3	0.0	25.0	1.7	1.9	4.2	1
2001	98	350	7.96	7.57	0.39	2.8	2.3	3.5	67.0	0.0	24.9	1.6	2.4	4.1	2
2001	208	361	8.48	8.10	0.38	4.2	3.2	4.6	75.9	0.0	18.4	1.2	1.4	3.2	3
2001	113	609	7.89	7.57	0.32	2.8	2.3	3.5	67.3	0.0	25.0	1.7	1.8	4.2	4
2001	111	371	7.88	7.57	0.31	2.8	2.3	3.5	67.5	0.0	25.0	1.5	1.8	4.1	5
2001	341	606	8.17	7.87	0.30	3.6	2.8	4.1	72.9	0.0	20.8	1.4	1.4	3.5	6
2001	331	363	8.10	7.82	0.29	3.4	2.7	4.0	71.2	0.0	21.3	1.5	2.3	3.7	7
2001	297	514	8.39	8.10	0.28	4.2	3.2	4.6	76.0	0.0	18.5	1.3	1.1	3.2	8
2001	279	514	8.37	8.10	0.27	4.2	3.2	4.6	75.9	0.0	18.4	1.2	1.5	3.1	9
2001	343	609	8.11	7.87	0.24	3.6	2.8	4.1	72.7	0.0	20.8	1.3	1.7	3.5	10
2001	198	381	8.34	8.10	0.23	4.2	3.2	4.6	76.0	0.0	18.4	1.2	1.4	3.1	11
2001	199	435	8.33	8.10	0.22	4.2	3.2	4.6	76.1	0.0	18.5	1.2	1.2	3.0	12
2001	298	364	8.31	8.10	0.21	4.2	3.2	4.6	75.9	0.0	18.4	1.3	1.3	3.2	13
2001	143	364	7.97	7.76	0.21	3.3	2.6	4.0	70.9	0.0	22.1	1.4	1.8	3.8	14
2001	225	606	8.41	8.21	0.20	4.5	3.3	4.9	77.1	0.0	17.4	1.1	1.3	3.1	15
2001	263	371	8.54	8.33	0.20	4.9	3.5	5.1	78.2	0.0	16.4	1.1	1.5	2.8	16
2001	141	435	7.95	7.76	0.19	3.3	2.6	4.0	70.6	0.0	22.1	1.5	2.0	3.8	17
2001	102	710	7.75	7.57	0.18	2.8	2.3	3.5	67.2	0.0	25.0	1.6	2.1	4.2	18
2001	158	475	8.27	8.10	0.17	4.2	3.2	4.6	75.6	0.0	18.4	1.1	1.8	3.2	19
2001	239	814	8.37	8.21	0.16	4.5	3.3	4.9	77.1	0.0	17.4	1.1	1.4	3.0	20
2002	129	354	8.30	7.73	0.57	3.3	2.6	4.0	70.4	0.0	22.1	1.5	2.3	3.7	1
2002	228	609	8.67	8.17	0.50	4.5	3.3	4.9	77.2	0.0	17.4	1.1	1.3	2.9	2
2002	107	474	7.89	7.54	0.35	2.8	2.3	3.5	67.1	0.0	25.0	1.6	2.0	4.2	3
2002	67	474	7.93	7.61	0.33	2.9	2.4	3.6	68.9	0.0	24.0	1.6	1.6	3.9	4
2002	106	351	7.86	7.54	0.31	2.8	2.3	3.5	66.8	0.0	24.8	1.7	2.6	4.1	5
2002	31	371	8.08	7.78	0.30	3.4	2.7	4.0	71.6	0.0	21.4	1.4	1.9	3.7	6
2002	226	434	8.43	8.17	0.26	4.5	3.3	4.9	77.0	0.0	17.4	1.2	1.5	2.9	7
2002	85	514	7.84	7.61	0.23	2.9	2.4	3.6	68.9	0.0	24.0	1.5	1.7	3.9	8
2002	66	363	7.83	7.61	0.23	2.9	2.4	3.6	68.5	0.0	23.9	1.5	2.1	4.0	9
2002	230	609	8.40	8.17	0.22	4.5	3.3	4.9	77.2	0.0	17.4	1.2	1.4	2.8	10
2002	356	349	8.02	7.84	0.18	3.6	2.8	4.1	72.4	0.0	20.8	1.3	2.0	3.5	11
2002	224	435	8.35	8.17	0.18	4.5	3.3	4.9	76.9	0.0	17.4	1.2	1.5	2.9	12
2002	128	341	7.90	7.73	0.16	3.3	2.6	4.0	71.0	0.0	22.1	1.4	1.7	3.7	13
2002	93	434	7.70	7.54	0.16	2.8	2.3	3.5	67.3	0.0	24.9	1.5	2.1	4.2	14
2002	28	562	7.94	7.78	0.16	3.4	2.7	4.0	71.8	0.0	21.4	1.5	1.8	3.5	15
2002	229	574	8.32	8.17	0.15	4.5	3.3	4.9	77.0	0.0	17.4	1.2	1.5	3.0	16
2002	330	513	7.93	7.78	0.15	3.4	2.7	4.0	71.2	0.0	21.4	1.2	2.5	3.7	17
2002	324	763	7.93	7.78	0.15	3.4	2.7	4.0	72.1	0.0	21.7	1.2	1.6	3.4	18
2002	225	429	8.32	8.17	0.15	4.5	3.3	4.9	77.5	0.0	17.4	1.2	0.9	3.0	19
2002	164	340	8.21	8.07	0.15	4.2	3.2	4.6	75.8	0.0	18.4	1.2	1.5	3.1	20
2003	304	351	8.45	8.07	0.38	4.2	3.2	4.6	75.7	0.0	18.3	1.2	1.8	3.0	1
2003	327	475	8.10	7.78	0.32	3.4	2.7	4.0	71.6	0.0	21.4	1.3	2.2	3.5	2
2003	246	474	8.59	8.30	0.30	4.9	3.5	5.1	78.2	0.0	16.3	1.0	1.6	2.8	3
2003	247	423	8.56	8.30	0.27	4.9	3.5	5.1	78.3	0.0	16.3	1.2	1.5	2.8	4
2003	163	356	8.33	8.07	0.26	4.2	3.2	4.6	75.7	0.0	18.4	1.2	1.7	3.1	5
2003	178	353	8.30	8.07	0.23	4.2	3.2	4.6	75.5	0.0	18.2	1.2	2.0	3.1	6
2003	165	373	8.29	8.07	0.23	4.2	3.2	4.6	75.2	0.0	18.2	1.2	2.2	3.2	7
2003	6	367	8.01	7.78	0.23	3.4	2.7	4.0	71.2	0.0	21.4	1.4	2.3	3.7	8
2003	35	372	7.85	7.64	0.21	3.0	2.5	3.7	69.5	0.0	23.5	1.6	1.6	3.9	9
2003	188	353	8.27	8.07	0.21	4.2	3.2	4.6	75.8	0.0	18.3	1.1	1.7	3.1	10
2003	187	340	8.27	8.07	0.21	4.2	3.2	4.6	76.0	0.0	18.4	1.1	1.5	3.1	11
2003	85	350	7.81	7.61	0.20	2.9	2.4	3.6	68.3	0.0	23.9	1.7	2.1	4.0	12
2003	320	513	7.96	7.78	0.17	3.4	2.7	4.0	71.7	0.0	21.5	1.3	1.6	3.8	13
2003	68	366	7.78	7.61	0.17	2.9	2.4	3.6	68.3	0.0	23.9	1.7	1.9	4.1	14
2003	156	341	8.24	8.07	0.17	4.2	3.2	4.6	75.4	0.0	18.3	1.3	1.8	3.1	15
2003	321	346	7.95	7.78	0.16	3.4	2.7	4.0	71.7	0.0	21.4	1.5	2.0	3.5	16
2003	235	558	8.32	8.17	0.15	4.5	3.3	4.9	77.1	0.0	17.4	1.2	1.5	2.9	17
2003	240	322	8.32	8.17	0.15	4.5	3.3	4.9	77.2	0.0	17.4	1.2	1.2	3.0	18
2003	164	514	8.21	8.07	0.14	4.2	3.2	4.6	75.9	0.0	18.3	1.3	1.3	3.2	19
2003	166	609	8.21	8.07	0.14	4.2	3.2	4.6	75.5	0.0	18.4	1.3	1.6	3.2	20

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for GSM (Top 25 Days Over 3 Years)

						F(RH)			% of Modeled Extinction by Species						
YEAR	DAY	REC	DV(Total)	DV(BKG)	DELTA DV	S	L	SS	%_SO4	%_NO3	%_OC	%_EC	%_PMC	%_PMF	Rank
2002	129	354	8.30	7.73	0.57	3.3	2.6	4.0	70.4	0.0	22.1	1.5	2.3	3.7	1
2002	228	609	8.67	8.17	0.50	4.5	3.3	4.9	77.2	0.0	17.4	1.1	1.3	2.9	2
2001	112	396	7.97	7.57	0.40	2.8	2.3	3.5	67.3	0.0	25.0	1.7	1.9	4.2	3
2001	98	350	7.96	7.57	0.39	2.8	2.3	3.5	67.0	0.0	24.9	1.6	2.4	4.1	4
2003	304	351	8.45	8.07	0.38	4.2	3.2	4.6	75.7	0.0	18.3	1.2	1.8	3.0	5
2001	208	361	8.48	8.10	0.38	4.2	3.2	4.6	75.9	0.0	18.4	1.2	1.4	3.2	6
2002	107	474	7.89	7.54	0.35	2.8	2.3	3.5	67.1	0.0	25.0	1.6	2.0	4.2	7
2002	67	474	7.93	7.61	0.33	2.9	2.4	3.6	68.9	0.0	24.0	1.6	1.6	3.9	8
2003	327	475	8.10	7.78	0.32	3.4	2.7	4.0	71.6	0.0	21.4	1.3	2.2	3.5	9
2001	113	609	7.89	7.57	0.32	2.8	2.3	3.5	67.3	0.0	25.0	1.7	1.8	4.2	10
2002	106	351	7.86	7.54	0.31	2.8	2.3	3.5	66.8	0.0	24.8	1.7	2.6	4.1	11
2001	111	371	7.88	7.57	0.31	2.8	2.3	3.5	67.5	0.0	25.0	1.5	1.8	4.1	12
2001	341	606	8.17	7.87	0.30	3.6	2.8	4.1	72.9	0.0	20.8	1.4	1.4	3.5	13
2002	31	371	8.08	7.78	0.30	3.4	2.7	4.0	71.6	0.0	21.4	1.4	1.9	3.7	14
2003	246	474	8.59	8.30	0.30	4.9	3.5	5.1	78.2	0.0	16.3	1.0	1.6	2.8	15
2001	331	363	8.10	7.82	0.29	3.4	2.7	4.0	71.2	0.0	21.3	1.5	2.3	3.7	16
2001	297	514	8.39	8.10	0.28	4.2	3.2	4.6	76.0	0.0	18.5	1.3	1.1	3.2	17
2001	279	514	8.37	8.10	0.27	4.2	3.2	4.6	75.9	0.0	18.4	1.2	1.5	3.1	18
2003	247	423	8.56	8.30	0.27	4.9	3.5	5.1	78.3	0.0	16.3	1.2	1.5	2.8	19
2003	163	356	8.33	8.07	0.26	4.2	3.2	4.6	75.7	0.0	18.4	1.2	1.7	3.1	20
2002	226	434	8.43	8.17	0.26	4.5	3.3	4.9	77.0	0.0	17.4	1.2	1.5	2.9	21
2001	343	609	8.11	7.87	0.24	3.6	2.8	4.1	72.7	0.0	20.8	1.3	1.7	3.5	22
2001	198	381	8.34	8.10	0.23	4.2	3.2	4.6	76.0	0.0	18.4	1.2	1.4	3.1	23
2003	178	353	8.30	8.07	0.23	4.2	3.2	4.6	75.5	0.0	18.2	1.2	2.0	3.1	24
2002	85	514	7.84	7.61	0.23	2.9	2.4	3.6	68.9	0.0	24.0	1.5	1.7	3.9	25

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Joyce-Kilmer (Top 20 Days Each Yr)

						F(RH)			% of Modeled Extinction by Species						
YEAR	**DAY**	**REC**	**DV(Total)**	**DV(BKG)**	**DELTA DV**	**S**	**L**	**SS**	**%_SO4**	**%_NO3**	**%_OC**	**%_EC**	**%_PMC**	**%_PMF**	**Rank**
2001	112	240	7.98	7.54	0.44	2.8	2.3	3.5	67.1	0.0	24.9	1.6	2.2	4.2	1
2001	98	225	7.94	7.54	0.40	2.8	2.3	3.5	66.7	0.0	24.8	1.7	2.6	4.2	2
2001	113	317	7.89	7.54	0.34	2.8	2.3	3.5	67.3	0.0	25.0	1.7	1.9	4.1	3
2001	111	225	7.87	7.54	0.33	2.8	2.3	3.5	67.2	0.0	24.9	1.6	2.0	4.2	4
2001	279	278	8.39	8.07	0.33	4.2	3.2	4.6	75.9	0.0	18.3	1.1	1.6	3.0	5
2001	297	310	8.39	8.07	0.32	4.2	3.2	4.6	76.1	0.0	18.4	1.2	1.2	3.1	6
2001	343	310	8.22	7.90	0.31	3.8	2.9	4.3	73.4	0.0	20.0	1.3	1.9	3.4	7
2001	198	226	8.44	8.17	0.27	4.5	3.3	4.9	77.2	0.0	17.4	1.2	1.3	3.0	8
2001	341	317	8.17	7.90	0.27	3.8	2.9	4.3	74.0	0.0	20.1	1.2	1.4	3.3	9
2001	208	225	8.43	8.17	0.26	4.5	3.3	4.9	76.9	0.0	17.3	1.2	1.5	3.0	10
2001	263	221	8.55	8.30	0.26	4.9	3.5	5.1	78.4	0.0	16.3	1.0	1.5	2.7	11
2001	199	278	8.42	8.17	0.25	4.5	3.3	4.9	77.3	0.0	17.5	1.1	1.3	2.9	12
2001	225	278	8.54	8.30	0.24	4.9	3.5	5.1	78.3	0.0	16.3	1.1	1.5	2.7	13
2001	331	225	8.00	7.78	0.22	3.4	2.7	4.0	71.3	0.0	21.2	1.5	2.4	3.6	14
2001	141	221	8.00	7.78	0.21	3.4	2.7	4.0	71.4	0.0	21.4	1.3	2.2	3.7	15
2001	298	225	8.28	8.07	0.21	4.2	3.2	4.6	76.0	0.0	18.4	1.1	1.5	3.0	16
2001	332	239	7.98	7.78	0.19	3.4	2.7	4.0	71.3	0.0	21.4	1.5	2.2	3.6	17
2001	158	310	8.25	8.07	0.19	4.2	3.2	4.6	75.5	0.0	18.4	1.2	2.0	2.9	18
2001	12	286	7.96	7.78	0.18	3.4	2.7	4.0	72.1	0.0	21.6	1.3	1.3	3.7	19
2001	239	221	8.46	8.30	0.17	4.9	3.5	5.1	78.6	0.0	16.4	1.1	1.1	2.9	20
2002	228	317	8.85	8.30	0.56	4.9	3.5	5.1	78.4	0.0	16.4	1.1	1.3	2.7	1
2002	129	225	8.28	7.78	0.49	3.4	2.7	4.0	71.3	0.0	21.3	1.4	2.4	3.6	2
2002	107	286	7.95	7.54	0.41	2.8	2.3	3.5	67.1	0.0	24.9	1.6	2.2	4.2	3
2002	67	278	8.00	7.61	0.39	2.9	2.4	3.6	68.6	0.0	24.0	1.6	1.8	4.0	4
2002	226	239	8.68	8.30	0.38	4.9	3.5	5.1	78.3	0.0	16.3	1.0	1.6	2.8	5
2002	31	221	8.14	7.78	0.35	3.4	2.7	4.0	71.4	0.0	21.4	1.4	2.1	3.7	6
2002	224	226	8.61	8.30	0.32	4.9	3.5	5.1	78.3	0.0	16.4	1.1	1.5	2.8	7
2002	106	225	7.85	7.54	0.31	2.8	2.3	3.5	66.9	0.0	24.8	1.5	2.6	4.1	8
2002	230	310	8.54	8.30	0.24	4.9	3.5	5.1	78.4	0.0	16.4	1.1	1.4	2.7	9
2002	35	221	7.93	7.69	0.24	3.2	2.5	3.8	69.2	0.0	22.5	1.5	2.7	4.1	10
2002	85	317	7.84	7.61	0.23	2.9	2.4	3.6	68.8	0.0	24.0	1.6	1.6	3.9	11
2002	28	278	8.00	7.78	0.21	3.4	2.7	4.0	71.9	0.0	21.4	1.3	2.0	3.5	12
2002	164	222	8.27	8.07	0.20	4.2	3.2	4.6	75.7	0.0	18.4	1.1	1.6	3.2	13
2002	128	226	7.97	7.78	0.18	3.4	2.7	4.0	71.7	0.0	21.4	1.3	2.0	3.5	14
2002	330	222	7.97	7.78	0.18	3.4	2.7	4.0	71.3	0.0	21.3	1.3	2.6	3.6	15
2002	356	225	8.09	7.90	0.18	3.8	2.9	4.3	73.2	0.0	19.9	1.3	2.3	3.3	16
2002	225	239	8.47	8.30	0.18	4.9	3.5	5.1	79.0	0.0	16.5	1.0	0.8	2.8	17
2002	138	270	7.95	7.78	0.16	3.4	2.7	4.0	72.0	0.0	21.6	1.4	1.4	3.5	19
2002	93	278	7.71	7.54	0.16	2.8	2.3	3.5	66.9	0.0	24.9	1.8	2.3	4.1	18
2002	66	225	7.77	7.61	0.16	2.9	2.4	3.6	68.4	0.0	23.8	1.5	2.1	4.2	20
2003	246	270	8.63	8.30	0.34	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.7	2.7	1
2003	327	310	8.12	7.78	0.34	3.4	2.7	4.0	71.4	0.0	21.3	1.4	2.3	3.6	2
2003	304	225	8.38	8.07	0.31	4.2	3.2	4.6	75.7	0.0	18.3	1.1	1.9	3.0	3
2003	247	241	8.60	8.30	0.31	4.9	3.5	5.1	78.4	0.0	16.4	1.1	1.3	2.8	4
2003	165	225	8.37	8.07	0.31	4.2	3.2	4.6	75.3	0.0	18.3	1.2	2.2	3.1	5
2003	187	241	8.47	8.17	0.30	4.5	3.3	4.9	76.8	0.0	17.3	1.2	1.8	2.9	6
2003	178	221	8.34	8.07	0.27	4.2	3.2	4.6	75.4	0.0	18.2	1.2	2.1	3.1	7
2003	6	239	8.03	7.78	0.25	3.4	2.7	4.0	71.0	0.0	21.3	1.5	2.4	3.7	8
2003	68	221	7.84	7.61	0.23	2.9	2.4	3.6	68.2	0.0	23.8	1.6	2.2	4.1	9
2003	188	222	8.40	8.17	0.23	4.5	3.3	4.9	76.8	0.0	17.4	1.2	1.8	2.9	10
2003	85	225	7.83	7.61	0.22	2.9	2.4	3.6	68.6	0.0	23.9	1.5	1.9	4.1	11
2003	35	225	7.91	7.69	0.22	3.2	2.5	3.8	69.9	0.0	22.8	1.5	1.9	3.9	12
2003	156	221	8.28	8.07	0.21	4.2	3.2	4.6	75.5	0.0	18.3	1.3	1.9	3.0	13
2003	163	225	8.25	8.07	0.18	4.2	3.2	4.6	75.8	0.0	18.3	1.2	1.7	3.0	14
2003	321	225	7.96	7.78	0.18	3.4	2.7	4.0	71.6	0.0	21.3	1.3	2.1	3.7	15
2003	52	223	7.86	7.69	0.18	3.2	2.5	3.8	69.8	0.0	22.7	1.3	2.4	3.8	16
2003	240	225	8.47	8.30	0.17	4.9	3.5	5.1	78.6	0.0	16.5	1.0	1.0	2.9	17
2003	357	222	8.07	7.90	0.17	3.8	2.9	4.3	73.6	0.0	19.9	1.4	1.6	3.5	18
2003	235	317	8.46	8.30	0.16	4.9	3.5	5.1	78.5	0.0	16.3	1.1	1.4	2.7	19
2003	291	240	8.23	8.07	0.16	4.2	3.2	4.6	75.3	0.0	18.2	1.1	2.0	3.4	20

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Joyce-Kil (Top 25 Days Over 3 Yrs)

						F(RH)			% of Modeled Extinction by Species						
YEAR	**DAY**	**REC**	**DV(Total)**	**DV(BKG)**	**DELTA DV**	**S**	**L**	**SS**	**%_SO4**	**%_NO3**	**%_OC**	**%_EC**	**%_PMC**	**%_PMF**	**Rank**
2002	228	317	8.85	8.30	0.56	4.9	3.5	5.1	78.4	0.0	16.4	1.1	1.3	2.7	1
2002	129	225	8.28	7.78	0.49	3.4	2.7	4.0	71.3	0.0	21.3	1.4	2.4	3.6	2
2001	112	240	7.98	7.54	0.44	2.8	2.3	3.5	67.1	0.0	24.9	1.6	2.2	4.2	3
2002	107	286	7.95	7.54	0.41	2.8	2.3	3.5	67.1	0.0	24.9	1.6	2.2	4.2	4
2001	98	225	7.94	7.54	0.40	2.8	2.3	3.5	66.7	0.0	24.8	1.7	2.6	4.2	5
2002	67	278	8.00	7.61	0.39	2.9	2.4	3.6	68.6	0.0	24.0	1.6	1.8	4.0	6
2002	226	239	8.68	8.30	0.38	4.9	3.5	5.1	78.3	0.0	16.3	1.0	1.6	2.8	7
2002	31	221	8.14	7.78	0.35	3.4	2.7	4.0	71.4	0.0	21.4	1.4	2.1	3.7	8
2001	113	317	7.89	7.54	0.34	2.8	2.3	3.5	67.3	0.0	25.0	1.7	1.9	4.1	9
2003	246	270	8.63	8.30	0.34	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.7	2.7	10
2003	327	310	8.12	7.78	0.34	3.4	2.7	4.0	71.4	0.0	21.3	1.4	2.3	3.6	11
2001	111	225	7.87	7.54	0.33	2.8	2.3	3.5	67.2	0.0	24.9	1.6	2.0	4.2	12
2001	279	278	8.39	8.07	0.33	4.2	3.2	4.6	75.9	0.0	18.3	1.1	1.6	3.0	13
2001	297	310	8.39	8.07	0.32	4.2	3.2	4.6	76.1	0.0	18.4	1.2	1.2	3.1	14
2002	224	226	8.61	8.30	0.32	4.9	3.5	5.1	78.3	0.0	16.4	1.1	1.5	2.8	15
2003	304	225	8.38	8.07	0.31	4.2	3.2	4.6	75.7	0.0	18.3	1.1	1.9	3.0	16
2001	343	310	8.22	7.90	0.31	3.8	2.9	4.3	73.4	0.0	20.0	1.3	1.9	3.4	17
2002	106	225	7.85	7.54	0.31	2.8	2.3	3.5	66.9	0.0	24.8	1.5	2.6	4.1	18
2003	247	241	8.60	8.30	0.31	4.9	3.5	5.1	78.4	0.0	16.4	1.1	1.3	2.8	19
2003	165	225	8.37	8.07	0.31	4.2	3.2	4.6	75.3	0.0	18.3	1.2	2.2	3.1	20
2003	187	241	8.47	8.17	0.30	4.5	3.3	4.9	76.8	0.0	17.3	1.2	1.8	2.9	21
2003	178	221	8.34	8.07	0.27	4.2	3.2	4.6	75.4	0.0	18.2	1.2	2.1	3.1	22
2001	198	226	8.44	8.17	0.27	4.5	3.3	4.9	77.2	0.0	17.4	1.2	1.3	3.0	23
2001	341	317	8.17	7.90	0.27	3.8	2.9	4.3	74.0	0.0	20.1	1.2	1.4	3.3	24
2001	208	225	8.43	8.17	0.26	4.5	3.3	4.9	76.9	0.0	17.3	1.2	1.5	3.0	25

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Shining Rk (Top 20 Days Each Yr)

							F(RH)		% of Modeled Extinction by Species						
YEAR	**DAY**	**REC**	**DV(Total)**	**DV(BKG)**	**DELTA DV**	**S**	**L**	**SS**	**%_SO4**	**%_NO3**	**%_OC**	**%_EC**	**%_PMC**	**%_PMF**	**Rank**
2001	298	1265	7.89	7.65	0.24	4.2	3.2	4.6	76.0	0.0	18.4	1.2	1.3	3.1	1
2001	331	1207	7.59	7.35	0.24	3.4	2.7	4.0	71.5	0.0	21.4	1.4	2.2	3.4	2
2001	102	1265	7.32	7.09	0.23	2.8	2.3	3.5	67.1	0.0	25.0	1.5	2.2	4.1	3
2001	279	1266	7.84	7.65	0.19	4.2	3.2	4.6	75.5	0.0	18.2	1.2	1.9	3.1	4
2001	208	1313	7.94	7.76	0.19	4.5	3.3	4.9	77.7	0.0	17.5	1.0	0.7	3.0	5
2001	342	1208	7.59	7.41	0.18	3.6	2.8	4.1	72.6	0.0	20.8	1.3	1.8	3.4	6
2001	52	1210	7.37	7.20	0.17	3.0	2.5	3.7	69.3	0.0	23.3	1.4	2.0	4.0	7
2001	330	1308	7.52	7.35	0.17	3.4	2.7	4.0	71.6	0.0	21.3	1.4	2.0	3.7	8
2001	148	1210	7.57	7.41	0.17	3.6	2.8	4.1	72.6	0.0	20.8	1.4	1.7	3.5	9
2001	199	1265	7.89	7.76	0.13	4.5	3.3	4.9	77.8	0.0	17.6	1.1	0.7	2.8	10
2001	156	1265	7.77	7.65	0.12	4.2	3.2	4.6	75.9	0.0	18.4	1.1	1.5	3.1	11
2001	209	1305	7.88	7.76	0.12	4.5	3.3	4.9	76.6	0.0	17.3	1.2	1.9	3.1	12
2001	173	1216	7.76	7.65	0.12	4.2	3.2	4.6	76.2	0.0	18.5	1.2	0.8	3.3	13
2001	149	1266	7.51	7.41	0.11	3.6	2.8	4.1	72.0	0.0	20.7	1.4	2.3	3.6	14
2001	48	1313	7.30	7.20	0.10	3.0	2.5	3.7	69.6	0.0	23.7	1.5	1.5	3.9	15
2001	98	1210	7.19	7.09	0.10	2.8	2.3	3.5	67.7	0.0	25.2	1.5	1.5	4.1	17
2001	343	1302	7.50	7.41	0.10	3.6	2.8	4.1	72.0	0.0	20.5	1.5	2.5	3.5	18
2001	224	1210	8.15	8.05	0.10	5.4	3.8	5.4	80.4	0.0	15.5	0.9	0.5	2.7	16
2001	198	1265	7.85	7.76	0.09	4.5	3.3	4.9	77.4	0.0	17.6	1.0	1.0	3.0	19
2001	210	1277	7.85	7.76	0.09	4.5	3.3	4.9	77.0	0.0	17.4	1.0	1.5	3.1	20
2002	330	1228	7.61	7.35	0.26	3.4	2.7	4.0	71.4	0.0	21.3	1.5	2.2	3.7	1
2002	29	1210	7.61	7.35	0.26	3.4	2.7	4.0	72.2	0.0	21.6	1.3	1.3	3.6	2
2002	129	1313	7.57	7.41	0.16	3.6	2.8	4.1	73.0	0.0	20.8	1.5	1.2	3.5	3
2002	147	1216	7.57	7.41	0.16	3.6	2.8	4.1	72.4	0.0	20.8	1.5	1.8	3.5	4
2002	66	1302	7.32	7.16	0.16	2.9	2.4	3.6	68.2	0.0	23.8	1.5	2.5	4.0	5
2002	31	1235	7.49	7.35	0.14	3.4	2.7	4.0	71.6	0.0	21.3	1.4	2.0	3.7	6
2002	35	1206	7.34	7.20	0.14	3.0	2.5	3.7	69.3	0.0	23.4	1.4	2.1	3.9	7
2002	84	1210	7.28	7.16	0.12	2.9	2.4	3.6	68.4	0.0	24.0	1.7	1.7	4.2	8
2002	77	1210	7.27	7.16	0.11	2.9	2.4	3.6	68.6	0.0	24.1	1.4	1.8	4.1	9
2002	75	1210	7.24	7.16	0.08	2.9	2.4	3.6	68.2	0.0	23.8	1.8	1.8	4.3	10
2002	145	1210	7.49	7.41	0.08	3.6	2.8	4.1	72.5	0.0	20.9	1.2	1.8	3.6	11
2002	165	1206	7.72	7.65	0.08	4.2	3.2	4.6	76.1	0.0	18.3	1.2	1.2	3.1	12
2002	225	1265	8.12	8.05	0.07	5.4	3.8	5.4	80.3	0.0	15.5	1.2	0.6	2.4	13
2002	178	1265	7.72	7.65	0.07	4.2	3.2	4.6	75.7	0.0	18.4	1.3	1.3	3.3	14
2002	67	1308	7.23	7.16	0.07	2.9	2.4	3.6	68.9	0.0	23.8	1.5	2.2	3.7	15
2002	164	1265	7.70	7.65	0.06	4.2	3.2	4.6	76.6	0.0	18.5	0.8	0.8	3.3	17
2002	134	1210	7.46	7.41	0.06	3.6	2.8	4.1	73.0	0.0	21.2	1.7	0.8	3.3	16
2002	192	1210	7.81	7.76	0.06	4.5	3.3	4.9	77.4	0.0	17.7	0.8	0.8	3.3	18
2002	229	1300	8.10	8.05	0.05	5.4	3.8	5.4	80.3	0.0	15.4	0.9	0.9	2.6	19
2002	226	1313	8.10	8.05	0.05	5.4	3.8	5.4	80.3	0.0	15.4	0.9	0.9	2.6	20
2003	85	1212	7.42	7.16	0.26	2.9	2.4	3.6	68.3	0.0	23.8	1.6	2.3	4.1	1
2003	343	1212	7.66	7.41	0.25	3.6	2.8	4.1	72.2	0.0	20.6	1.3	2.5	3.4	2
2003	35	1211	7.45	7.20	0.25	3.0	2.5	3.7	69.2	0.0	23.4	1.6	1.9	3.9	3
2003	357	1210	7.62	7.41	0.21	3.6	2.8	4.1	72.1	0.0	20.7	1.4	2.3	3.6	4
2003	178	1251	7.85	7.65	0.20	4.2	3.2	4.6	76.4	0.0	18.5	1.2	0.9	3.0	5
2003	247	1266	8.09	7.89	0.20	4.9	3.5	5.1	78.4	0.0	16.4	1.1	1.4	2.8	6
2003	52	1206	7.38	7.20	0.19	3.0	2.5	3.7	68.9	0.0	23.3	1.6	2.1	4.0	7
2003	356	1208	7.59	7.41	0.18	3.6	2.8	4.1	72.2	0.0	20.6	1.3	2.4	3.5	8
2003	188	1206	7.93	7.76	0.18	4.5	3.3	4.9	77.3	0.0	17.5	1.0	1.3	2.9	9
2003	327	1206	7.51	7.35	0.17	3.4	2.7	4.0	71.5	0.0	21.5	1.5	2.0	3.5	10
2003	240	1211	8.21	8.05	0.16	5.4	3.8	5.4	80.3	0.0	15.3	1.1	0.8	2.5	11
2003	320	1266	7.49	7.35	0.15	3.4	2.7	4.0	71.6	0.0	21.4	1.3	2.0	3.7	12
2003	130	1210	7.54	7.41	0.13	3.6	2.8	4.1	72.2	0.0	20.6	1.5	2.2	3.6	13
2003	316	1209	7.47	7.35	0.12	3.4	2.7	4.0	71.9	0.0	21.6	1.2	1.6	3.7	14
2003	72	1208	7.28	7.16	0.12	2.9	2.4	3.6	68.1	0.0	23.9	1.7	2.5	3.8	15
2003	166	1314	7.76	7.65	0.12	4.2	3.2	4.6	76.3	0.0	18.4	1.2	1.2	2.9	16
2003	344	1312	7.52	7.41	0.11	3.6	2.8	4.1	73.0	0.0	20.7	1.3	1.7	3.4	17
2003	160	1206	7.76	7.65	0.11	4.2	3.2	4.6	75.9	0.0	18.2	1.3	1.7	2.9	18
2003	58	1252	7.30	7.20	0.10	3.0	2.5	3.7	69.0	0.0	23.3	1.4	2.4	3.8	19
2003	291	1214	7.75	7.65	0.10	4.2	3.2	4.6	76.1	0.0	18.4	0.9	1.8	2.7	20

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change - Shining Rk (Top 25 Days Over 3 Yrs)

						F(RH)			% of Modeled Extinction by Species						
YEAR	DAY	REC	DV(Total)	DV(BKG)	DELTA DV	S	L	SS	%_SO4	%_NO3	%_OC	%_EC	%_PMC	%_PMF	Rank
2002	330	1228	7.61	7.35	0.26	3.4	2.7	4.0	71.4	0.0	21.3	1.5	2.2	3.7	1
2002	29	1210	7.61	7.35	0.26	3.4	2.7	4.0	72.2	0.0	21.6	1.3	1.3	3.6	2
2003	85	1212	7.42	7.16	0.26	2.9	2.4	3.6	68.3	0.0	23.8	1.6	2.3	4.1	3
2003	343	1212	7.66	7.41	0.25	3.6	2.8	4.1	72.2	0.0	20.6	1.3	2.5	3.4	4
2003	35	1211	7.45	7.20	0.25	3.0	2.5	3.7	69.2	0.0	23.4	1.6	1.9	3.9	5
2001	298	1265	7.89	7.65	0.24	4.2	3.2	4.6	76.0	0.0	18.4	1.2	1.3	3.1	6
2001	331	1207	7.59	7.35	0.24	3.4	2.7	4.0	71.5	0.0	21.4	1.4	2.2	3.4	7
2001	102	1265	7.32	7.09	0.23	2.8	2.3	3.5	67.1	0.0	25.0	1.5	2.2	4.1	8
2003	357	1210	7.62	7.41	0.21	3.6	2.8	4.1	72.1	0.0	20.7	1.4	2.3	3.6	9
2003	178	1251	7.85	7.65	0.20	4.2	3.2	4.6	76.4	0.0	18.5	1.2	0.9	3.0	10
2003	247	1266	8.09	7.89	0.20	4.9	3.5	5.1	78.4	0.0	16.4	1.1	1.4	2.8	11
2001	279	1266	7.84	7.65	0.19	4.2	3.2	4.6	75.5	0.0	18.2	1.2	1.9	3.1	12
2001	208	1313	7.94	7.76	0.19	4.5	3.3	4.9	77.7	0.0	17.5	1.0	0.7	3.0	13
2003	52	1206	7.38	7.20	0.19	3.0	2.5	3.7	68.9	0.0	23.3	1.6	2.1	4.0	14
2001	342	1208	7.59	7.41	0.18	3.6	2.8	4.1	72.6	0.0	20.8	1.3	1.8	3.4	15
2003	356	1208	7.59	7.41	0.18	3.6	2.8	4.1	72.2	0.0	20.6	1.3	2.4	3.5	16
2003	188	1206	7.93	7.76	0.18	4.5	3.3	4.9	77.3	0.0	17.5	1.0	1.3	2.9	17
2001	52	1210	7.37	7.20	0.17	3.0	2.5	3.7	69.3	0.0	23.3	1.4	2.0	4.0	18
2001	330	1308	7.52	7.35	0.17	3.4	2.7	4.0	71.6	0.0	21.3	1.4	2.0	3.7	19
2001	148	1210	7.57	7.41	0.17	3.6	2.8	4.1	72.6	0.0	20.8	1.4	1.7	3.5	20
2003	327	1206	7.51	7.35	0.17	3.4	2.7	4.0	71.5	0.0	21.5	1.5	2.0	3.5	21
2003	240	1211	8.21	8.05	0.16	5.4	3.8	5.4	80.3	0.0	15.3	1.1	0.8	2.5	22
2002	129	1313	7.57	7.41	0.16	3.6	2.8	4.1	73.0	0.0	20.8	1.5	1.2	3.5	23
2002	147	1216	7.57	7.41	0.16	3.6	2.8	4.1	72.4	0.0	20.8	1.5	1.8	3.5	24
2002	66	1302	7.32	7.16	0.16	2.9	2.4	3.6	68.2	0.0	23.8	1.5	2.5	4.0	25

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Sipsey (Top 20 Days Each Year)

						F(RH)				% of Modeled Extinction by Species					
YEAR	DAY	REC	DV(Total)	DV(BKG)	DELTA DV	S	L	SS	%_SO4	%_NO3	%_OC	%_EC	%_PMC	%_PMF	Rank
2001	259	1058	8.39	8.17	0.22	4.2	3.2	4.6	75.9	0.0	18.4	1.2	1.4	3.1	1
2001	311	1165	8.01	7.88	0.13	3.4	2.7	4.0	71.6	0.0	21.3	1.4	2.1	3.6	2
2001	164	1077	8.20	8.08	0.12	4.0	3.0	4.5	74.5	0.0	19.1	1.1	1.9	3.4	3
2001	215	1205	8.28	8.17	0.11	4.2	3.2	4.6	76.2	0.0	18.5	1.2	0.8	3.2	4
2001	273	1199	8.27	8.17	0.10	4.2	3.2	4.6	75.3	0.0	18.3	1.4	1.8	3.2	5
2001	205	1058	8.27	8.17	0.10	4.2	3.2	4.6	75.6	0.0	18.3	1.4	1.4	3.3	6
2001	216	1147	8.26	8.17	0.09	4.2	3.2	4.6	76.3	0.0	18.4	1.1	1.1	3.2	7
2001	304	1129	8.16	8.08	0.08	4.0	3.0	4.5	75.0	0.0	19.2	1.2	1.2	3.5	8
2001	170	1092	8.16	8.08	0.08	4.0	3.0	4.5	75.2	0.0	19.5	1.2	1.2	3.0	9
2001	274	1201	8.24	8.17	0.07	4.2	3.2	4.6	75.3	0.0	18.3	1.3	1.9	3.2	10
2001	120	1092	7.73	7.66	0.07	2.8	2.3	3.6	68.0	0.0	24.3	1.4	2.1	4.2	11
2001	346	1205	8.00	7.94	0.06	3.6	2.8	4.1	72.3	0.0	20.4	1.5	2.2	3.7	12
2001	213	1204	8.23	8.17	0.06	4.2	3.2	4.6	76.1	0.0	18.2	0.8	1.6	3.2	13
2001	326	1129	7.93	7.88	0.05	3.4	2.7	4.0	71.5	0.0	21.2	1.8	1.8	3.7	14
2001	43	1092	7.82	7.78	0.05	3.2	2.5	3.8	70.7	0.0	23.3	1.0	1.0	4.0	15
2001	312	1092	7.92	7.88	0.04	3.4	2.7	4.0	72.5	0.0	21.7	1.2	1.2	3.5	16
2001	320	1129	7.92	7.88	0.04	3.4	2.7	4.0	72.6	0.0	21.4	1.2	1.2	3.6	17
2001	206	1147	8.21	8.17	0.04	4.2	3.2	4.6	76.0	0.0	18.1	1.2	1.2	3.5	18
2001	89	1058	7.73	7.69	0.04	2.9	2.4	3.6	68.3	0.0	24.2	1.3	2.5	3.8	19
2001	178	1204	8.12	8.08	0.04	4.0	3.0	4.5	74.9	0.0	19.0	1.2	1.2	3.7	20
2002	3	1092	8.17	7.94	0.24	3.6	2.8	4.1	72.8	0.0	20.8	1.3	1.5	3.5	1
2002	268	1092	8.39	8.17	0.22	4.2	3.2	4.6	75.7	0.0	18.3	1.2	1.6	3.1	2
2002	241	1067	8.35	8.17	0.18	4.2	3.2	4.6	75.7	0.0	18.3	1.2	1.5	3.2	3
2002	247	1147	8.32	8.17	0.15	4.2	3.2	4.6	76.0	0.0	18.5	1.2	1.2	3.1	4
2002	220	1110	8.32	8.17	0.15	4.2	3.2	4.6	75.5	0.0	18.4	1.2	1.8	3.1	5
2002	216	1065	8.31	8.17	0.13	4.2	3.2	4.6	75.7	0.0	18.3	1.3	1.7	3.0	6
2002	245	1147	8.30	8.17	0.13	4.2	3.2	4.6	76.4	0.0	18.5	1.0	1.0	3.1	7
2002	244	1147	8.29	8.17	0.12	4.2	3.2	4.6	76.1	0.0	18.5	1.2	1.2	3.1	8
2002	170	1092	8.19	8.08	0.11	4.0	3.0	4.5	74.7	0.0	19.1	1.2	1.6	3.3	9
2002	253	1065	8.28	8.17	0.11	4.2	3.2	4.6	76.3	0.0	18.3	1.2	1.2	2.9	10
2002	242	1058	8.28	8.17	0.11	4.2	3.2	4.6	76.0	0.0	18.5	1.3	1.3	2.9	11
2002	243	1092	8.27	8.17	0.10	4.2	3.2	4.6	75.9	0.0	18.4	1.3	1.3	3.1	12
2002	240	1129	8.26	8.17	0.09	4.2	3.2	4.6	76.6	0.0	18.4	1.0	1.0	3.0	13
2002	189	1147	8.23	8.17	0.06	4.2	3.2	4.6	75.2	0.0	18.3	1.4	2.1	2.9	14
2002	273	1165	8.23	8.17	0.06	4.2	3.2	4.6	75.1	0.0	18.4	1.4	2.2	2.9	15
2002	288	1093	8.14	8.08	0.05	4.0	3.0	4.5	74.4	0.0	19.4	0.9	1.8	3.6	16
2002	344	1205	7.99	7.94	0.05	3.6	2.8	4.1	71.9	0.0	20.7	0.9	2.8	3.7	17
2002	339	1205	7.98	7.94	0.04	3.6	2.8	4.1	73.1	0.0	20.8	1.0	2.1	3.1	18
2002	234	1092	8.21	8.17	0.04	4.2	3.2	4.6	75.8	0.0	17.9	1.1	2.1	3.2	19
2002	252	1065	8.21	8.17	0.04	4.2	3.2	4.6	76.2	0.0	18.4	1.1	1.1	3.2	20
2003	251	1148	8.48	8.17	0.31	4.2	3.2	4.6	76.1	0.0	18.4	1.2	1.2	3.2	1
2003	314	1058	8.11	7.88	0.23	3.4	2.7	4.0	71.8	0.0	21.6	1.4	1.6	3.6	3
2003	282	1067	8.32	8.08	0.23	4.0	3.0	4.5	74.3	0.0	19.1	1.4	2.0	3.3	2
2003	308	1147	8.07	7.88	0.19	3.4	2.7	4.0	71.9	0.0	21.5	1.5	1.5	3.7	4
2003	250	1201	8.31	8.17	0.14	4.2	3.2	4.6	75.6	0.0	18.3	1.3	1.6	3.2	5
2003	281	1092	8.22	8.08	0.14	4.0	3.0	4.5	74.9	0.0	19.1	1.3	1.3	3.3	6
2003	286	1201	8.20	8.08	0.12	4.0	3.0	4.5	74.6	0.0	19.2	1.1	1.5	3.4	7
2003	283	1201	8.19	8.08	0.11	4.0	3.0	4.5	74.4	0.0	19.0	1.2	2.1	3.3	8
2003	261	1201	8.25	8.17	0.08	4.2	3.2	4.6	76.0	0.0	18.3	1.1	1.7	2.9	9
2003	255	1147	8.25	8.17	0.08	4.2	3.2	4.6	76.9	0.0	18.5	1.2	0.6	2.9	10
2003	285	1204	8.15	8.08	0.06	4.0	3.0	4.5	74.5	0.0	19.2	1.4	1.4	3.5	11
2003	348	1201	7.99	7.94	0.06	3.6	2.8	4.1	72.2	0.0	20.6	1.6	2.4	3.2	12
2003	284	1204	8.14	8.08	0.05	4.0	3.0	4.5	75.6	0.0	19.1	0.9	0.9	3.5	13
2003	74	1147	7.74	7.69	0.05	2.9	2.4	3.6	69.0	0.0	23.8	2.1	1.0	4.1	14
2003	77	1204	7.74	7.69	0.04	2.9	2.4	3.6	67.9	0.0	23.4	2.2	2.2	4.3	15
2003	227	1147	8.21	8.17	0.04	4.2	3.2	4.6	76.0	0.0	18.6	1.1	1.1	3.3	16
2003	262	1201	8.21	8.17	0.04	4.2	3.2	4.6	75.6	0.0	18.7	1.1	1.1	3.4	17
2003	238	1147	8.21	8.17	0.03	4.2	3.2	4.6	76.8	0.0	18.0	1.3	1.3	2.6	18
2003	254	1147	8.20	8.17	0.03	4.2	3.2	4.6	75.8	0.0	18.6	1.4	1.4	2.8	19
2003	175	1205	8.12	8.08	0.03	4.0	3.0	4.5	74.0	0.0	18.9	1.4	2.9	2.9	20

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Sipsey (Top 25 Days Over 3 Years)

YEAR	DAY	REC	DV(Total)	DV(BKG)	DELTA DV	F(RH) S	F(RH) L	F(RH) SS	% of Modeled Extinction by Species % SO4	% NO3	% OC	% EC	% PMC	% PMF	Rank
2003	251	1148	8.48	8.17	0.31	4.2	3.2	4.6	76.1	0.0	18.4	1.2	1.2	3.2	1
2002	3	1092	8.17	7.94	0.24	3.6	2.8	4.1	72.8	0.0	20.8	1.3	1.5	3.5	2
2003	282	1067	8.32	8.08	0.23	4.0	3.0	4.5	74.3	0.0	19.1	1.4	2.0	3.3	3
2003	314	1058	8.11	7.88	0.23	3.4	2.7	4.0	71.8	0.0	21.6	1.4	1.6	3.6	4
2001	259	1058	8.39	8.17	0.22	4.2	3.2	4.6	75.9	0.0	18.4	1.2	1.4	3.1	5
2002	268	1092	8.39	8.17	0.22	4.2	3.2	4.6	75.7	0.0	18.3	1.2	1.6	3.1	6
2003	308	1147	8.07	7.88	0.19	3.4	2.7	4.0	71.9	0.0	21.5	1.5	1.5	3.7	7
2002	241	1067	8.35	8.17	0.18	4.2	3.2	4.6	75.7	0.0	18.3	1.2	1.5	3.2	8
2002	247	1147	8.32	8.17	0.15	4.2	3.2	4.6	76.0	0.0	18.5	1.2	1.2	3.1	9
2002	220	1110	8.32	8.17	0.15	4.2	3.2	4.6	75.5	0.0	18.4	1.2	1.8	3.1	10
2003	250	1201	8.31	8.17	0.14	4.2	3.2	4.6	75.6	0.0	18.3	1.3	1.6	3.2	11
2003	281	1092	8.22	8.08	0.14	4.0	3.0	4.5	74.9	0.0	19.1	1.3	1.3	3.3	12
2002	216	1065	8.31	8.17	0.13	4.2	3.2	4.6	75.7	0.0	18.3	1.3	1.7	3.0	13
2001	311	1165	8.01	7.88	0.13	3.4	2.7	4.0	71.6	0.0	21.3	1.4	2.1	3.6	14
2002	245	1147	8.30	8.17	0.13	4.2	3.2	4.6	76.4	0.0	18.5	1.0	1.0	3.1	15
2001	164	1077	8.20	8.08	0.12	4.0	3.0	4.5	74.5	0.0	19.1	1.1	1.9	3.4	16
2003	286	1201	8.20	8.08	0.12	4.0	3.0	4.5	74.6	0.0	19.2	1.1	1.5	3.4	17
2002	244	1147	8.29	8.17	0.12	4.2	3.2	4.6	76.1	0.0	18.5	1.2	1.2	3.1	18
2001	215	1205	8.28	8.17	0.11	4.2	3.2	4.6	76.2	0.0	18.5	1.2	0.8	3.2	19
2002	170	1092	8.19	8.08	0.11	4.0	3.0	4.5	74.7	0.0	19.1	1.2	1.6	3.3	20
2003	283	1201	8.19	8.08	0.11	4.0	3.0	4.5	74.4	0.0	19.0	1.2	2.1	3.3	21
2002	253	1065	8.28	8.17	0.11	4.2	3.2	4.6	76.3	0.0	18.3	1.2	1.2	2.9	22
2002	242	1058	8.28	8.17	0.11	4.2	3.2	4.6	76.0	0.0	18.5	1.3	1.3	2.9	23
2002	243	1092	8.27	8.17	0.10	4.2	3.2	4.6	75.9	0.0	18.4	1.3	1.3	3.1	24
2001	273	1199	8.27	8.17	0.10	4.2	3.2	4.6	75.3	0.0	18.3	1.4	1.8	3.2	25

Appendix C

Agglomerator Cost Estimate from Indigo Industries, Inc.

indigo TECHNOLOGIES

creating technology

March 21, 2005

[redacted]

Dear [redacted]

Indigo Technologies is please to submit this budget proposal for the design, supply and installation of our Bi-Polar Agglomerator technology on Units #1 and #2 at the [redacted] I apologize for the delay in getting this proposal to you. The delay was due to our rapid growth, the need to respond to the high degree of interest in our technology, and moving our offices to accommodate our growth. Our Australia office also moved to more spacious facilities to accommodate their growth and the international interest in the Agglomerator. I trust that you still interest in our exciting new technology.

There has been a lot happening since we met at [redacted]ate last year. We have been working to get our US patent application approved. We just received notification from the US Patent and Trademark Office that our patent will be issued on March 30. It is a broad based patent and we believe it will offer Indigo the intellectual property protection we need to be successful. Patents have also been granted in Australia, Japan, China, and South Africa, and patents are pending in many other countries.

[redacted] we received an order from [redacted] for an Agglomerator to be installed on [redacted] This unit is rated [redacted] and burns a blend of 85% PRB coal and 15% eastern bituminous coal. That unit will be installed and operational by the end of May 2005, just two months from now. I know you and the other [redacted] personnel were concerned about the use of the Agglomerator on PRB coal applications. We are confident the fine particles generated by the combustion of PRB coals will be controlled by the Agglomerator.

In my presentation I told you how the Agglomerator works and how it mitigates fine particle problems. I do not want to focus on the technology in this letter. Rather I want to focus on how that technology is appropriate and cost effective for [redacted] Enclosed is a copy of the most recent paper on the 4 current Agglomerator installations.

• Indigo Technologies, LLC • Suite 205 • 8980 Perry Highway • Pittsburgh, PA 15237 USA •
• Tel: +1-412-358-0171 • Fax: +1-412-358-0174 • Email: rcrynack@indigotechnologies-us.com •

BUDGETARY COST ESTIMATE

Since I only had a brief visit [illegible] we can only provide a budget estimate at this time. We are confident of our materials and fabrication costs. It is only the installation costs that are in question, since they are site specific and can vary widely. We have made some conservative estimates at this time, and have assumed union labor rates for installation. A firm price proposal can be submitted once we do a more formal site inspection to determine more accurately the installation requirements and costs.

85MW 235MW

Our budgetary estimate for the design, supply, and installation of the Agglomerators for Unit #1 is $1.1 M and for Unit #2 is $2.6 M. This is an all-inclusive price, including all design engineering, fabrication of internal parts, delivery, installation, electrical energization equipment, start up services, and training. This price also includes the cost of the structural evaluation of the existing duct support systems for the additional loads presented by the Agglomerator and includes the cost of any reinforcement.

SCHEDULE

We prefer to have about six months to design, fabricate, and supply the Agglomerator components prior to the installation. It is possible to design and supply Agglomerators on a fast track schedule in as little as 4 months. A fast track schedule would increase the cost by about 10-15% for expediting material purchases, fabrication, and shipping. The exact impact must be determined when a specific schedule is set.

In my initial visit, I did not see any easy access to the installation sites that would allow us to build the Agglomerators on the ground near the installation sites and then lift them into place. Therefore, the Agglomerators would require in-situ installation, where the duct modifications are made and then components are loaded into the modified ducts. The above pricing is based on installation times of 30 days for Unit #1 and 45 days for Unit #2. Again, these schedules can be refined after a thorough site inspection.

OPERATION AND MAINTENANCE

The Agglomerator does not collect ash, so hoppers and rappers are not required. There are no moving parts in the Agglomerator, so maintenance is minimal. Annual inspection is recommended. There should not be any significant annual maintenance costs.

Power consumption of the Agglomerator is small. Each Agglomerator will require one high voltage power supply. Each power supply houses both the positive and negative energization capability and is rated for 50 kV at 50 MA for each of the positive and negative outputs. A 480/575 V, 20A, 3-phase circuit for each power supply is all that is required.

Pressure loss for the Agglomerator is also low. The pressure loss across the Agglomerator is less than one inch of water, and more typically 0.7 inches of water.

To limit the risk of installing the Indigo Agglomerator technology [redacted] may opt to install one Agglomerator on one of the two ESP ducts of either boiler unit. This is what was done [redacted] They have decided to install the second half in spring 2006, but of course the combined cost is higher.

[redacted]

SUMMARY

The Indigo Agglomerator is a cost effective technology that can address [redacted]

I look forward to further discussions with you and other [redacted] and [redacted] personnel on the installation of the Agglomerator on either Unit #1 or Unit #2 of the [redacted] We are excited about this potential project and look forward to the opportunity to meeting to discuss the Indigo Agglomerator technology and its installation [redacted] We would be delight to arrange a site visit [redacted] Please do not hesitate to contact me if you have any questions or if you need further clarification.

Sincerely yours,

RR Crynack

Robert R. Crynack, Ph.D.
President

[redacted]

Appendix D

BART Determination Modeling Protocol:
Georgia Power Company
Plant Bowen

BART Determination Modeling Protocol:

Georgia Power Company
Plant Bowen

Prepared by:

Southern Company Services and ENSR Corporation
for Georgia Power Company

November 2006

Contents

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1.0 Introduction

1.1 Objectives

The Regional Haze Rule requires Best Available Retrofit Technology (BART) for any BART-eligible source that ‘‘emits any air pollutant which may reasonably be anticipated to cause or contribute to any impairment of visibility” in any mandatory Class I federal area. Pursuant to federal regulations, states have the option of exempting a BART-eligible source from the BART requirements based on dispersion modeling demonstrating that the source cannot reasonably be anticipated to cause or contribute to visibility impairment in a Class I area. In addition, the Environmental Protection Agency (EPA) has promulgated a rule allowing states subject to the Clean Air Interstate Rule (CAIR) to determine that CAIR satisfies the BART requirements for SO_2 and NO_x for electric generating units (EGUs). Preliminary feedback from the Georgia Environmental Protection Division indicates that they anticipate making the decision that CAIR satisfies BART for SO_2 and NO_x for EGUs. Therefore, this modeling protocol focuses on performing the BART modeling analysis for particulate matter (PM) only.

Units 1, 2, 3, and 4 at Plant Bowen, located near Cartersville, which is owned and operated by Georgia Power Company, has been identified as a BART-eligible source. The purpose of this document is to summarize the procedures by which modeling analyses will be conducted for this source. Georgia Power has determined that Plant Bowen is subject to BART for PM. Therefore, the procedures below will be used to evaluate the visibility improvement factor in the BART determination step (determination modeling). The modeling procedures are consistent with those outlined in the updated final VISTAS common BART modeling protocol (dated December 22, 2005, revision 3.2 – August 31, 2006), available at http://www.vistas-sesarm.org/BART/BARTModelingProtocol_rev3.2_31Aug2006.pdf. This source-specific BART modeling protocol references relevant portions of the common VISTAS modeling protocol.

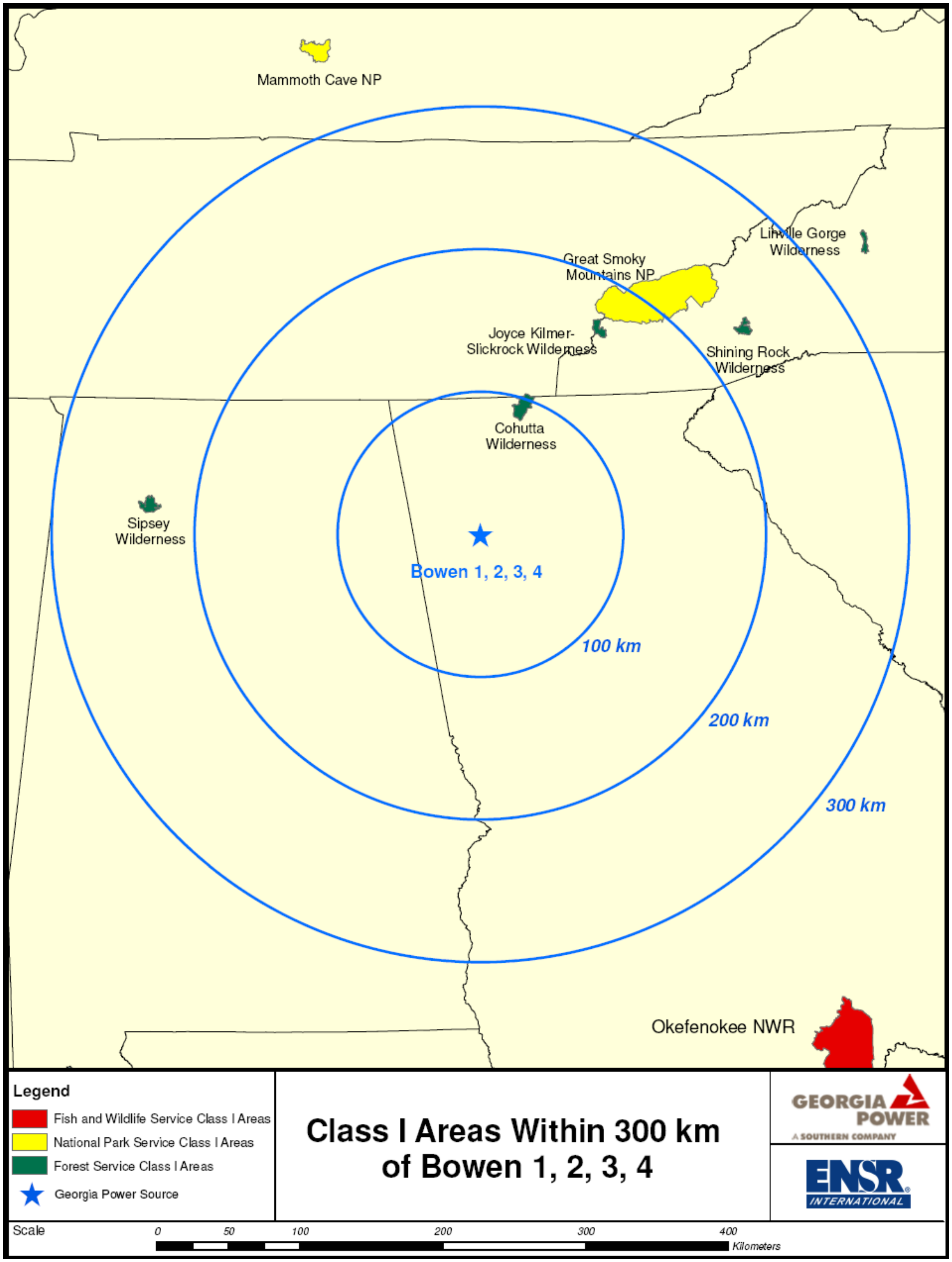
1.2 Location of source vs. relevant Class I Areas

The Georgia Environmental Protection Division, which is in charge of the state’s BART program, has determined that Units 1, 2, 3, and 4 at Plant Bowen are BART-eligible for PM. Figure 1-1 shows a plot of Plant Bowen relative to nearby Class I Areas. There are five Class I areas within 300 km of the plant: Cohutta (84.8 km), Great Smoky Mountains (175.9 km), Joyce Kilmer (162.3 km), Shinning Rock (228.0 km), and Sipsey (223.5 km). Baseline modeling will be conducted for each of these Class I areas in accordance with the referenced VISTAS common BART modeling protocol and the procedures described in this source-specific BART modeling protocol. Visibility improvement modeling for the BART determination analysis will be performed for those Class I areas where the baseline modeling shows a greater than 0.5 deciview impact.

1.3 Organization of protocol document

Section 2 of this protocol describes the baseline to be used for the BART determination, identifies the PM emissions controls that will be modeled, and outlines the source emissions that will be used as input to the BART determination modeling. Section 3 describes the input data to be used for the modeling including the modeling domain, terrain and land use, and meteorological data. Section 4 describes the air quality modeling procedures and Section 5 discusses how the modeling results will be presented. Since all of the references cited are also included in the VISTAS common BART modeling protocol (Section 7.), no reference section is included in this document. Appendices A and B provide additional information on the baseline source emissions.

Figure 1-1 Location of Class I Areas in Relation to Plant Bowen



2.0 Source description and emissions data

2.1 BART determination baseline

SO_2 scrubbers have been permitted and are under construction for all four units at Plant Bowen. The scrubbers will go on line in 2008 for Units 3 and 4, 2009 for Unit 2, and 2010 for Unit 1. So, these scrubbers will be "existing" controls for Bowen well ahead of the estimated implementation date for BART (~2014). It has been determined that impacts from Bowen 1-4 (the BART eligible source) will be greater than 0.5 deciview on at least one Class I area even with the PM emissions reductions that occur from scrubbers. In addition, using the scrubbers as baseline provides consistency that allows for straight forward (i.e., effect of emission reduction only) interpretation of results. That is, there will be consistency in stack parameters and emissions that might otherwise confound interpretation of modeling results. Finally, this approach is consistent with the BART statutory factor that requires consideration of "any existing pollution control technology in use at the source." For these reasons, scrubbers on the Bowen units will be the starting point (baseline) for the PM BART determination and visibility improvement modeling.

2.2 PM emissions controls to be modeled

Georgia Power has initiated the PM BART determination analysis for Bowen. Preliminary results include identification of technically feasible PM controls and performance of a removal cost analysis for these controls. This preliminary cost analysis considers the installed capital and operating cost (including sorbent cost, where appropriate), capacity and energy penalties associated with station service impacts, PM species specific removal efficiencies for each control, emissions derived based on 2003-2005 actuals adjusted by removal efficiencies, and financial assumptions consistent with the EPA Control Cost Manual and industry-accepted capital and operating cost estimates..

Table 2-1 summarizes preliminary cost analysis results for each technically feasible PM control. Due to space constraints, COHPAC (on all four units) and the addition of a new electrostatic precipitator (ESP) collection field in a new case (on Units 3 and 4) were not considered. A detailed description of potentially available PM controls and their feasibility for Bowen and a detailed discussion of the cost analysis will be provided in the final BART determination analysis report to be submitted later. Further refinements to the analysis are possible, but it is not anticipated that the conclusions will be significantly different. As described in the EPA BART guidance, the data in Table 2-1 was used to create a graphical plot of the total annualized cost for the total PM emissions reductions for all feasible control alternatives (Figures 2-1 thru 2-4). A curve was fit to the data in order to identify a "least-cost envelope" of dominant control choices. Control options that lie inside of the least-cost envelope are considered inferior options based on cost because the cost per ton of particulate removed is inconsistent with other competing alternatives.

Figures 2-1 through 2-4 show that the dominant control choices for all four units include WESP, the addition of JuiceCan technology on existing transformer/rectifier (T/R) sets, the particle agglomerator, and the combination of JuiceCan/particle agglomerator. Gas flow optimization, lime injection, the addition of a new electrical field (on Units 1 and 2), and the combination of WESP/lime injection have been eliminated because they fall inside of the least-cost envelope. These options are considered inferior based on cost and, therefore, have been eliminated from further consideration. Rather than performing visibility improvement modeling for all of the remaining controls, modeling will be performed for two of the remaining options: (1) Agglomerator/Juice Can - the highest removal option of the set of relatively lower cost controls, and (2) Wet ESP - the remaining control with the overall highest total PM removal. This will bracket the overall visibility improvement results.

2.3 Unit-specific source data

The emissions data used to assess the visibility impacts at the Class I areas within 300 km of Plant Bowen are discussed in this section. As noted earlier, indications from the Georgia Environmental Protection Division are that they will issue rules stating that CAIR will suffice for EGU BART for SO_2 and NO_x. Therefore, this protocol focuses only on PM_{10}. Since various components of PM_{10} emissions have different visibility extinction efficiencies, the PM_{10} emissions are divided, or "speciated," into several components (VISTAS common protocol Sections 4.3.3 and 4.4.2). The VISTAS protocol (Section 5.) allows for the use of source-specific emissions and speciation factors and/or default values from AP-42. The PM_{10} emissions and speciation

Table 2-1 Plant Bowen Preliminary BART Cost Analysis Results

	Total PM10 Removed	Annualized Cost	Removal Cost	Total PM10 Removed	Annualized Cost	Removal Cost
Control Option	**Bowen 1**			**Bowen 2**		
	Tons	$/Yr	$ per Ton	Tons	$/Yr	$ per Ton
Optimize Gas Flow	5.6	$125,600	$22,274	7.8	$125,600	$16,089
Juice Can Retrofit	11.3	$82,317	$7,299	15.6	$82,317	$5,272
Lime Injection	33.1	$2,714,893	$82,026	38.1	$2,714,893	$71,323
Agglomerator Retrofit	62.0	$1,236,108	$19,929	85.9	$1,236,108	$14,395
Add field in new casing	65.8	$3,433,973	$52,199	91.1	$3,433,973	$37,705
Agglomerator/JuiceCan	73.3	$1,318,425	$17,986	101.5	$1,318,425	$12,991
WESP	261.0	$13,102,142	$50,209	336.2	$13,102,142	$38,973
WESP/Lime Injection	271.0	$15,817,034	$58,375	347.4	$15,817,034	$45,527
Control Option	**Bowen 3**			**Bowen 4**		
	Tons	$/Yr	$ per Ton	Tons	$/Yr	$ per Ton
Optimize Gas Flow	14.1	$161,486	$11,465	16.0	$161,486	$10,074
Juice Can Retrofit	21.1	$105,836	$5,009	24.0	$105,836	$4,402
Lime Injection	44.6	$3,490,576	$78,224	43.2	$3,490,576	$80,850
Agglomerator Retrofit	51.6	$1,589,281	$30,772	58.8	$1,589,281	$27,039
Agglomerator/JuiceCan	72.8	$1,695,117	$23,292	82.8	$1,695,117	$20,467
WESP	334.8	$16,845,611	$50,319	360.5	$16,845,611	$46,731
WESP/Lime Injection	348.2	$20,336,187	$58,396	373.6	$20,336,187	$54,440
Add field in new casing	n/a	n/a	n/a	n/a	n/a	n/a

Figure 2-1 **Plant Bowen Unit 1 - Annualized Cost versus PM Removed**

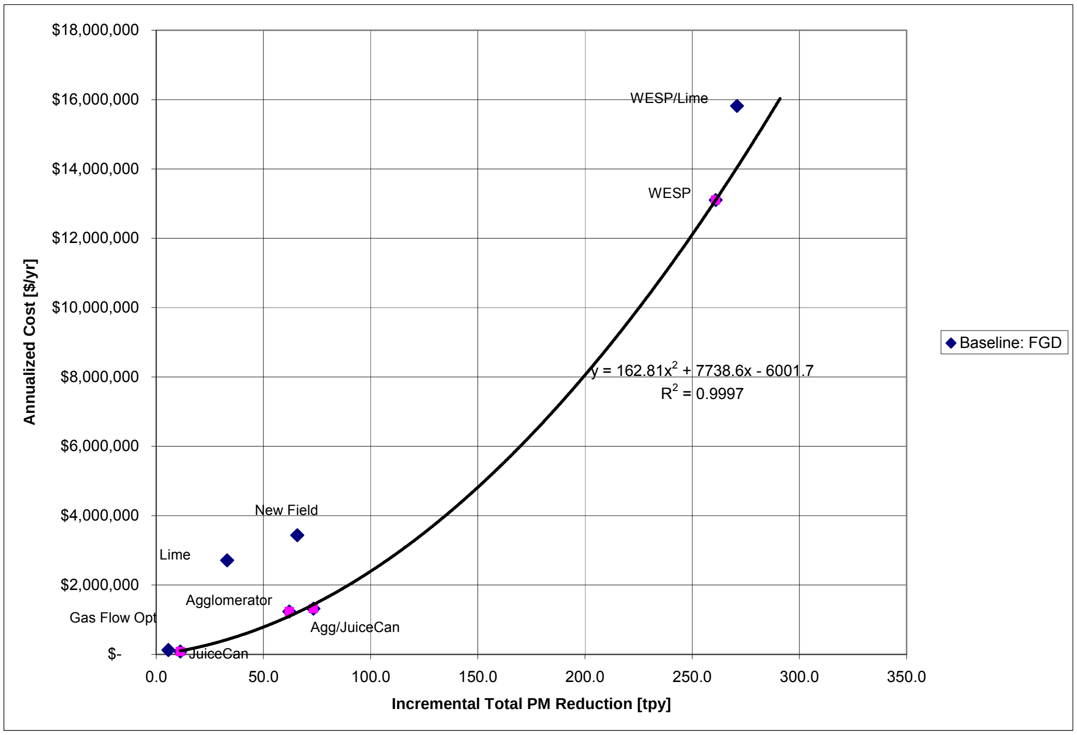


Figure 2-2 **Plant Bowen Unit 2 - Annualized Cost versus PM Removed**

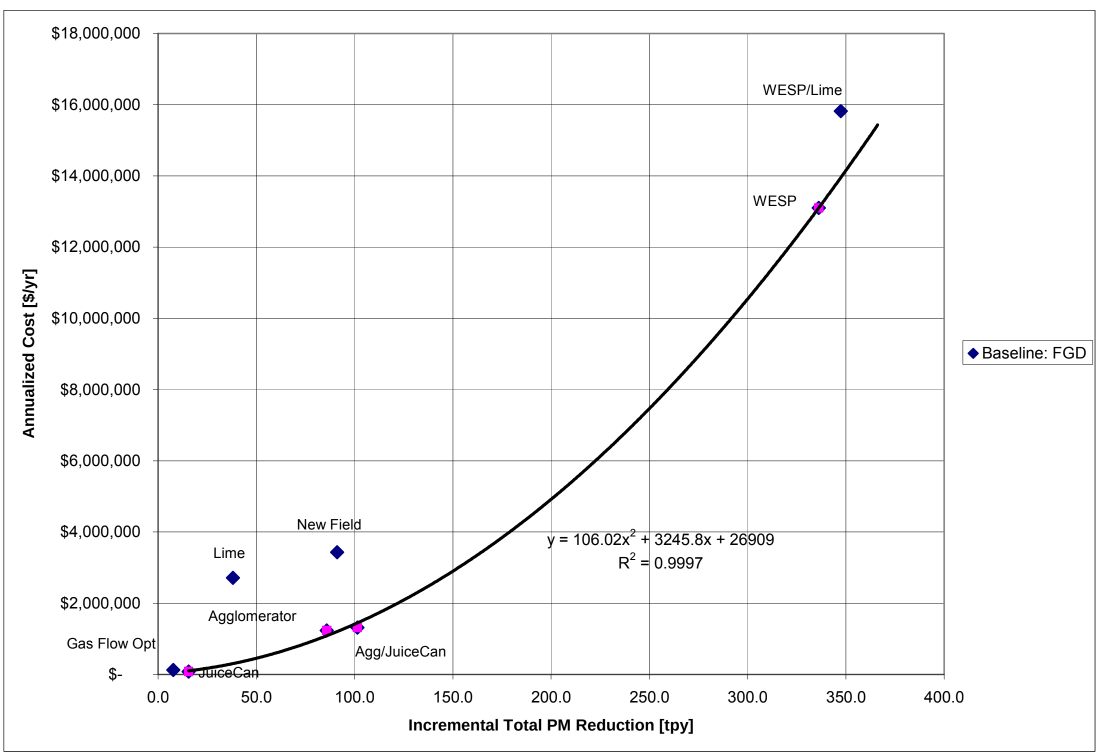


Figure 2-3 **Plant Bowen Unit 3 - Annualized Cost versus PM Removed**

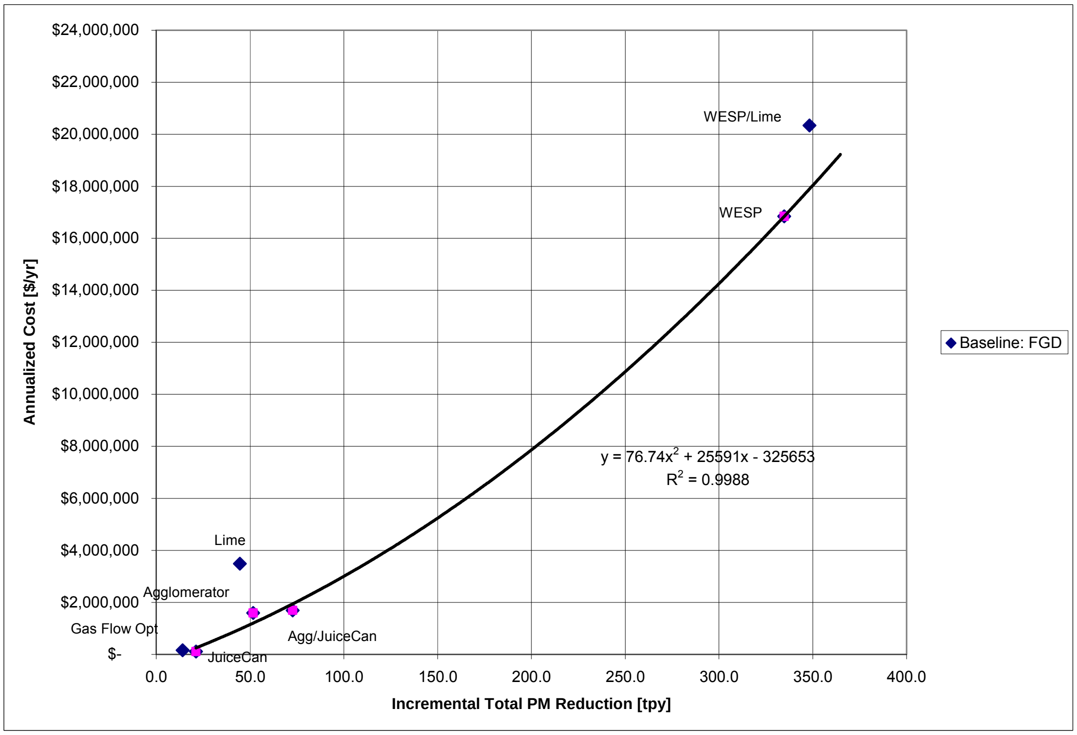
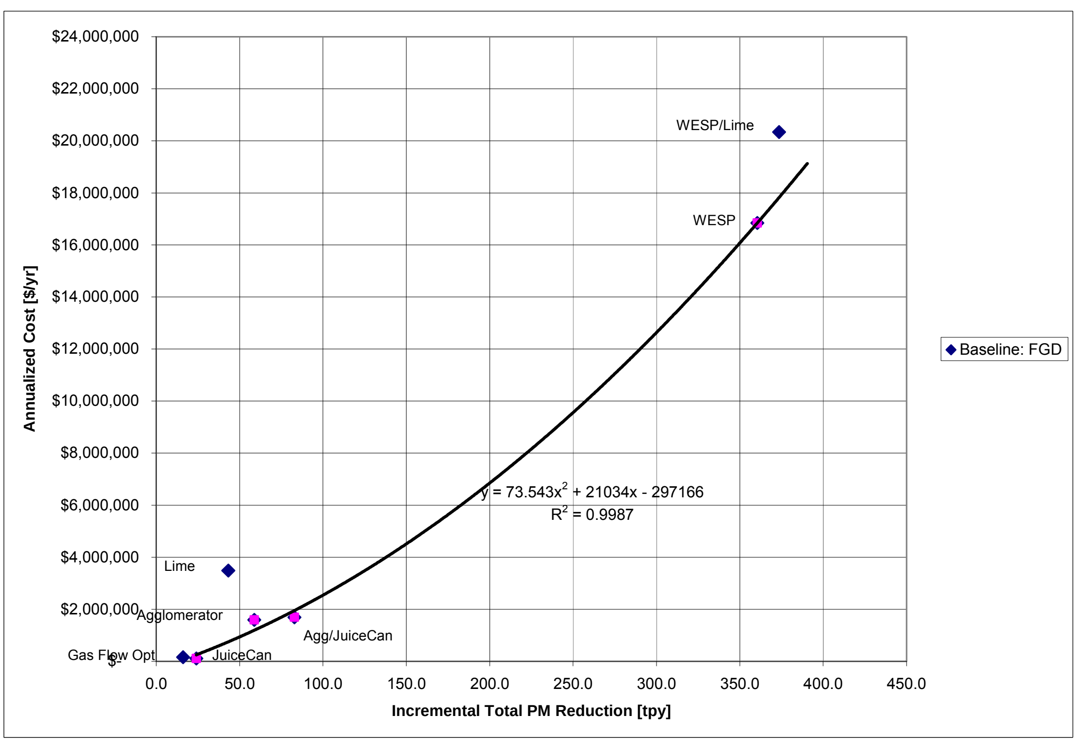


Figure 2-4 **Plant Bowen Unit 4 - Annualized Cost versus PM Removed**



approach to be used for the modeling described in this protocol is indicated in the bullets below. Where default speciation values are used, the data represents a unit where current (baseline) emission controls include ESPs and selective catalytic reduction (SCR) systems, but no post-combustion SO_2 control equipment exists.

As indicated in Section 2.1, it has been determined that the baseline for the BART determination analysis and visibility improvement modeling will include scrubbers on all of the Bowen units. Therefore, the foundation for deriving the baseline and control option emissions for the BART determination modeling was to establish "maximum 24-hour average emission rates" based on the current configuration consistent with the VISTAS common protocol and then to apply the species specific control efficiencies as appropriate. To establish emission rates for the BART determination baseline modeling, scrubber control efficiencies were applied to the maximum 24-hour average rates.

- Total PM_{10} is comprised of filterable and condensable emissions.
- Filterable PM_{10} emissions are based on the highest stack test for the most recent 3-year period (2003-2005). This stack test is combined with the highest 24 hour heat input value for this period from CEMS data to calculate the "maximum 24-hour average emission rate" as required by the VISTAS protocol.
- Filterable PM_{10} will be subdivided by size category consistent with the default approach from AP-42 Table 1-1.6, and as noted on pages 43 and 44 of the VISTAS common BART modeling protocol. The AP-42 Table 1-1.6 specifies for the emission controls indicated above that 55.6% of filterable PM_{10} emissions is coarse (greater than 2.5 microns in size) and 44.4% is fine. Of the fine portion, 3.7% is elemental carbon and the remainder is inorganic fine particulates (soil).
- Condensable PM_{10} consists of inorganic and organic compounds. The inorganic portion is by default assumed to be H_2SO_4, although other non-sulfate inorganic condensables could be present. The organic portion is modeled as organic aerosols.
- H_2SO_4 emissions are calculated consistent with the method used by Georgia Power to derive these emissions for TRI purposes. This approach assumes that the H_2SO_4 emissions released from the stack are proportional to SO_2 emissions from combustion and are dependent on the fuel type and the removal of H_2SO_4 by downstream equipment (i.e., ESP and air heater). For eastern bituminous coal the fundamental H_2SO_4 release rate (without scrubbers or add-on PM controls) is in the range of 0.3 to 0.8% of the SO_2 emissions. Appendix A provides the basis for the site-specific values used.
- Emissions of condensable organics (the remaining portion of condensable PM_{10}) are derived based on the supporting field observational information in Appendix B and is estimated as 0.32% of SO_2 emitted.
- Coarse filterable particles (between 2.5 and 10 microns in size) will be modeled with a geometric mass mean diameter of 5 microns, while fine filterable and all condensable particles will be modeled with a geometric mass mean diameter of 0.48 microns, consistent with the CALPUFF default value for fine particles. The geometric standard deviation for both fine and coarse particles will be set to 2 microns, consistent with the CALPUFF default value. The 0.48 micron diameter value for fine particles comes from the default values in sample input files presented on the TRC web site. There is no default value presented for the coarse particles on the TRC web site. However, since 5 is the geometric mass mean diameter of 2.5 and 10 (the bounds of coarse particle sizes), it is a reasonable estimate for the geometric mass mean diameter for that class of particles.

In practice, CALPUFF allows for the user to input certain components of PM_{10} as separate species and separate sizes, which will result in more accurate wet and dry deposition velocity results and also more accurate effects on light scattering. As noted above, the particle size distribution information is provided in AP-42 Table 1-1.6, and will be used for the BART determination modeling.

Table 2-2 provides a summary of the modeling emission parameters to be used in the BART CALPUFF modeling, consistent with the source emissions data presented in Appendices A and B for the current configuration. The foundation for all of the emissions in Table 2-2 were derived from CEMS data for the 2003 to 2005 period and represent the maximum 24-hour average lb/hr rates (excluding days where startup, shutdown, or malfunctions occurred). For NO_x and SO_2 the current configuration values are directly from CEMS. Filterable PM_{10} emissions were calculated using the highest stack test over the 2003 to 2005 period and multiplying these values times the maximum 24-hour average heat input derived from CEMS. These values were then adjusted using AP-42 factors from Table 1.1-6 that indicate that PM_{10} is 67% of total PM for a pulverized coal unit with an ESP. PM_{10} speciation was then performed as indicated above such that total Filterable PM_{10} is made up of Coarse Soil plus total Fine PM and total Fine PM is made up of Fine Soil plus Elemental Carbon (EC). Since these units include SCRs, a consistent set of seasonal emissions data was developed representing periods with and without SCR operation. For these, the maximum 24-hour average rates were extracted from the seasonal (May - September) and non-seasonal (October - April) CEMS data. For visibility improvement modeling, only the emissions representing SCR operation was used as the foundation for establishing the baseline (scrubbed) emission rates and the emission rates for PM controls under consideration.

Table 2-2 Plant Bowen modeling emission parameters

Case	Source / Unit	Location UTM (Zone 16 NAD-83)		Actual Stack Ht	Base Elev.	Flue Dia-meter	Gas Exit Vel.	Stack Gas Exit Temp.	Emissions[1]			Particle Speciation[2]							
		UTM East	UTM North						SO_2	NO_X	PM_{10}	Filt. PM_{10}	Coarse Soil	Fine PM	Fine Soil	EC	Cond. PM_{10}	H_2SO_4	Organic
		m	m	m	m	m	m/s	deg K	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr
FUNDAMENTAL EMISSIONS DATA																			
Fundamental Data (Unit Basis)																			
Current Config.	Unit 1	691,893	3,778,033	304.8	219.8	7.6	20.8	403.0	15374.22	1565.42	510.21	378.07	210.20	167.86	161.65	6.21	132.14	82.95	49.20
Current Config.	Unit 2	691,893	3,778,033	304.8	219.8	7.6	20.8	403.0	16059.38	1253.44	545.86	407.51	226.58	180.94	174.24	6.69	138.35	86.96	51.39
Current Config.	Unit 3	691,893	3,778,033	304.8	219.8	7.6	27.1	409.7	18519.37	773.00	478.86	268.01	149.01	119.00	114.59	4.40	210.85	151.58	59.26
Current Config.	Unit 4	691,893	3,778,033	304.8	219.8	7.6	27.1	409.7	19504.06	971.92	521.14	297.26	165.28	131.98	127.10	4.88	223.88	161.47	62.41
BART DETERMINATION BASELINE EMISSIONS																			
Scrubber Baseline Data (Unit Basis)																			
Baseline	Unit 1	691,893	3,778,033	207.5	219.5	7.6	12.5	327.0	768.71	1565.42	174.58	75.61	42.04	33.57	32.33	1.24	98.97	49.77	49.20
Baseline	Unit 2	691,893	3,778,033	207.5	219.5	7.6	12.5	327.0	802.97	1253.44	185.07	81.50	45.32	36.19	34.85	1.34	103.56	52.17	51.39
Baseline	Unit 3	691,893	3,778,033	207.5	219.5	7.6	15.8	327.0	925.97	773.00	173.03	53.60	29.80	23.80	22.92	0.88	119.43	60.16	59.26
Baseline	Unit 4	691,893	3,778,033	207.5	219.5	7.6	15.8	327.0	975.20	971.92	185.10	59.45	33.06	26.40	25.42	0.98	125.65	63.24	62.41
Scrubber Baseline Data (Stack Basis)																			
				Modeled Stk Ht[3]		Eq. Dia.													
		m	m	m	m	m	m/s	deg K	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	1571.68	2818.85	359.64	157.12	87.36	69.76	67.18	2.58	202.53	101.94	100.59
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	1901.17	1744.92	358.13	113.05	62.86	50.20	48.34	1.86	245.08	123.40	121.67
Stack Basis Emissions Converted to g/sec									g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	198.03	355.18	45.32	19.80	11.01	8.79	8.46	0.33	25.52	12.84	12.67
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	239.55	219.86	45.12	14.24	7.92	6.32	6.09	0.23	30.88	15.55	15.33

Table 2-2 (Continued) Plant Bowen modeling emission parameters

Case	Source / Unit	Location UTM (Zone 16 NAD-83)		Actual Stack Ht	Base Elev.	Flue Dia-meter	Gas Exit Vel.	Stack Gas Exit Temp.	Emissions[1]			Particle Speciation[2]							
		UTM East	UTM North						SO_2	NO_X	PM_{10}	Filt. PM_{10}	Coarse Soil	Fine PM	Fine Soil	EC	Cond. PM_{10}	H_2SO_4	Organic
		m	m	m	m	m	m/s	deg K	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr
EMISSIONS for MODELED CONTROL OPTIONS																			
Agglomerator/Juice Can Data (Unit Basis)																			
Agglom/JC	Unit 1	691,893	3,778,033	207.5	219.5	7.6	12.5	327.0	768.71	1565.42	145.09	46.12	25.98	20.14	19.40	0.75	98.97	49.77	49.20
Agglom/JC	Unit 2	691,893	3,778,033	207.5	219.5	7.6	12.5	327.0	802.97	1253.44	153.28	49.72	28.00	21.71	20.91	0.80	103.56	52.17	51.39
Agglom/JC	Unit 3	691,893	3,778,033	207.5	219.5	7.6	15.8	327.0	925.97	773.00	156.41	36.99	23.42	13.57	13.06	0.50	119.43	60.16	59.26
Agglom/JC	Unit 4	691,893	3,778,033	207.5	219.5	7.6	15.8	327.0	975.20	971.92	166.67	41.02	25.98	15.05	14.49	0.56	125.65	63.24	62.41
Agglomerator/Juice Can Data (Stack Basis) - Unit 1 Only Controlled																			
				Modeled Stk Ht[3]		Eq. Dia.													
		m	m	m	m	m	m/s	deg K	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	1571.68	2818.85	330.16	127.63	71.30	56.33	54.25	2.08	202.53	101.94	100.59
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	1901.17	1744.92	358.13	113.05	62.86	50.20	48.34	1.86	245.08	123.40	121.67
Stack Basis Emissions Converted to g/sec									g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	198.03	355.18	41.60	16.08	8.98	7.10	6.84	0.26	25.52	12.84	12.67
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	239.55	219.86	45.12	14.24	7.92	6.32	6.09	0.23	30.88	15.55	15.33
Agglomerator/Juice Can Data (Stack Basis) - Unit 2 Only Controlled																			
				Modeled Stk Ht[3]		Eq. Dia.													
		m	m	m	m	m	m/s	deg K	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	1571.68	2818.85	327.86	125.33	70.05	55.28	53.24	2.05	202.53	101.94	100.59
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	1901.17	1744.92	358.13	113.05	62.86	50.20	48.34	1.86	245.08	123.40	121.67
Stack Basis Emissions Converted to g/sec									g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	198.03	355.18	41.31	15.79	8.83	6.97	6.71	0.26	25.52	12.84	12.67
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	239.55	219.86	45.12	14.24	7.92	6.32	6.09	0.23	30.88	15.55	15.33

Table 2-2 (Continued) Plant Bowen modeling emission parameters

Case	Source / Unit	Location UTM (Zone 16 NAD-83)		Actual Stack Ht	Base Elev.	Flue Dia-meter	Gas Exit Vel.	Stack Gas Exit Temp.	Emissions[1]			Particle Speciation[2]							
		UTM East	UTM North						SO_2	NO_X	PM_{10}	Filt. PM_{10}	Coarse Soil	Fine PM	Fine Soil	EC	Cond. PM_{10}	H_2SO_4	Organic
Agglomerator/Juice Can Data (Stack Basis) - Unit 3 Only Controlled																			
				Modeled Stk Ht[3]		**Eq. Dia.**													
		m	m	m	m	m	m/s	deg K	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	1571.68	2818.85	359.64	157.12	87.36	69.76	67.18	2.58	202.53	101.94	100.59
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	1901.17	1744.92	341.51	96.44	56.48	39.96	38.48	1.48	245.08	123.40	121.67
Stack Basis Emissions Converted to g/sec									g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	198.03	355.18	45.32	19.80	11.01	8.79	8.46	0.33	25.52	12.84	12.67
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	239.55	219.86	43.03	12.15	7.12	5.04	4.85	0.19	30.88	15.55	15.33
Agglomerator/Juice Can Data (Stack Basis) - Unit 4 Only Controlled																			
				Modeled Stk Ht[3]		**Eq. Dia.**													
		m	m	m	m	m	m/s	deg K	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	1571.68	2818.85	359.64	157.12	87.36	69.76	67.18	2.58	202.53	101.94	100.59
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	1901.17	1744.92	339.70	94.62	55.78	38.85	37.41	1.44	245.08	123.40	121.67
Stack Basis Emissions Converted to g/sec									g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	198.03	355.18	45.32	19.80	11.01	8.79	8.46	0.33	25.52	12.84	12.67
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	239.55	219.86	42.80	11.92	7.03	4.89	4.71	0.18	30.88	15.55	15.33

Table 2-2 (Continued) Plant Bowen modeling emission parameters

Case	Source / Unit	Location UTM (Zone 16 NAD-83)		Actual Stack Ht	Base Elev.	Flue Dia-meter	Gas Exit Vel.	Stack Gas Exit Temp.	Emissions[1]			Particle Speciation[2]							
		UTM East	UTM North						SO_2	NO_X	PM_{10}	Filt. PM_{10}	Coarse Soil	Fine PM	Fine Soil	EC	Cond. PM_{10}	H_2SO_4	Organic
Wet ESP Data (Unit Basis)																			
Wet ESP	Unit 1	691,893	3,778,033	207.5	219.5	7.6	12.5	327.0	768.71	1565.42	66.71	7.56	4.20	3.36	3.23	0.12	59.15	9.95	49.20
Wet ESP	Unit 2	691,893	3,778,033	207.5	219.5	7.6	12.5	327.0	802.97	1253.44	69.98	8.15	4.53	3.62	3.48	0.13	61.82	10.43	51.39
Wet ESP	Unit 3	691,893	3,778,033	207.5	219.5	7.6	15.8	327.0	925.97	773.00	76.65	5.36	2.98	2.38	2.29	0.09	71.29	12.03	59.26
Wet ESP	Unit 4	691,893	3,778,033	207.5	219.5	7.6	15.8	327.0	975.20	971.92	81.01	5.95	3.31	2.64	2.54	0.10	75.06	12.65	62.41
Wet ESP Data (Stack Basis) - Unit 1 Only Controlled																			
				Modeled Stk Ht[3]		Eq. Dia.													
		m	m	m	m	m	m/s	deg K	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	1571.68	2818.85	251.78	89.06	49.52	39.54	38.08	1.46	162.72	62.13	100.59
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	1901.17	1744.92	358.13	113.05	62.86	50.20	48.34	1.86	245.08	123.40	121.67
Stack Basis Emissions Converted to g/sec									g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	198.03	355.18	31.72	11.22	6.24	4.98	4.80	0.18	20.50	7.83	12.67
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	239.55	219.86	45.12	14.24	7.92	6.32	6.09	0.23	30.88	15.55	15.33
Wet ESP Data (Stack Basis) - Unit 2 Only Controlled																			
				Modeled Stk Ht[3]		Eq. Dia.													
		m	m	m	m	m	m/s	deg K	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	1571.68	2818.85	244.55	83.76	46.57	37.19	35.81	1.38	160.79	60.20	100.59
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	1901.17	1744.92	358.13	113.05	62.86	50.20	48.34	1.86	245.08	123.40	121.67
Stack Basis Emissions Converted to g/sec									g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec
Stack 1	1&2	691,893	3,778,033	304.8	219.5	14.2	12.5	327.0	198.03	355.18	30.81	10.55	5.87	4.69	4.51	0.17	20.26	7.59	12.67
Stack 2	3&4	691,893	3,778,033	304.8	219.5	14.2	15.8	327.0	239.55	219.86	45.12	14.24	7.92	6.32	6.09	0.23	30.88	15.55	15.33
Wet ESP Data (Stack Basis) - Unit 3 Only Controlled																			
				Modeled Stk Ht[3]		Eq. Dia.													
		m	m	m	m	m	m/s	deg K	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	1571.68	2818.85	359.64	157.12	87.36	69.76	67.18	2.58	202.53	101.94	100.59
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	1901.17	1744.92	261.76	64.81	36.04	28.78	27.71	1.06	196.94	75.27	121.67
Stack Basis Emissions Converted to g/sec									g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	198.03	355.18	45.32	19.80	11.01	8.79	8.46	0.33	25.52	12.84	12.67
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	239.55	219.86	32.98	8.17	4.54	3.63	3.49	0.13	24.81	9.48	15.33

Table 2-2 (Continued) Plant Bowen modeling emission parameters

Case	Source / Unit	Location UTM (Zone 16 NAD-83)		Actual Stack Ht	Base Elev.	Flue Dia-meter	Gas Exit Vel.	Stack Gas Exit Temp.	Emissions[1]			Particle Speciation[2]							
		UTM East	UTM North						SO_2	NO_X	PM_{10}	Filt. PM_{10}	Coarse Soil	Fine PM	Fine Soil	EC	Cond. PM_{10}	H_2SO_4	Organic
Wet ESP Data (Stack Basis) - Unit 4 Only Controlled																			
				Modeled Stk Ht[3]		Eq. Dia.													
		m	m	m	m	m	m/s	deg K	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr	lbs/hr
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	1571.68	2818.85	359.64	157.12	87.36	69.76	67.18	2.58	202.53	101.94	100.59
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	1901.17	1744.92	254.03	59.55	33.11	26.44	25.46	0.98	194.49	72.81	121.67
Stack Basis Emissions Converted to g/sec									g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec	g/sec
Stack 1	1&2	691,893	3,778,033	207.5	219.5	14.2	12.5	327.0	198.03	355.18	45.32	19.80	11.01	8.79	8.46	0.33	25.52	12.84	12.67
Stack 2	3&4	691,893	3,778,033	207.5	219.5	14.2	15.8	327.0	239.55	219.86	32.01	7.50	4.17	3.33	3.21	0.12	24.51	9.17	15.33

Notes:

[1] SO_2 and NO_x emissions are not BART-applicable for EGU sources in CAIR states, if the state agency agrees with EPA's interpretation of the BART final rule. The emissions for SO_2 and NO_x are provided for information purposes, and for reference in the computation of certain particle species such as H_2SO_4.

[2] Elemental carbon (EC) and Fine PM are a part of Filterable PM_{10} and H_2SO_4 and Organics are a part of Condensable PM_{10}. Note that H_2SO_4 is input to CALPUFF as SO_4. The molecular weights of H_2SO_4 and SO_4 are 98 and 96 respectively; therefore the conversion factor from H_2SO_4 to SO_4 is 96/98.

[3] Stack credit is equal to actual stack height since this stack is grandfathered.

3.0 Input data to the CALPUFF model

3.1 General modeling procedures:

VISTAS has developed five sub-regional 4-km CALMET meteorological databases for three years (2001-2003) (VISTAS common protocol Section 4.4.2). The sub-regional modeling domains are strategically designed to cover all potential BART eligible sources within VISTAS states and all PSD Class I areas within 300 km of those sources (to the nearest edge). The extents of the 4-km sub-regional domains are shown in Figure 4-4 of the VISTAS common BART modeling protocol. The BART modeling for Plant Bowen will be done using the 4-km subdomain 4.

USGS 90-meter Digital Elevation Model (DEM) files were used by VISTAS to generate the terrain data at 4-km resolution for input to the 4-km sub-regional CALMET run. Likewise, USGS 90-meter Composite Theme Grid (CTG) files were used by VISTAS to generate the land use data at 4-km resolution for input to the 4-km sub-regional CALMET run.

Three years of MM5 data (2001-2003) were used by VISTAS to generate the 4-km sub-regional meteorological datasets. See Sections 4.3.2 and 4.4.2 in the VISTAS common BART modeling protocol for more detail on these issues.

It is intended that all of the modeling for Plant Bowen will use the 4-km subdomain 4. However, if the results indicate that the modeling could be improved with a CALPUFF run using a finer grid, then refinements in the modeling procedures will be considered and the Georgia Environmental Protection Division will be asked to approve these refinements.

In the event that a finer grid resolution is used, CALMET must be rerun. Other modifications to inputs of CALMET would include the extent of the modeling domain, the resolution of the terrain and land use data, and other relevant settings. The same MM5 data and observations as used for the 4-km sub-regional CALMET simulations would be used. The extent of the modeling domain may need to be changed because of disk space restrictions. The size of the CALMET output is directly proportional to the grid resolution of the run. The domain would be limited to the source and the exclusive Class I area(s) being assessed with a higher grid resolution, including a 50-km buffer in all directions.

If CALMET needs to be run at even a finer grid resolution, then the appropriate model setting/files (specifically the GEO.DAT file) will be modified. A summary of these modifications would be provided to the Georgia Environmental Protection Division for review and approval.

3.2 Air quality database (background ozone and ammonia)

Hourly measurements of ozone from all non-urban monitors, as generated by VISTAS and available on the VISTAS CALPUFF page on the Earth Tech web site (http://www.src.com/verio/download/sample_files.htm), will be used as input to CALPUFF. For ammonia, a 0.5 ppb background value as recommended by VISTAS will be used. However, since only PM emissions are being modeled, ozone and ammonia data is not really needed given that this data has no effect on PM results in CALPUFF.

3.3 Natural conditions and monthly f(RH) at Class I Areas

For each of the applicable Class I areas, natural background conditions must be established in order to determine a change in natural conditions related to a source's emissions. The modeling described by this protocol document intends to use annual average natural background light extinction (EPA 2003 values).

To determine the input to CALPUFF, it is first necessary to convert the deciviews to extinction using the equation:

Extinction (Mm^{-1}) = 10 exp(deciviews/10).

For example, the EPA guidance document indicates for Great Smoky Mountains National Park that the deciview value for the average of the days is 7.60. This is equivalent to an extinction of 21.38 inverse megameters (Mm^{-1}).

This extinction includes the default 10 Mm-1 for Rayleigh scattering. The remaining extinction is due to naturally occurring particles, and should be held constant for the entire year's simulation. Therefore, the data provided to CALPOST for Great Smoky Mountains would be the total natural background extinction minus 10 (expressed in Mm^{-1}), or 11.38. This is most easily input as fine soil concentrations (11.38 $\mu g/m^3$) in CALPOST, since the extinction efficiency of soil (PM-fine) is 1.0 and there is no f(RH) component. The concentration entries for all other particle constituents would be set to zero, and the fine soil concentration would be kept the same for each month of the year. The monthly values for f(RH) that CALPOST needs will be taken from "Guidance for Tracking Progress Under the Regional Haze Rule" (EPA, 2003) Appendix A, Table A-3.

4.0 Air quality modeling procedures

This section provides a summary of the modeling procedures outlined in the VISTAS protocol that will be used for the refined CALPUFF analysis to be conducted for Plant Bowen.

4.1 Model selection and features

As noted in the VISTAS protocol (Summary, Recommendations Section II.), VISTAS will use CALPUFF Version 5.754 and CALMET Version 5.7, which can be obtained at http://www.src.com/verio/download/download.htm#VISTAS_VERSION. These versions contain enhancements funded by the Minerals Management Service (MMS) and VISTAS. They are maintained on TRC's Atmospheric Studies Group CALPUFF website for public access. This release includes CALMET, CALPUFF, CALPOST, CALSUM, and POSTUTIL as well as CALVIEW.

The major features of the CALPUFF modeling system, including those of CALMET and the post processors (CALPOST and POSTUTIL), are referenced in Section 3 of the VISTAS protocol.

The baseline BART modeling will be conducted for Bowen Units 1 thru 4 (BART eligible units) for each Class I area within 300 km of the source. Unit 1 thru 4 will each be modeled separately for the visibility improvement modeling for the BART determination step for the Class I areas where baseline modeling shows a greater than 0.5 deciview impact.

4.2 Modeling domain and receptors

The initial Plant Bowen BART runs will use the sub-domain 4, 4-km CALMET data supplied by VISTAS, as discussed above. This domain includes all Class I areas within 300 km of the source, plus a 50-km buffer. If there is the need for a refined analysis with a finer grid, a supplement to this modeling protocol will be provided describing the proposed procedures.

The receptors used for each of the Class I areas are based on the NPS database of Class I receptors, as recommended by the VISTAS common protocol (Section 4.3.3).

4.3 Technical options used in the modeling

CALMET modeling for the VISTAS-provided 4-km subdomains will be performed per the procedures specified in the VISTAS common BART modeling protocol. If it is decided to conduct additional modeling with a finer grid than 4 km, this modeling protocol will be updated to specify the technical options to be used in the CALMET run, in order to allow for state agency review and approval.

For CALPUFF model options, Plant Bowen will follow the VISTAS common BART modeling protocol (Section 4.4.1), which states that we should use IWAQM (EPA, 1998) guidance. The VISTAS protocol (Section 4.3.3) also notes that building downwash effects are not required to be included unless the state directs the source to include these effects. Since Plant Bowen is more than 50 km from the nearest Class I area, building downwash effects will not be included in the CALPUFF modeling.

The POSTUTIL utility program (VISTAS common protocol Section 4.4.2) will be used to repartition HNO_3 and NO_3 using VISTAS-provided ammonia concentrations derived from previous 2002 CMAQ modeling conducted by EPA or the alternate ammonia concentrations approach recommended by VISTAS, if the CMAQ data is unavailable. As indicated earlier, since only PM emissions are being modeled, the treatment of ammonia should not have an affect on PM results from CALPUFF.

4.4 Light extinction and haze impact calculations

The CALPOST postprocessor will be used as prescribed in the VISTAS protocol for the calculation of the impact from the modeled source's primary and secondary particulate matter concentrations on light extinction. The formula that is currently used in CALPOST is the existing (not the November 2005 revised) IMPROVE/EPA formula, which is applied to determine a change in light extinction due to increases in the particulate matter component concentrations. Using the notation of CALPOST, the formula is the following:

b_{ext} = 3 f(RH) [$(NH_4)2SO_4$] + 3 f(RH) [NH_4NO_3] + 4[OC] + 1[Soil] + 0.6[Coarse Mass] + 10[EC] + b_{Ray}

The concentrations, in square brackets, are in ug/m^3 and b_{ext} is in units of Mm^{-1}. The Rayleigh scattering term (b_{Ray}) has a default value of 10 Mm^{-1}, as recommended in EPA guidance for tracking reasonable progress (EPA, 2003a).

The extinction formula shown above is known to be inadequate in its representation of light extinction from sea salt and its usage of 1.4 as the organic mass to carbon mass ratio. Furthermore, guidance for this formula did not provide for site-specific Rayleigh scattering. In December of 2005, the IMPROVE Steering Committee adopted a new formula for determining light extinction that addresses these and other shortcomings. The new formula is shown below..

$$
\begin{aligned}
b_{ext} \approx\ & 2.2 \times f_S(RH) \times [Small\ Sulfate] + 4.8 \times f_L(RH) \times [Large\ Sulfate] \\
& + 2.4 \times f_S(RH) \times [Small\ Nitrate] + 5.1 \times f_L(RH) \times [Large\ Nitrate] \\
& + 2.8 \times [Small\ Organic\ Mass] + 6.1 \times [Large\ Organic\ Mass] \\
& + 10 \times [Elemental\ Carbon] \\
& + 1 \times [Fine\ Soil] \\
& + 1.7 \times f_{SS}(RH) \times [Sea\ Salt] \\
& + 0.6 \times [Course\ Mass] \\
& + Rayleigh\ Scattering\ (Site\ Specific) \\
& + 0.33 \times [NO_2\ (ppb)]
\end{aligned}
$$

The apportionment of the total concentration of sulfate compounds into the concentrations of the small and large size fractions is accomplished using the following equations.

$$[Large\ Sulfate] = \frac{[Total\ Sulfate]}{20\mu g/m^3} \times [Total\ Sulfate], \quad [Total\ Sulfate] < 20\mu g/m^3$$

$$[Large\ Sulfate] = [Total\ Sulfate], \quad [Total\ Sulfate] \geq 20\mu g/m^3$$

$$[Small\ Sulfate] = [Total\ Sulfate] - [Large\ Sulfate]$$

This revised version of the IMPROVE Equation will be used to calculate visibility improvement results for the BART determination modeling. Dr. Ivar Tombach (VISTAS consultant) has produced a spreadsheet tool (September 29, 2006) to allow the new IMPROVE formula results to be derived from the basic CALPOST outputs. Also, since the BART determination modeling is focused only on PM, NO_2 will be set to zero in the new formula. For informational purposes only, results from the old equation will also be presented.

The assessment of visibility impacts at the Class I areas will use CALPOST Method 6 (VISTAS common protocol Section 4.3.2). Each hour's source-caused extinction is calculated by first using the hygroscopic components of the source-caused concentrations, due to ammonium sulfate and nitrate, and monthly Class I area-specific f(RH) values. The contribution to the total source-caused extinction from ammonium sulfate and nitrate is then added to the other, non-hygroscopic components of the particulate concentration (from coarse and fine soil, secondary organic aerosols, and from elemental carbon) to yield the total hourly source-caused extinction.

The BART rule significance threshold for the contribution to visibility impairment is 0.5 deciviews. The VISTAS protocol (Section 4.3.2) indicates that with the use of the 4-km sub-regional CALMET database, a source does not cause or contribute to visibility impairment if the 98th percentile (or 8th highest) day's change in extinction from natural conditions does not exceed 0.5 deciviews for any of the modeled years (an added check is: the 22nd highest prediction over the three years modeled should also not exceed 0.5 deciviews for a source to be exempted from a BART determination). Both the 98th percentile (or 8th highest) day's change in extinction from natural conditions for any modeled year and the 22nd highest prediction over the three years modeled will be evaluated.

Figure 4-1 of the VISTAS common BART modeling protocol presents a flow chart showing the components of that common protocol. The modeling for Plant Bowen will focus on Subregional Fine-Scale modeling as depicted in the lower half of the figure.

The source will perform BART determination modeling for the baseline and each control option in the manner described in this document.

5.0 Presentation of modeling results

The BART determination modeling results for Plant Bowen will be provided to the state agency in a manner as described in the VISTAS protocol (Section 4.5). The results will include the following elements (as suggested in the VISTAS protocol):

1. A map of the source location and Class I areas within 300 km of the source.

2. For the CALPUFF modeling domain, a table listing all Class I areas in the VISTAS domain and those in neighboring states and impacts from the BART 4-km grid baseline modeling at those Class I areas within 300 km of the source, as illustrated in Table 4-3 of the VISTAS protocol.

3. Identify from the baseline modeling the number of Class I areas with visibility impairment due to source emissions for the 98th percentile days in each year (and the 98th percentile over all three years modeled) greater than 0.5 dv.

4. For the Class I area with the maximum impact, identification of the number of days beyond those excluded (e.g., the 98th percentile for refined analyses) that the impact of the source exceeds 0.5 dv, the number of receptors in the Class I area where the impact exceeds 0.5 dv, and the maximum impact.

The BART determination modeling will be performed for those Class I areas shown in the baseline modeling to exceed 0.5 dv impact. The results presented will be a comparison of the 98^{th} percentile value for the baseline and each control option and emissions unit derived as is outlined above for the baseline modeling. A summary of the relative results among all emission scenarios run would be produced.

Additionally, the appropriate electronic files used to conduct the CALPUFF modeling will be submitted on CD-ROM or DVD media.

Appendix A

Basis for Source-Specific Sulfuric Acid Emissions

Appendix A

Basis for Source-Specific Sulfuric Acid Emissions

Sulfuric Acid (H2SO4) Emissions

During the combustion of sulfur-containing fuels, a percentage of the SO_2 formed is further oxidized to SO_3. As the flue gas cools across the air heater, this SO_3 combines with flue gas moisture to form vapor-phase and/or condensed sulfuric acid (H_2SO_4). The H_2SO_4 emissions shown in Table 2-1 of this BART modeling protocol were calculated consistent with the method used by Southern Company to derive these emissions for Toxics Release Inventory (TRI) purposes. This method is documented in a report titled Estimating Total Sulfuric Acid Emissions from Stationary Power Plants: Revision 3 (2005) prepared by Keith Harrison and Dr. Larry Monroe (Southern Company Services) and Edward Cichanowicz (Consultant). The approach described in this report assumes that H_2SO_4 emissions released from the stack are proportional to SO_2 emissions from combustion and are dependent on the fuel type and the removal of H_2SO_4 by downstream equipment (i.e., ESP and air heater) and add-on emissions control equipment (scrubber).

Since this facility contains post-combustion NOx control (SCR), the baseline sulfuric acid emissions estimate accounts for the manufacture of H_2SO_4 through combustion and through further oxidation of SO_2 in the SCR. Calculated sulfuric acid releases then account for loss or removal within the system. The equations below show how the manufacture and release calculations are made. Table A-1 shows the resulting H_2SO_4 emissions calculations .

Sulfuric Acid Manufactured from Combustion (EMComb):
EMComb = K x F1 x E2
where,
EMComb = total sulfuric acid manufactured from combustion, lbs/yr
K = Molecular weight and units conversion constant = 98.07 / 64.04 * 2000 = 3,063
(98.07 = Molecular weight of sulfuric acid; 64.04 = Molecular weight of SO2; Conversion from tons per year to pounds per year – multiply by 2000.)
F1 = Fuel Impact Factor (from the emissions estimating report)
E2 = Sulfur dioxide emissions, tons (from CEMS data).

Sulfuric Acid Released from Combustion (ERComb)
ERComb = EMComb x F2 (technology impact factors for air heater and ESP)
ERComb = EMComb x (0.49) x (0.49)

Sulfuric Acid Manufactured by SCR (EMSCR)
EMSCR = K * S2 * fs * E2
where,
EMSCR = Total sulfuric acid manufactured from SCR, lbs per year
K = Conversion factor = 3063
S2 = SCR catalyst SO2 oxidation rate (specified as a decimal)
fs = Operating factor of SCR system, fraction of coal burn when SCR operates
E2 = SO2 produced, tons per year

Sulfuric Acid Released from SCR (ERSCR)
ERSCR = [EMSCR – (Ks * B * fs * SNH3)] * F2x
where,
ERSCR = Total sulfuric acid released from SCR, lbs per year
EMSCR = Total sulfuric acid manufactured from SCR, lbs per year
Ks = Conversion factor = 3799
B = Coal burn in TBtu/hr

fs = Operating factor of SCR system, fraction of coal burn when SCR operates
SNH3 = NH3 slip from SCR, ppmv at 3% O2
F2x = Technology Impact Factors, all that apply

Sulfuric Acid Manufactured from Flue Gas Conditioning (EMfgc):
EMfgc = Ke x B x fe x Is
where,
EMfgc = total sulfuric acid manufactured from flue gas conditioning system, lbs/hr
Ke = Conversion Factor = 3,799
B = Coal burn in TBtu/hr
fe = Operating factor of FGC system, fraction of coal burned when FGC operates
Is =SO3 injection rate in ppmv at 6% O2, wet

Sulfuric Acid Released from FGC (ERfgc)
ERfgc = [EMfgc – (Ke * B * fe * I_{NH3})] * F3 x F2
where,
ERfgc = Total sulfuric acid released from FGC, lbs per hour
EMfgc = Total sulfuric acid manufactured from FGC, lbs per hour
Ke = Conversion factor = 3799
B = Coal burn in TBtu/hr
fe = Operating factor of FGC system, fraction of coal burn when FGC operates
I_{NH3} = NH3 injection for dual flue gas conditioning system, ppmv at 6% O2, wet (= 0 if no NH3 used)
F3 = Technology Impact Factors for FGC
F2 = Technology Impact Factors for equipment after ESP only
If no control after ESP, F2 = 1

Total Sulfuric Acid Released (TSAR):
TSAR = ERComb + ERSCR + ERfgc[Bowen 3 and 4 only]

Table A-1 Plant Bowen sulfuric acid calculations

Case		Source / Unit	SO2	Conv. Factor	Fuel Impact Factor	Manuf from Combut.	APH Factor	ESP Factor	Released From Combust.	SCR Oxid. Rate	SCR Op. Factor	Manuf by SCR	Coal Burn, B	Conv. Factor	NH3 Slip	Releas. from SCR
			lbs/hr	K	F1	lbs/hr	F2	F2	lbs/hr	S2	fs	lbs/hr	TBtu/hr	Ks	SNH3	lbs/hr
EC	NS	Unit 1	17069.4	3063	0.008	209.1	0.49	0.49	50.2	0.0075	0	0.0	0.00684	3799	0.75	0.0
EC	S	Unit 1	15374.2	3063	0.008	188.4	0.49	0.49	45.2	0.0075	1	176.6	0.00684	3799	0.75	37.7
Baseline	S	Unit 1	15374.2	3063	0.008	188.4	0.49	0.49	45.2	0.0075	1	176.6	0.00684	3799	0.75	37.7
EC	NS	Unit 2	17247.6	3063	0.008	211.3	0.49	0.49	50.7	0.0075	0	0.0	0.00669	3799	0.75	0.0
EC	S	Unit 2	16059.4	3063	0.008	196.8	0.49	0.49	47.2	0.0075	1	184.5	0.00669	3799	0.75	39.7
Baseline	S	Unit 2	16059.4	3063	0.008	196.8	0.49	0.49	47.2	0.0075	1	184.5	0.00669	3799	0.75	39.7
EC	NS	Unit 3	20652.4	3063	0.008	253.0	0.49	0.49	60.8	0.0075	0	0.0	0.00772	3799	0.75	0.0
EC	S	Unit 3	18519.4	3063	0.008	226.9	0.49	0.49	54.5	0.0075	1	212.7	0.00772	3799	0.75	45.8
Baseline	S	Unit 3	18519.4	3063	0.008	226.9	0.49	0.49	54.5	0.0075	1	212.7	0.00772	3799	0.75	45.8
EC	NS	Unit 4	20097.2	3063	0.008	246.2	0.49	0.49	59.1	0.0075	0	0.0	0.00843	3799	0.75	0.0
EC	S	Unit 4	19504.1	3063	0.008	239.0	0.49	0.49	57.4	0.0075	1	224.0	0.00843	3799	0.75	48.0
Baseline	S	Unit 4	19504.1	3063	0.008	239.0	0.49	0.49	57.4	0.0075	1	224.0	0.00843	3799	0.75	48.0

EC= Existing Configuration (i.e., no scrubber) Baseline=Scrubbed NS = No SCR Operation S= SCR Operation

Case		Source / Unit	Conv. Factor	FGC Op. Factor	SO3 Injection Rate	Manuf by FGC	Tech Impact Factor for FGC	Tech Impact Factor for Equip after ESP	NH3 Injection Rate	Released From FGC	Total Released without Scrubber	Removal Rate for Scrubber	Total Released after Scrubber
			Ke	fe	Is	lbs/hr	F3	F2	I_{NH3}	lbs/hr	lbs/hr	%	lbs/hr
EC	NS	Unit 1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	50.2		
EC	S	Unit 1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	83.0		
Baseline	S	Unit 1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	83.0	40	49.8
EC	NS	Unit 2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	50.7		
EC	S	Unit 2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	87.0		
Baseline	S	Unit 2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	87.0	40	52.2
EC	NS	Unit 3	3799	1.0	7.0	205.2	0.25	1.0	0.0	51.3	112.1		
EC	S	Unit 3	3799	1.0	7.0	205.5	0.25	1.0	0.0	51.3	151.6		
Baseline	S	Unit 3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	100.3	40	60.2
EC	NS	Unit 4	3799	1.0	7.0	224.3	0.25	1.0	0.0	56.1	115.2		
EC	S	Unit 4	3799	1.0	7.0	224.3	0.25	1.0	0.0	56.1	161.5		
Baseline	S	Unit 4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	105.4	40	63.2

EC= Existing Configuration (i.e., no scrubber) Baseline=Scrubbed NS = No SCR Operation S= SCR Operation

Appendix B

Estimated Emissions of Primary Total Carbon and Primary Sulfate From Coal-Fired Power Plants

[The above titled paper is included as a separate document along with this site specific BART modeling protocol. This paper was prepared for Southern Company by Eric S. Edgerton of Atmospheric Research & Analysis, Inc.]

Estimated Emissions of Condensable Carbon and Condensable SO_3 From Coal-Fired Power Plants

Prepared for

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June 11, 2006

ABSTRACT

Data from the SEARCH network were used to estimate condensable carbon and condensable SO_3 emissions from coal-fired power plants (CFPPs). Continuous trace gas and $PM_{2.5}$ measurements were used to identify CFPP plumes and to quantify incremental fine particulate total carbon (TC) and fine particulate total sulfate (SO_4) during the period October 2005-May 2006. As measured in the field, incremental TC includes emitted particulate OC, particulate EC and condensable carbon as well as secondary organic aerosol (SOA). Incremental SO_4 includes emitted particulate SO_4, condensable SO_3, and secondary SO_4. As such, TC and SO_4 provide upper bounds for CFPP emissions of condensable carbon and condensable SO_3. Plume events were selected so as to avoid confounding of TC and SO_4 signals by other sources, and to minimize in-plume production of secondary SO_4 and SOA. Results are presented as ratios relative to SO_2, for example, pounds TC per pound SO_2 (lb TC/lb SO_2,). Plume increments can be interpreted as emission ratios for TC and primary SO_4. For TC, 14 plume events from 4 sites and 7 CFPPs exhibited sufficiently stable data for analysis. Of these, 11 events yielded an average TC/SO_2 emission ratio of 3.2 x 10^{-3} lb/lb (range 1.1 x 10^{-3} to 6.6 x 10^{-3}). In other words, TC emissions represented about 0.32 percent of SO_2 emissions, on a mass basis. The 3 remaining events yielded negative emission ratios using the default approach, and an average emission ratio of 1.5 x 10^{-3} using an alternate approach. For SO_4, a total of 20 events from 4 sites and 8 CFPPs were analyzed. Results showed an average SO_4/SO_2 emission ratio of 6.4 x 10^{-3} lb/lb (range 2.1 x 10^{-3} to 15.0 x 10^{-3}). On average, SO_4 was found to represent about 0.64 percent of SO_2 emissions during the study period. Inferred emission ratios should be considered upper bound estimates because: 1) the measurements include, in addition to the condensable

carbon and condensable SO_3 emissions of interest, primary particulate carbon (EC and OC) and primary particulate sulfate emitted by the CFPP; 2) may include secondary carbon and secondary sulfate produced in the atmosphere; and 3) could be inflated due to preferential loss of SO_2 from the plume (due to conversion and/or dry deposition) in transit from the CFPP to the research site.

INTRODUCTION

The Southeastern Aerosol Research and Characterization Study (SEARCH) was designed to provide extensive, long-term data on the sources and chemical characteristics of $PM_{2.5}$ and PM_{coarse} for the southeastern U. S. SEARCH is unique in that continuous $PM_{2.5}$ measurements of all major components are made at urban/rural pairs of sites in and around four southeastern U. S. cities. In conjunction with co-measured meteorological and trace gas data, continuous $PM_{2.5}$ measurements provide opportunities for: (1) investigating sources and physico-chemical dynamics of $PM_{2.5}$; (2) evaluating chemical transport and transformation models; (3) assessing the effectiveness of emissions reduction programs; and (4) examining relationships between PM mass and composition and various health end points.

CFPPs emit three forms of primary particulate carbon to the atmosphere: filterable organic carbon (OC), filterable elemental carbon (EC) and condensable carbon. OC and EC are emitted as particles, while condensable carbon is emitted in the vapor phase and is presumed to condense rapidly onto pre-existing particles. These three forms of carbon, plus secondary organic aerosol

(SOA), are measured collectively in the SEARCH network, as total carbon (TC), using continuous measurement techniques. CFPPs also emit two forms of primary particulate sulfate: filterable sulfate and condensable sulfur trioxide (SO_3). In the atmosphere, condensable SO_3 reacts more or less instantaneously with water vapor to produce particulate sulfate. These forms of sulfate, plus secondary sulfate from oxidation of SO_2, are also measured in the SEARCH network using continuous techniques.

This report uses SEARCH data to: (1) identify CFPP plumes observed at numerous sites during the fall of 2005 through spring of 2006; and, (2) calculate total carbon (TC) and total sulfate (SO_4) associated with such plumes. Results are used to estimate CFPP emission ratios of TC and SO_4, relative to SO_2. Given that the measurement techniques do not discriminate between the various form of particulate carbon and particulate sulfate present in the plume, results can be used as upper bound estimates of emission ratios for condensable carbon and condensable SO_3.

EXPERIMENTAL

Continuous measurements of trace gases fine particulate TC and fine particulate SO_4 were made at the Southeastern Aerosol Research and Characterization (SEARCH) sites shown in Figure 1. Analyzable plume events were observed at 5 of the 8 SEARCH sites between early October 2005 and early May 2006: Yorkville, GA; Jefferson Street, GA; Centreville, AL; OLF, FL; and Gulfport, MS. Brief descriptions for these 5 sites are provided below.

Yorkville, GA - Yorkville (lat. 33.9283 N, long. 85.0456 W) is a rural/agricultural site 55 km WNW and 40 km SSW of Atlanta, GA and Rome, GA, respectively. The site is on a broad ridge (elev. 395 m) in a large (>150 ha) clearing devoted largely to pasture. CFPPs in the vicinity of Yorkville are shown in Figure 2.

Centreville, AL – Centreville (lat. 32.9029 N, long. 87.2497 W) is located on private property in rural Bibb County, approximately 85 km SSW of Birmingham, AL. The surrounding area includes the Talladega National Forest and is heavily wooded with mixed deciduous (oak-hickory) and loblolly pine. CFPPs in the vicinity of Centreville are shown in Figure 2.

Jefferson Street (Atlanta), GA - Jefferson Street (lat. 33.7775 N, long. 84.4167 W) is an urban/industrial-residential site 4.5 kilometers NW of downtown Atlanta, GA. The site is located at 829 Jefferson Street NW, on Georgia Power Company property in a 70m by 125m grass-covered clearing on a knoll 15 meters above street level. CFPPs in the vicinity of Jefferson Street are shown in Figure 3.

Outlying Landing Field #8 (OLF), FL - OLF (lat. 30.5496 N, long. 87.3734 W) is a suburban site 21 km NW of downtown Pensacola, FL and 20 km N of the Gulf of Mexico. The site is adjacent to a paved, lightly traveled (< 200 vehicles/day) road on the northern edge of a large (>500 ha) grass-covered field. CFPPs in the vicinity of OLF are shown in Figure 3.

<u>Gulfport, MS</u> – Gulfport (lat. 30.3901 N, long. 89.0498 W) is located 1.5 km from the Gulf of Mexico on the premises of the Harrison County Youth Court at 47 Maples Ave. The area is covered with sparse forest and grass, with single family homes to the east, an elementary school to the north and athletic fields to the south. CFPPs in the vicinity of OLF are shown in Figure 3.

Continuous Trace Gas and Particle Measurements

SO_2, NO_y and CO are measured at each site and used to: 1) screen for periods of influence from point sources (specifically CFPPs) and non-point sources; 2) identify specific CFPPs based on SO_2:NO_y ratios; and 3) calculate TC/SO_2 and SO_4/SO_2 ratios. Continuous (1-minute average) measurements were made at a reference height of 10 m above ground level. Sample air is pulled through a weather-proof inlet box and then into the equipment shelter via ¼" o.d. heavy wall PFA Teflon tubing. The inlet box contains catalytic converters (for NOy), solenoids and plumbing for introduction of zero air and calibrant gases. Calibration gases (+/- 1% for CO and NO and +/- 2% for SO_2) were supplied by Scott-Marrin, Inc. (Riverside, CA).

SO_2 is measured via pulsed UV fluorescence with a TEI Model 43ctl analyzer operated on a 0-200 ppb scale. The instrument is calibrated every third day by gas replacement and zeroed 10 out of every 90 minutes by diverting sample air through a sodium carbonate impregnated annular denuder (URG, Carrboro, NC). The analyzer is also subjected to weekly multipoint gas replacement calibrations (GRC).

CO is measured via gas filter correlation with non-dispersive infrared detection using a TEI Model 48ctl analyzer operated on a 0-3000 ppb scale (0-10,000 ppb at JST). The analyzer is calibrated and zeroed on the same schedule as the SO2 analyzer. Zeroing is performed by diverting the sample stream through a heated (50-100C) trap containing approximately 200 grams of 1% Pt on alumina (DeGussa, Seviersville, TN).

NO_y is measured via ozone-NO chemiluminescence following reduction to NO on a 350 ºC Mo catalytic converter, using a dual-channel TEI Model ctl NO-NO_x analyzer operated on a 0-200 ppb scale. The analyzer is zeroed four times per day and calibrated every third day via gas replacement. Converter efficiency is checked once a week with n-propyl nitrate.

SO_4 is measured continuously using a variation of the Harvard School of Public Health (HSPH) approach. This method uses a 1000 °C inconel steel tube to reduce particulate SO4 to sulfur dioxide (SO_2). The SO_2 is then detected using a Thermo-Environmental Instruments (TEI, Franklin, MA) Model 43S or 43Ctl high sensitivity, pulsed ultra-violet fluorescence SO_2 analyzer. Sample air is pulled through a 2.5 μm sharp-cut cyclone inlet (BGI, Atlanta, GA), then through two 30 mm o.d., 254 mm long sodium carbonate and citric acid coated annular denuders (URG, Carrboro, NC) followed by a 30 mm o.d., 100 mm long carbon honeycomb denuder (MAST Carbon Ltd., Surrey, UK). The denuders effectively remove a wide range of interferents, including SO_2, reduced sulfur gases, nitrogen oxides and volatile organic compounds. Sample air then passes through a 300 mm section of inconel tubing heated to 1000 °C in a Lindberg/Blue M horizontal tube furnace. Every 90 minutes, the system is zeroed for 10 minutes by diverting sample air through an inline filter upstream of the converter. The SO_2 analyzer is subjected to manual and automated gas replacement audits on a weekly schedule.

Total carbon (TC) is measured continuously with a Sunset Laboratory Model RT-OCEC Aerosol Carbon Analyzer. This device operates on an hourly cycle, with 47 minutes devoted to sample collection and 13 minutes devoted to sample analysis. In sample mode, ambient air is pulled through an activated carbon monolith denuder (Novacarb™, Mast Carbon Ltd., UK) at a flow rate of 8.5 lpm, then through dual quartz fiber filters. In analysis mode, the filters are heated through several temperature plateaus to a final temperature of 900 ºC. CO_2 produced during the heating cycle is quantified with a non-dispersive infra-red (NDIR) detector and TC is calculated based on CO_2 produced and sample volume. The TC analyzer is automatically calibrated with 5% methane in helium after every analysis cycle.

Trajectory Calculations

Twenty-four hour back trajectories are generated using the interactive version of the NOAA HYSPLIT4 model on the NOAA-ARL web site (*12*). Back trajectories use EDAS 40 km meteorological data and default vertical motion, with starting heights of 1000 m, 500 m and 250 m, for the time (hour) of peak SO_2 concentration during each event. The 250 m trajectory is used to determine which CFPP affected the site, as well as time of emission at the CFPP.

Event Selection and Data Reduction

Event selection attempted to identify episodes with minimal contamination from non-CFPP sources. In general, this means that different episodes are used for TC and SO_4 analyses. For TC, we look for clean, well-ventilated conditions during the middle of the day, with low and stable CO concentrations. This avoids rush hour emissions and near-surface sources that tend to accumulate under the nocturnal boundary layer. While some VOC to SOA conversion is possible, the effect should be small during fall and winter because of: 1) low biogenic precursor emissions; and 2) low temperatures; and 3) low solar insolation. For SO_4, in contrast, we are less concerned with contamination from non-CFPP sources, but want to avoid strong sunlight and consequent photochemical production of secondary SO_4 within the plume. Thus, the majority of SO_4 events selected for this analysis occurred either at night or during the early morning hours.

TC emission ratios are calculated using the "ratio of deltas" method, as shown below,

$$ER_{TC} = (TC_{Plume}-TC_{Base})/(SO2_{Plume}-SO2_{Base}) = \Delta TC/\Delta SO_2, \quad \text{(Eq. 1)}$$

where subscripts Plume and Base refer to concentrations measured during the plume event and before or after the event, respectively. The technique is illustrated in Figure 4, which shows an event that occurred at Yorkville on April 9, 2006. The upper panel shows SO_2 and CO during the course of the day. Note that the regular gaps in the time series reflect zeroing cycles. SO_2 concentrations were <5 ppb until about 1430 local standard time (LST), when they increased sharply and remained above 40 ppb until about 1630, then fell below 5 ppb for the remainder of the day. CO concentrations were between 80 and 100 ppb for the entire day, indicating no evidence of plumes from biomass burning, transportation and other activities.

The lower panel shows time series for SO_2 (red symbols) and TC (black bars), also for April 9, 2006. In this case, SO_2 concentrations have been averaged to coincide exactly with the 47-minute Sunset collection period. The plume event is shown in the red box and the downward facing arrows indicate the two values used (i.e., averaged) to calculate Base concentration. The symbols and bars at 1500 LST and 1600 LST are averaged to calculate Plume concentration. Base and Plume concentrations are then used to calculate the ratio of deltas, as shown in Equation 1. Note that ΔTC during this event (0.22 $\mu g/m^3$) is quite small compared to the overall range of TC observed during the day, despite the fact that average SO_2 concentrations exceeded 75 ppb for the 47-minute period beginning at 1600 LST. This is typical of CFPP plume events and underscores the fact that CFPPs are minor sources of particulate carbon. In other words, large plumes are needed in order to even "see" an increase in TC. The small increment of TC associated with CFPP events places a high premium on stable TC measurements.

For several CFPP events, ΔTC was negative, indicating that Base concentrations were slightly higher than the Plume concentrations. Based on Equation 1, this implies a physically unrealistic negative ER. For these events, we used the detection limit for the Sunset analyzer (0.1 $\mu g/m^3$) in the numerator of Equation 1.

SO_4 emission ratios are calculated by linear least square regression of 1-minute SO_4 concentrations versus 1-minute SO_2 concentrations. The regression slope is equivalent to the primary SO_4/SO_2 emission ratio and the intercept is equivalent to the baseline SO_4 concentration in absence of the plume. Figure 5 illustrates an example SO_4 event which occurred at Yorkville on February 25, 2006. In the upper panel, SO_2 concentration is < 5 ppb until approximately 0400 (LST), increases to nearly 50 ppb just before 0600, then falls below 5 ppb by 0900. SO_4 concentrations (right hand scale) are < 1 ppb (3.9 $\mu g/m^3$) the entire day, but show several minor excursions, some of which are associated with SO_2 excursions and some of which are not. The lower panel shows the scattergram of SO_4 versus SO_2 and associated regression statistics. Data for the regression correspond to the red box in the upper panel. Results show a highly significant relationship between SO_4 and SO_2 ($p<0.01$) with a regression slope of 0.0042 on a ppb/ppb basis. Given that the molecular weight of SO_4 is 1.5 times that of SO_2, the emission ratio for this event is 0.0063 lb/lb or 0.63 %.

It should be noted that both the ratio of deltas approach and the linear regression approach give upper bound estimates of TC and SO_4. The principal reason for this is dry deposition, which removes gaseous SO_2 from the plume much faster than particles. If we assume dry deposition to be a first order loss process, then the effect is to reduce ΔSO_2 in the denominator of equation 1 and thereby inflate the ratio $\Delta TC/\Delta SO_2$. Another reason is photochemical or non-photochemical production of secondary SO_4 and OC, which would increase SO_4 and, at the same time, decrease SO_2 in the plume. Although events have been carefully selected to minimize these effects, we cannot be certain they have been eliminated completely.

RESULTS

Table 1 summarizes results for 14 TC plume events observed at 4 sites. Data include the site which observed the CFPP plume, the likely source of the plume (based on trajectory analyses and SO_2/NO_y ratios) and concentration data for the ratio of deltas calculation. Mean $\Delta TC/\Delta SO_2$ for 11 events is 0.0032 +/- 0.0014 with a range of 0.0011 to 0.0066. OLF and Yorkville both observed 5 events. At OLF, all 5 events were from the Crist CFPP and these gave an emission ratio of 0.0020 +/- 0.0012 lb/lb. At Yorkville, the plume events likely originated from 3 different CFPPs and these gave an average ratio of 0.0033 +/- 0.0021 lb/lb. These events clearly show that TC is a small and difficult to detect component of CFPP emissions.

Table 2 summarizes results for 20 SO_4 plume events observed at 4 sites and likely originating from 8 different CFPPs. Data include the maximum observed 1-minute SO_2 concentration, plus the regression slope and r-squared for SO_4 vs. SO_2. Calculated values for $\Delta SO_4/\Delta SO_2$ range from 0.0030 to 0.0180 lb/lb with an average of 0.0064 lb/lb. In most cases, the regression is highly significant; however, r-square tends to decrease as slope decreases because instrument noise starts to dominate the SO_4 signal. These events clearly show that SO_4 is a small and difficult to detect component of CFPP emissions.

CONCLUSIONS

Continuous field measurements can be used to derive emission estimates for TC and SO_4 from CFPPs which are upper bound estimates of condensable carbon and condensable SO_3. Careful attention must be paid to plume event selection in order to avoid contamination from non-CFPP sources (TC) and photochemical activity in the CFPP plume (SO_4). Optimal conditions for both TC and SO_4 estimates appear to occur during the cooler months when photochemical activity is low and persistent winds advect relatively fresh CFPP plumes to the research sites. Plume analysis results show that primary TC emissions and primary SO_4 emissions from CFPPs are well below 1% of SO2 on a mass basis. For primary TC, analysis of 14 events from 7 different CFPPs gave an overall average emission ratio of 0.0032 lb TC/lb SO_2 (or 0.32% of SO2. For primary SO_4, analysis of 20 events from 8 different CFPPs gave an overall average emission ratio of 0.0064 lb SO_4/lb SO_2 (or 0.64% of SO_2).

Figure 1. The SEARCH Network

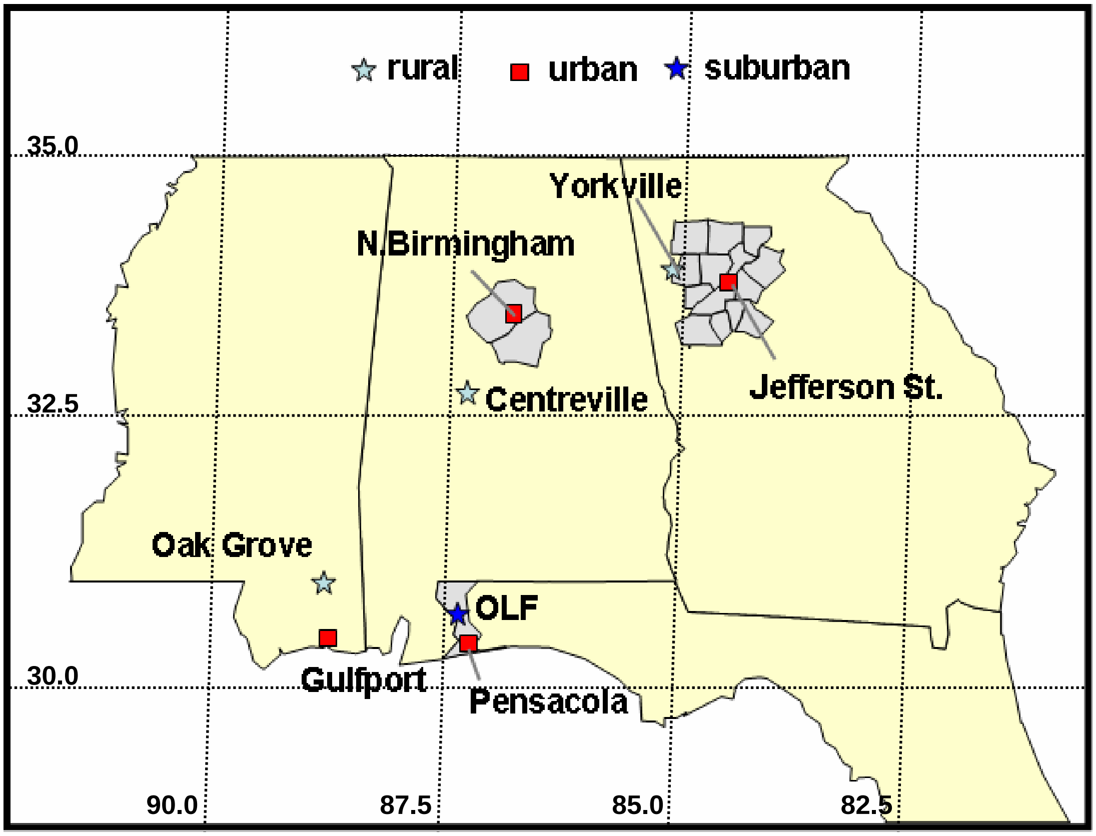


Figure 2. CFPPs observed at YRK (top) and CTR (bottom).

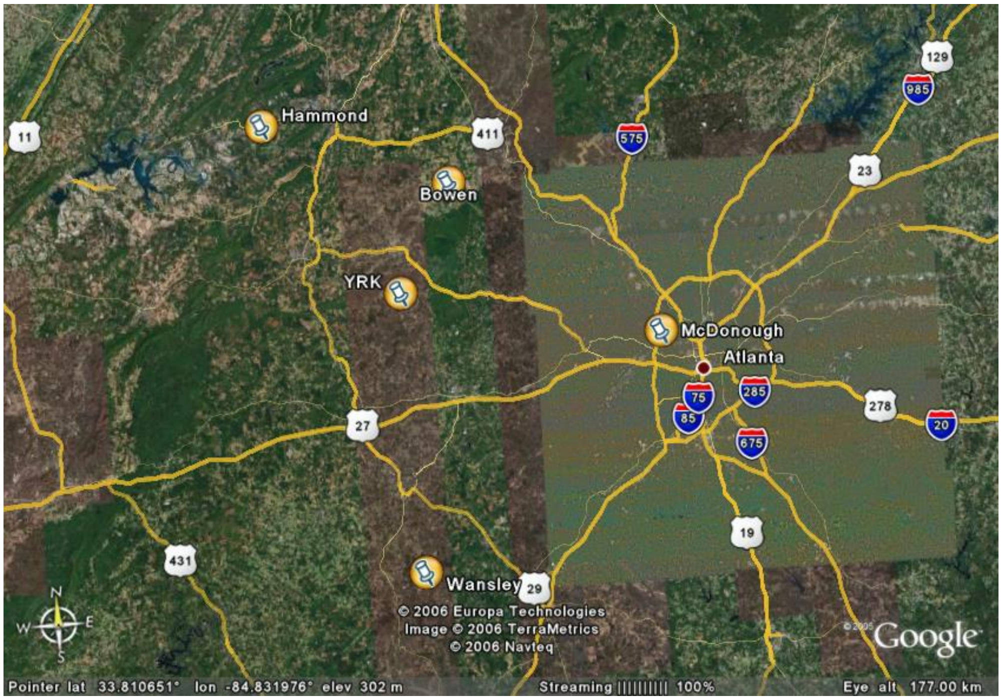


Figure 3. CFPPs observed at JST (top), OLF (middle) and GFP (bottom).

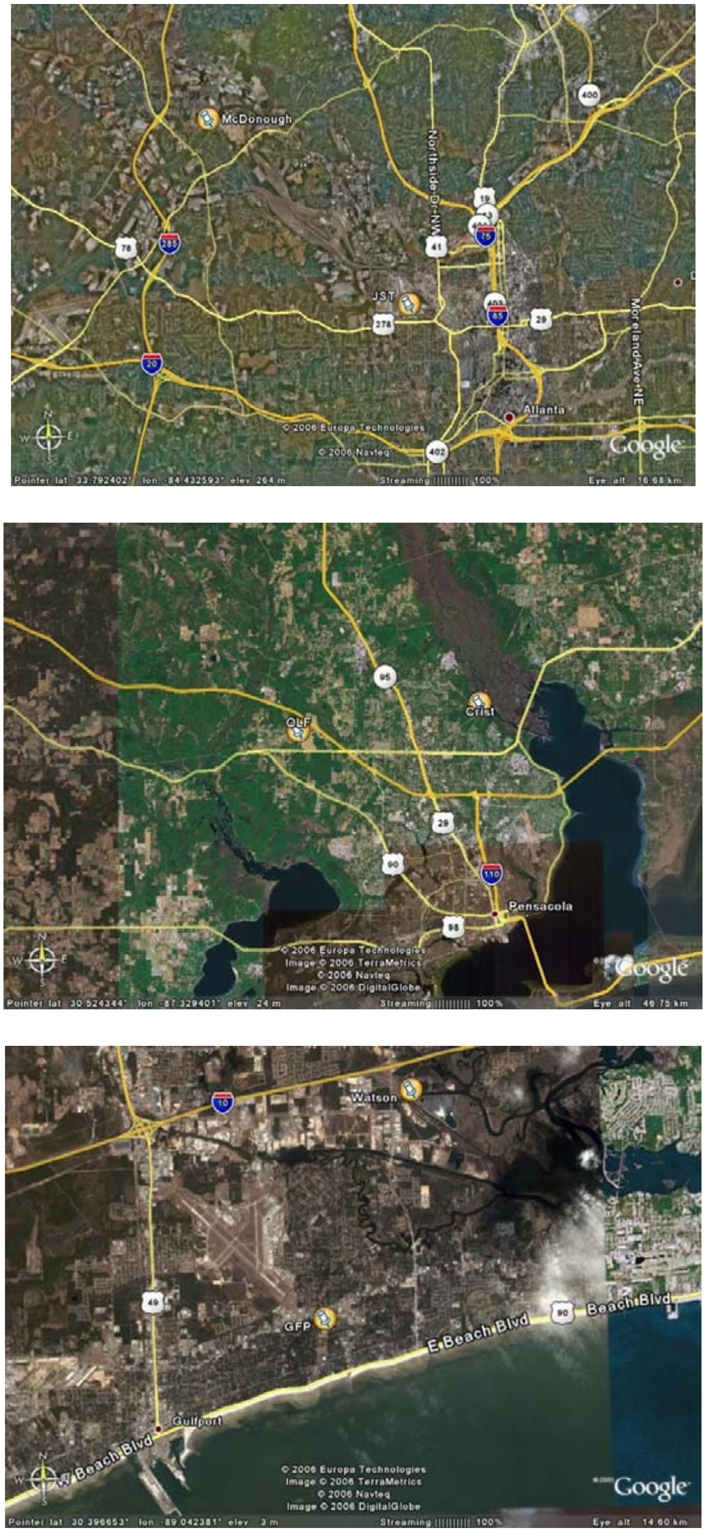
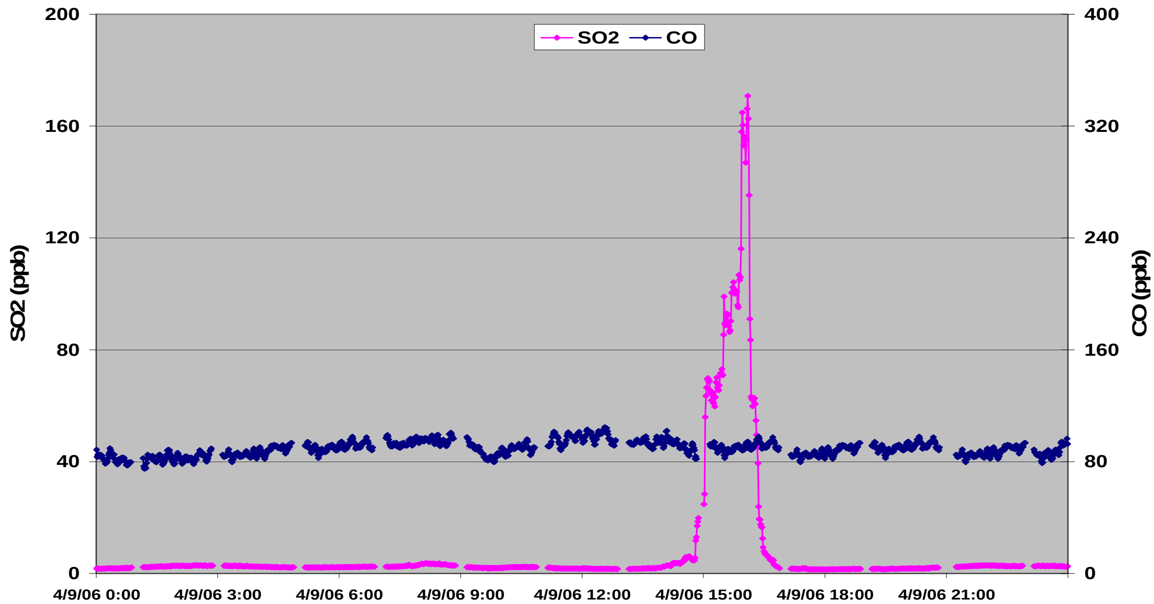


Figure 4. CFPP plume event at YRK showing 1-minute SO_2 and CO (top), 47-minute SO_2 and TC (bottom).



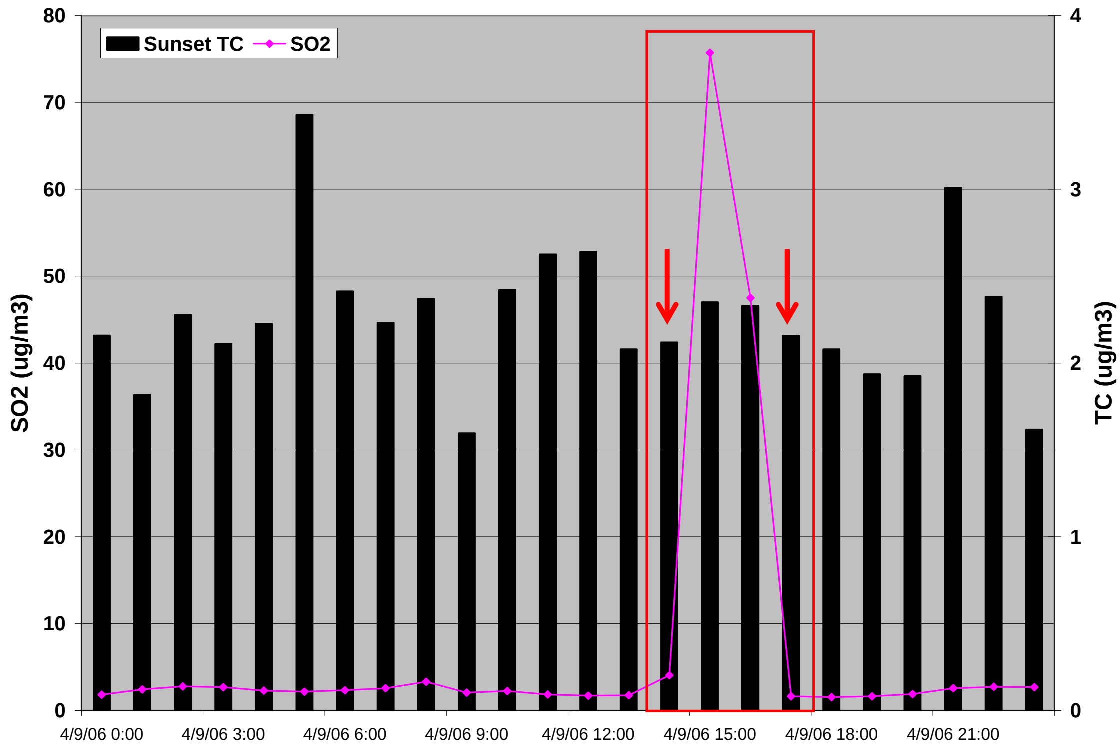
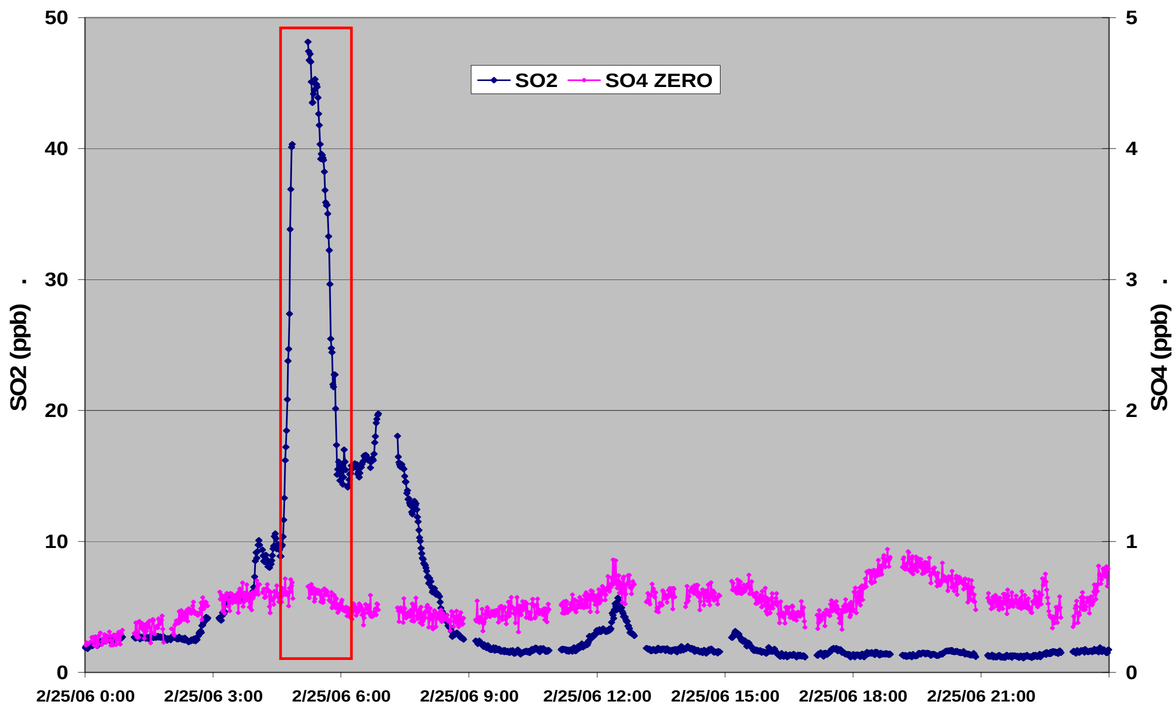


Figure 5. CFPP plume event at YRK showing SO_2 and SO_4 (top) and SO_4 vs. SO_2 (bottom).



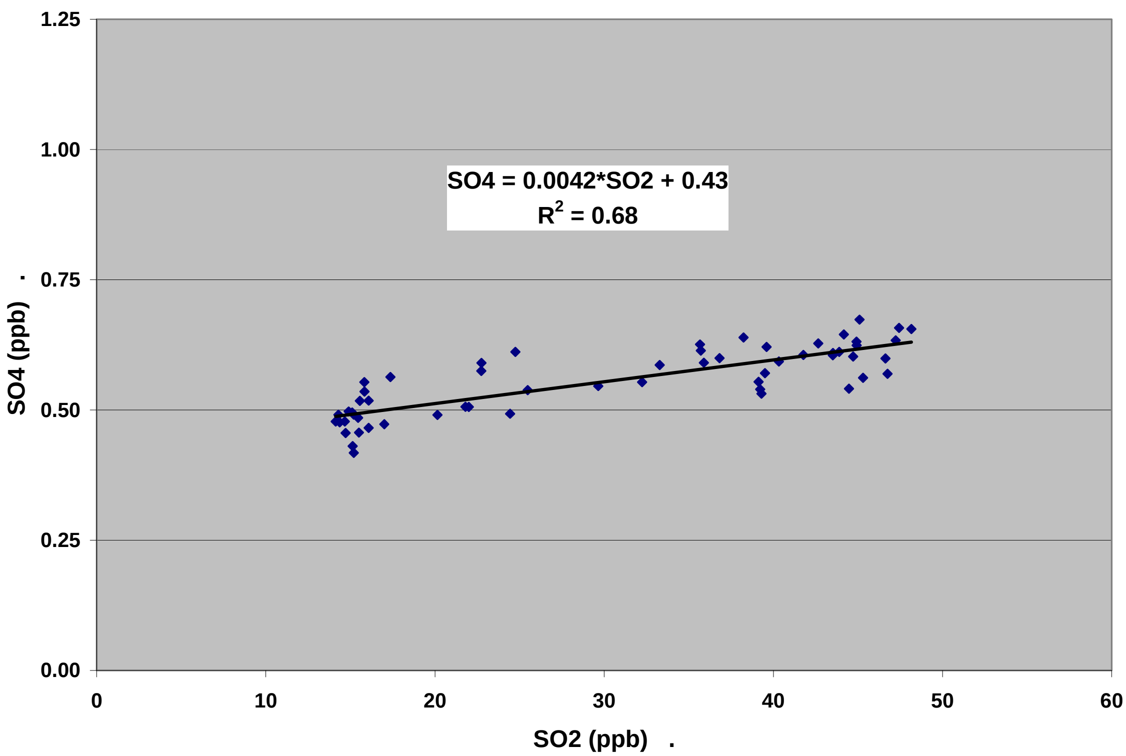


Table 1. Summary of Total Carbon Events.

Site	Date	Probable CFPP	Base SO_2 (ppb)	Plume SO_2 (ppb)	Base TC (µg/m3)	Plume TC (µg/m3)	$\Delta TC/\Delta SO_2$ (lb/lb)	Alternate $\Delta TC/\Delta SO_2$ (lb/lb)
CTR	12/18/05	Gaston	15.6	51.2	2.96	3.30	3.7×10^{-3}	
CTR	12/20/05	Gorgas	15.1	23.1	1.30	1.38	3.8×10^{-3}	
CTR	02/23/06	Miller	5.1	20.6	1.71	1.49	< 0	2.5×10^{-3}
JST	05/06/06	McDonough	3.5	64.5	3.35	3.6	1.6×10^{-3}	
OLF	11/25/05	Crist	11.9	38.9	2.22	2.38	2.3×10^{-3}	
OLF	02/07/06	Crist	4.2	34.6	2.22	2.38	2.0×10^{-3}	
OLF	02/24/06	Crist	11.1	35.0	1.48	1.70	3.5×10^{-3}	
OLF	04/28/06	Crist	4.3	41.2	3.53	3.48	< 0	1.2×10^{-3}
OLF	05/06/06	Crist	3.3	85.3	3.31	3.55	1.1×10^{-3}	
YRK	10/31/05	McDonough	6.3	48.8	2.72	3.45	6.59×10^{-3}	
YRK	02/25/06	Bowen	4.7	39.5	2.24	2.52	3.08×10^{-3}	
YRK	03/04/06	Bowen	5.5	33.4	3.49	3.72	3.15×10^{-3}	
YRK	03/11/06	Wansley	1.8	52.2	4.06	3.87	< 0	7.6×10^{-4}
YRK	04/09/06	Bowen	1.7	61.6	2.12	2.34	3.63×10^{-3}	
Mean (s.d.)							**3.2×10^{-3} (1.4×10^{-3})**	**1.5×10^{-3} (0.9×10^{-3})**

Note: Base and Peak concentrations based on 47-minute averages.

Table 2. Summary of SO_4 Events.

Site	Date	Probable CFPP	1-min Max. SO_2 (ppb)	SO_4 vs. SO_2 Slope	SO_4 vs. SO_2 R^2	$\Delta SO_4/\Delta SO_2$ (lb/lb)
CTR	12/07/05	Gorgas	49.7	5.6×10^{-3}	0.77	8.4×10^{-3}
CTR	12/17/05	Gorgas	21.4	2.0×10^{-3}	0.02	3.0×10^{-3}
CTR	12/17/05	Miller	29.6	2.5×10^{-3}	0.09	3.7×10^{-3}
CTR	12/18/05	Gaston	55.3	4.4×10^{-3}	0.70	6.6×10^{-3}
CTR	12/19/05	Gorgas	30.1	3.6×10^{-3}	0.13	5.4×10^{-3}
CTR	12/20/05	Gorgas	43.3	5.9×10^{-3}	0.81	8.9×10^{-3}
CTR	01/27/06	Miller	20.2	5.1×10^{-3}	0.20	7.7×10^{-3}
GFP	01/26/06	Watson	137.1	3.8 x 10-3	0.95	5.7×10^{-3}
GFP	02/19/06	Watson	49.9	3.6 x 10-3	0.34	5.4×10^{-3}
OLF	11/19/05	Crist	42.8	2.5×10^{-3}	0.08	3.7×10^{-3}
OLF	02/07/06	Crist	52.1	1.4×10^{-3}	0.02	2.1×10^{-3}
OLF	02/24/06	Crist	59.1	4.3×10^{-3}	0.29	6.5×10^{-3}
OLF	4/13/06	Crist	186.	5.4×10^{-3}	0.68	8.1×10^{-3}
YRK	10/09/05	Bowen	33.8	1.2×10^{-3}	0.10	1.8×10^{-3}
YRK	10/31/05	McDonough	73.4	10.0×10^{-3}	0.90	15.0×10^{-3}
YRK	11/11/05	McDonough	48.3	3.3×10^{-3}	0.43	4.9×10^{-3}
YRK	12/18/05	Bowen	202.8	6.6×10^{-3}	0.96	9.9×10^{-3}
YRK	02/08/06	Hammond	31.2	7.6×10^{-3}	0.64	11.4×10^{-3}
YRK	02/25/06	Bowen	47.4	4.4×10^{-3}	0.69	6.6×10^{-3}
YRK	03/04/06	Bowen	60.9	2.4×10^{-3}	0.09	3.6×10^{-3}
Mean (s.d.)						**6.4×10^{-3} (3.3×10^{-3})**

Appendix E

Determination Modeling

Delta-Deciview Values for the Top 20 Days – for Each Year/Each Class I Area and for the Top 25 Days – Over Three Years

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 20 Days Each Year)
Bowen 1-4 Results - Unit 1 Controlled with Agglomerator/Juice Can

						F(RH)			% of Modeled Extinction by Species						
YEAR	**DAY**	**REC**	**DV(Total)**	**DV(BKG)**	**DELTA DV**	**S**	**L**	**SS**	**% SO4**	**% NO3**	**% OC**	**% EC**	**% PMC**	**% PMF**	**Rank**
2001	341	2	9.30	7.94	1.36	3.8	2.9	4.3	73.7	0.0	20.1	1.1	2.2	3.0	1
2001	113	1	8.59	7.60	0.98	2.8	2.3	3.6	67.9	0.0	24.4	1.4	2.7	3.6	2
2001	225	3	9.27	8.33	0.93	4.9	3.5	5.1	78.4	0.0	16.4	1.0	1.8	2.4	3
2001	297	3	8.97	8.10	0.87	4.2	3.2	4.6	75.9	0.0	18.4	1.1	1.9	2.8	4
2001	114	4	8.42	7.60	0.82	2.8	2.3	3.6	68.2	0.0	24.5	1.4	2.3	3.6	5
2001	279	1	8.87	8.10	0.76	4.2	3.2	4.6	75.9	0.0	18.4	1.0	2.0	2.7	6
2001	220	54	9.09	8.33	0.76	4.9	3.5	5.1	78.5	0.0	16.4	1.0	1.7	2.5	7
2001	111	16	8.33	7.60	0.73	2.8	2.3	3.6	68.1	0.0	24.5	1.4	2.4	3.6	8
2001	294	1	8.78	8.10	0.68	4.2	3.2	4.6	75.8	0.0	18.3	1.0	2.1	2.8	9
2001	51	8	8.38	7.72	0.67	3.2	2.5	3.8	70.3	0.0	22.8	1.2	2.3	3.3	10
2001	102	9	8.19	7.60	0.59	2.8	2.3	3.6	68.1	0.0	24.5	1.3	2.5	3.6	11
2001	229	16	8.88	8.33	0.55	4.9	3.5	5.1	78.8	0.0	16.5	0.9	1.3	2.4	12
2001	110	3	8.12	7.60	0.51	2.8	2.3	3.6	68.1	0.0	24.5	1.4	2.4	3.6	13
2001	142	3	8.34	7.87	0.47	3.6	2.8	4.1	73.1	0.0	20.9	1.2	1.8	3.1	14
2001	112	35	8.07	7.60	0.47	2.8	2.3	3.6	68.2	0.0	24.5	1.4	2.3	3.6	15
2001	343	97	8.40	7.94	0.46	3.8	2.9	4.3	73.6	0.0	20.0	1.2	2.1	3.1	16
2001	158	25	8.56	8.10	0.45	4.2	3.2	4.6	75.9	0.0	18.4	1.0	2.1	2.6	17
2001	126	3	8.31	7.87	0.44	3.6	2.8	4.1	72.9	0.0	20.8	1.2	2.0	3.1	18
2001	236	25	8.77	8.33	0.43	4.9	3.5	5.1	78.4	0.0	16.4	0.9	1.9	2.4	19
2001	198	9	8.62	8.21	0.41	4.5	3.3	4.9	77.2	0.0	17.5	1.0	1.7	2.7	20
2002	224	3	9.66	8.33	1.32	4.9	3.5	5.1	78.4	0.0	16.4	0.9	1.8	2.4	1
2002	15	16	9.06	7.82	1.25	3.4	2.7	4.0	72.0	0.0	21.5	1.2	2.2	3.1	2
2002	227	8	9.51	8.33	1.18	4.9	3.5	5.1	78.5	0.0	16.4	0.9	1.7	2.4	3
2002	365	16	9.08	7.94	1.14	3.8	2.9	4.3	73.6	0.0	20.0	1.2	2.2	3.0	4
2002	67	3	8.71	7.67	1.04	3.0	2.5	3.7	69.3	0.0	23.4	1.3	2.5	3.4	5
2002	228	97	9.33	8.33	0.99	4.9	3.5	5.1	78.5	0.0	16.4	0.9	1.7	2.5	6
2002	230	3	9.31	8.33	0.97	4.9	3.5	5.1	78.4	0.0	16.4	0.9	1.8	2.4	7
2002	226	97	9.27	8.33	0.94	4.9	3.5	5.1	78.4	0.0	16.4	0.9	1.8	2.4	8
2002	314	2	8.75	7.87	0.88	3.6	2.8	4.1	72.7	0.0	20.8	1.2	2.3	3.1	9
2002	35	9	8.56	7.72	0.84	3.2	2.5	3.8	70.1	0.0	22.7	1.2	2.6	3.3	10
2002	222	16	9.12	8.33	0.79	4.9	3.5	5.1	78.8	0.0	16.5	0.9	1.4	2.4	11
2002	28	3	8.58	7.82	0.76	3.4	2.7	4.0	71.9	0.0	21.5	1.2	2.2	3.2	12
2002	107	97	8.32	7.60	0.71	2.8	2.3	3.6	67.9	0.0	24.4	1.4	2.6	3.7	13
2002	207	9	8.89	8.21	0.69	4.5	3.3	4.9	77.3	0.0	17.5	1.0	1.5	2.7	14
2002	85	97	8.24	7.67	0.56	3.0	2.5	3.7	69.4	0.0	23.4	1.3	2.5	3.5	15
2002	323	3	8.42	7.87	0.55	3.6	2.8	4.1	72.7	0.0	20.8	1.2	2.3	3.1	16
2002	105	8	8.13	7.60	0.52	2.8	2.3	3.6	68.1	0.0	24.5	1.3	2.4	3.6	17
2002	191	16	8.72	8.21	0.51	4.5	3.3	4.9	77.6	0.0	17.5	0.9	1.3	2.6	18
2002	128	3	8.37	7.87	0.50	3.6	2.8	4.1	72.6	0.0	20.8	1.2	2.3	3.1	19
2002	106	8	8.08	7.60	0.47	2.8	2.3	3.6	67.8	0.0	24.4	1.4	2.7	3.7	20
2003	271	3	9.29	8.33	0.96	4.9	3.5	5.1	78.5	0.0	16.4	0.9	1.7	2.4	1
2003	270	1	9.28	8.33	0.94	4.9	3.5	5.1	78.5	0.0	16.4	0.9	1.7	2.5	2
2003	178	3	8.79	8.10	0.69	4.2	3.2	4.6	75.8	0.0	18.3	1.0	2.1	2.8	3
2003	356	16	8.60	7.94	0.67	3.8	2.9	4.3	73.7	0.0	20.0	1.1	2.2	3.0	4
2003	68	3	8.32	7.67	0.65	3.0	2.5	3.7	69.1	0.0	23.3	1.3	2.7	3.5	5
2003	246	3	8.98	8.33	0.64	4.9	3.5	5.1	78.6	0.0	16.5	0.9	1.5	2.5	6
2003	107	1	8.23	7.60	0.62	2.8	2.3	3.6	68.0	0.0	24.5	1.3	2.5	3.7	7
2003	163	3	8.69	8.10	0.58	4.2	3.2	4.6	76.0	0.0	18.4	1.1	1.8	2.7	8
2003	164	97	8.68	8.10	0.58	4.2	3.2	4.6	76.0	0.0	18.4	1.1	1.8	2.7	9
2003	187	3	8.79	8.21	0.58	4.5	3.3	4.9	77.0	0.0	17.4	1.0	2.0	2.6	10
2003	35	10	8.24	7.72	0.53	3.2	2.5	3.8	70.2	0.0	22.8	1.3	2.3	3.3	11
2003	242	16	8.84	8.33	0.50	4.9	3.5	5.1	78.6	0.0	16.4	0.9	1.5	2.5	12
2003	160	3	8.59	8.10	0.49	4.2	3.2	4.6	75.7	0.0	18.3	1.1	2.2	2.8	13
2003	326	1	8.35	7.87	0.48	3.6	2.8	4.1	72.5	0.0	20.7	1.1	2.5	3.1	14
2003	247	97	8.81	8.33	0.47	4.9	3.5	5.1	78.8	0.0	16.5	0.9	1.3	2.5	15
2003	304	1	8.56	8.10	0.46	4.2	3.2	4.6	75.9	0.0	18.4	1.0	2.0	2.7	16
2003	108	3	8.05	7.60	0.45	2.8	2.3	3.6	68.0	0.0	24.5	1.4	2.5	3.7	17
2003	259	3	8.78	8.33	0.44	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.9	2.4	18
2003	197	9	8.65	8.21	0.44	4.5	3.3	4.9	77.0	0.0	17.5	1.0	2.0	2.5	19
2003	166	46	8.53	8.10	0.43	4.2	3.2	4.6	75.9	0.0	18.4	1.0	1.9	2.8	20

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 25 Days for 3 Years)
Bowen 1-4 Results - Unit 1 Controlled with Agglomerator/Juice Can

						F(RH)			% of Modeled Extinction by Species						
YEAR	**DAY**	**REC**	**DV(Total)**	**DV(BKG)**	**DELTA DV**	**S**	**L**	**SS**	**%_SO4**	**%_NO3**	**%_OC**	**%_EC**	**%_PMC**	**%_PMF**	**Rank**
2001	341	2	9.30	7.94	1.36	3.8	2.9	4.3	73.7	0.0	20.1	1.1	2.2	3.0	1
2002	224	3	9.66	8.33	1.32	4.9	3.5	5.1	78.4	0.0	16.4	0.9	1.8	2.4	2
2002	15	16	9.06	7.82	1.25	3.4	2.7	4.0	72.0	0.0	21.5	1.2	2.2	3.1	3
2002	227	8	9.51	8.33	1.18	4.9	3.5	5.1	78.5	0.0	16.4	0.9	1.7	2.4	4
2002	365	16	9.08	7.94	1.14	3.8	2.9	4.3	73.6	0.0	20.0	1.2	2.2	3.0	5
2002	67	3	8.71	7.67	1.04	3.0	2.5	3.7	69.3	0.0	23.4	1.3	2.5	3.4	6
2002	228	97	9.33	8.33	0.99	4.9	3.5	5.1	78.5	0.0	16.4	0.9	1.7	2.5	7
2001	113	1	8.59	7.60	0.98	2.8	2.3	3.6	67.9	0.0	24.4	1.4	2.7	3.6	8
2002	230	3	9.31	8.33	0.97	4.9	3.5	5.1	78.4	0.0	16.4	0.9	1.8	2.4	9
2003	271	3	9.29	8.33	0.96	4.9	3.5	5.1	78.5	0.0	16.4	0.9	1.7	2.4	10
2003	270	1	9.28	8.33	0.94	4.9	3.5	5.1	78.5	0.0	16.4	0.9	1.7	2.5	11
2002	226	97	9.27	8.33	0.94	4.9	3.5	5.1	78.4	0.0	16.4	0.9	1.8	2.4	12
2001	225	3	9.27	8.33	0.93	4.9	3.5	5.1	78.4	0.0	16.4	1.0	1.8	2.4	13
2002	314	2	8.75	7.87	0.88	3.6	2.8	4.1	72.7	0.0	20.8	1.2	2.3	3.1	14
2001	297	3	8.97	8.10	0.87	4.2	3.2	4.6	75.9	0.0	18.4	1.1	1.9	2.8	15
2002	35	9	8.56	7.72	0.84	3.2	2.5	3.8	70.1	0.0	22.7	1.2	2.6	3.3	16
2001	114	4	8.42	7.60	0.82	2.8	2.3	3.6	68.2	0.0	24.5	1.4	2.3	3.6	17
2002	222	16	9.12	8.33	0.79	4.9	3.5	5.1	78.8	0.0	16.5	0.9	1.4	2.4	18
2002	28	3	8.58	7.82	0.76	3.4	2.7	4.0	71.9	0.0	21.5	1.2	2.2	3.2	19
2001	279	1	8.87	8.10	0.76	4.2	3.2	4.6	75.9	0.0	18.4	1.0	2.0	2.7	20
2001	220	54	9.09	8.33	0.76	4.9	3.5	5.1	78.5	0.0	16.4	1.0	1.7	2.5	21
2001	111	16	8.33	7.60	0.73	2.8	2.3	3.6	68.1	0.0	24.5	1.4	2.4	3.6	22
2002	107	97	8.32	7.60	0.71	2.8	2.3	3.6	67.9	0.0	24.4	1.4	2.6	3.7	23
2003	178	3	8.79	8.10	0.69	4.2	3.2	4.6	75.8	0.0	18.3	1.0	2.1	2.8	24
2002	207	9	8.89	8.21	0.69	4.5	3.3	4.9	77.3	0.0	17.5	1.0	1.5	2.7	25

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 20 Days Each Year)
Bowen 1-4 Results - Unit 2 Controlled with Agglomerator/Juice Can

						F(RH)			% of Modeled Extinction by Species						
YEAR	**DAY**	**REC**	**DV(Total)**	**DV(BKG)**	**DELTA DV**	**S**	**L**	**SS**	**% SO4**	**% NO3**	**% OC**	**% EC**	**% PMC**	**% PMF**	**Rank**
2001	341	2	9.30	7.94	1.36	3.8	2.9	4.3	73.7	0.0	20.1	1.1	2.2	3.0	1
2001	113	1	8.59	7.60	0.98	2.8	2.3	3.6	67.9	0.0	24.4	1.4	2.7	3.6	2
2001	225	3	9.27	8.33	0.93	4.9	3.5	5.1	78.4	0.0	16.4	1.0	1.8	2.4	3
2001	297	3	8.97	8.10	0.87	4.2	3.2	4.6	76.0	0.0	18.4	1.1	1.9	2.7	4
2001	114	4	8.42	7.60	0.82	2.8	2.3	3.6	68.2	0.0	24.5	1.4	2.3	3.6	5
2001	279	1	8.87	8.10	0.76	4.2	3.2	4.6	75.9	0.0	18.4	1.0	2.0	2.7	6
2001	220	54	9.09	8.33	0.76	4.9	3.5	5.1	78.5	0.0	16.4	1.0	1.6	2.5	7
2001	111	16	8.33	7.60	0.73	2.8	2.3	3.6	68.1	0.0	24.5	1.4	2.4	3.6	8
2001	294	1	8.78	8.10	0.68	4.2	3.2	4.6	75.9	0.0	18.3	1.0	2.0	2.8	9
2001	51	8	8.38	7.72	0.67	3.2	2.5	3.8	70.3	0.0	22.8	1.2	2.3	3.3	10
2001	102	9	8.19	7.60	0.59	2.8	2.3	3.6	68.1	0.0	24.5	1.3	2.5	3.6	11
2001	229	16	8.88	8.33	0.55	4.9	3.5	5.1	78.8	0.0	16.5	0.9	1.3	2.4	12
2001	110	3	8.12	7.60	0.51	2.8	2.3	3.6	68.1	0.0	24.5	1.4	2.4	3.6	13
2001	142	3	8.34	7.87	0.47	3.6	2.8	4.1	73.2	0.0	20.9	1.2	1.7	3.1	14
2001	112	35	8.07	7.60	0.47	2.8	2.3	3.6	68.2	0.0	24.5	1.4	2.3	3.6	15
2001	343	97	8.39	7.94	0.46	3.8	2.9	4.3	73.7	0.0	20.1	1.2	2.1	3.0	16
2001	158	25	8.56	8.10	0.45	4.2	3.2	4.6	75.9	0.0	18.4	1.0	2.1	2.6	17
2001	126	3	8.31	7.87	0.44	3.6	2.8	4.1	72.9	0.0	20.8	1.2	2.0	3.1	18
2001	236	25	8.77	8.33	0.43	4.9	3.5	5.1	78.4	0.0	16.4	0.9	1.9	2.4	19
2001	198	9	8.62	8.21	0.41	4.5	3.3	4.9	77.3	0.0	17.5	1.0	1.7	2.6	20
2002	224	3	9.66	8.33	1.32	4.9	3.5	5.1	78.5	0.0	16.4	0.9	1.7	2.4	1
2002	15	16	9.06	7.82	1.25	3.4	2.7	4.0	72.0	0.0	21.5	1.2	2.1	3.1	2
2002	227	8	9.51	8.33	1.18	4.9	3.5	5.1	78.5	0.0	16.5	0.9	1.7	2.4	3
2002	365	16	9.08	7.94	1.14	3.8	2.9	4.3	73.7	0.0	20.1	1.2	2.2	3.0	4
2002	67	3	8.71	7.67	1.04	3.0	2.5	3.7	69.4	0.0	23.4	1.3	2.4	3.5	5
2002	228	97	9.33	8.33	0.99	4.9	3.5	5.1	78.6	0.0	16.4	0.9	1.7	2.4	6
2002	230	3	9.31	8.33	0.97	4.9	3.5	5.1	78.4	0.0	16.4	0.9	1.8	2.4	7
2002	226	97	9.27	8.33	0.94	4.9	3.5	5.1	78.4	0.0	16.4	0.9	1.8	2.4	8
2002	314	2	8.75	7.87	0.88	3.6	2.8	4.1	72.7	0.0	20.8	1.2	2.3	3.0	9
2002	35	9	8.56	7.72	0.84	3.2	2.5	3.8	70.2	0.0	22.8	1.2	2.5	3.3	10
2002	222	16	9.12	8.33	0.79	4.9	3.5	5.1	78.8	0.0	16.5	0.9	1.4	2.4	11
2002	28	3	8.58	7.82	0.76	3.4	2.7	4.0	71.9	0.0	21.5	1.2	2.2	3.1	12
2002	107	97	8.32	7.60	0.71	2.8	2.3	3.6	68.0	0.0	24.5	1.4	2.6	3.6	13
2002	207	9	8.89	8.21	0.69	4.5	3.3	4.9	77.3	0.0	17.5	1.0	1.5	2.6	14
2002	85	97	8.24	7.67	0.56	3.0	2.5	3.7	69.4	0.0	23.4	1.3	2.5	3.5	15
2002	323	3	8.42	7.87	0.55	3.6	2.8	4.1	72.8	0.0	20.8	1.2	2.2	3.1	16
2002	105	8	8.13	7.60	0.52	2.8	2.3	3.6	68.2	0.0	24.6	1.3	2.4	3.5	17
2002	191	16	8.72	8.21	0.51	4.5	3.3	4.9	77.6	0.0	17.5	0.9	1.3	2.6	18
2002	128	3	8.37	7.87	0.50	3.6	2.8	4.1	72.6	0.0	20.8	1.2	2.3	3.1	19
2002	313	8	8.34	7.87	0.47	3.6	2.8	4.1	72.9	0.0	20.9	1.2	2.1	3.0	20
2003	271	3	9.29	8.33	0.96	4.9	3.5	5.1	78.5	0.0	16.5	0.9	1.6	2.4	1
2003	270	1	9.28	8.33	0.94	4.9	3.5	5.1	78.5	0.0	16.4	0.9	1.7	2.4	2
2003	178	3	8.79	8.10	0.69	4.2	3.2	4.6	75.8	0.0	18.4	1.0	2.1	2.7	3
2003	356	16	8.60	7.94	0.67	3.8	2.9	4.3	73.7	0.0	20.1	1.1	2.2	2.9	4
2003	68	3	8.32	7.67	0.65	3.0	2.5	3.7	69.2	0.0	23.3	1.4	2.6	3.5	5
2003	246	3	8.98	8.33	0.64	4.9	3.5	5.1	78.6	0.0	16.5	0.9	1.5	2.5	6
2003	107	1	8.23	7.60	0.62	2.8	2.3	3.6	68.1	0.0	24.5	1.3	2.5	3.6	7
2003	163	3	8.69	8.10	0.58	4.2	3.2	4.6	76.0	0.0	18.4	1.1	1.8	2.7	8
2003	164	97	8.68	8.10	0.58	4.2	3.2	4.6	76.0	0.0	18.4	1.1	1.8	2.7	9
2003	187	3	8.79	8.21	0.58	4.5	3.3	4.9	77.0	0.0	17.4	1.0	2.0	2.6	10
2003	35	10	8.24	7.72	0.53	3.2	2.5	3.8	70.2	0.0	22.8	1.3	2.3	3.3	11
2003	242	16	8.84	8.33	0.50	4.9	3.5	5.1	78.7	0.0	16.4	0.9	1.5	2.4	12
2003	160	3	8.59	8.10	0.49	4.2	3.2	4.6	75.8	0.0	18.3	1.1	2.1	2.7	13
2003	326	1	8.35	7.87	0.48	3.6	2.8	4.1	72.7	0.0	20.8	1.1	2.4	3.0	14
2003	247	97	8.81	8.33	0.47	4.9	3.5	5.1	78.8	0.0	16.5	0.9	1.3	2.5	15
2003	304	1	8.56	8.10	0.46	4.2	3.2	4.6	76.0	0.0	18.4	1.0	2.0	2.6	16
2003	108	3	8.05	7.60	0.45	2.8	2.3	3.6	68.1	0.0	24.5	1.4	2.5	3.6	17
2003	259	3	8.78	8.33	0.44	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.9	2.4	18
2003	197	9	8.65	8.21	0.44	4.5	3.3	4.9	77.0	0.0	17.5	1.0	2.0	2.5	19
2003	166	46	8.53	8.10	0.43	4.2	3.2	4.6	76.0	0.0	18.4	1.0	1.9	2.7	20

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 25 Days for 3 Years)
Bowen 1-4 Results - Unit 2 Controlled with Agglomerator/Juice Can

						F(RH)			% of Modeled Extinction by Species						
YEAR	DAY	REC	DV(Total)	DV(BKG)	DELTA DV	S	L	SS	% SO4	% NO3	% OC	% EC	% PMC	% PMF	Rank
2001	341	2	9.30	7.94	1.36	3.8	2.9	4.3	73.7	0.0	20.1	1.1	2.2	3.0	1
2002	224	3	9.66	8.33	1.32	4.9	3.5	5.1	78.5	0.0	16.4	0.9	1.7	2.4	2
2002	15	16	9.06	7.82	1.25	3.4	2.7	4.0	72.0	0.0	21.5	1.2	2.1	3.1	3
2002	227	8	9.51	8.33	1.18	4.9	3.5	5.1	78.5	0.0	16.5	0.9	1.7	2.4	4
2002	365	16	9.08	7.94	1.14	3.8	2.9	4.3	73.7	0.0	20.1	1.2	2.2	3.0	5
2002	67	3	8.71	7.67	1.04	3.0	2.5	3.7	69.4	0.0	23.4	1.3	2.4	3.5	6
2002	228	97	9.33	8.33	0.99	4.9	3.5	5.1	78.6	0.0	16.4	0.9	1.7	2.4	7
2001	113	1	8.59	7.60	0.98	2.8	2.3	3.6	67.9	0.0	24.4	1.4	2.7	3.6	8
2002	230	3	9.31	8.33	0.97	4.9	3.5	5.1	78.4	0.0	16.4	0.9	1.8	2.4	9
2003	271	3	9.29	8.33	0.96	4.9	3.5	5.1	78.5	0.0	16.5	0.9	1.6	2.4	10
2003	270	1	9.28	8.33	0.94	4.9	3.5	5.1	78.5	0.0	16.4	0.9	1.7	2.4	11
2002	226	97	9.27	8.33	0.94	4.9	3.5	5.1	78.4	0.0	16.4	0.9	1.8	2.4	12
2001	225	3	9.27	8.33	0.93	4.9	3.5	5.1	78.4	0.0	16.4	1.0	1.8	2.4	13
2002	314	2	8.75	7.87	0.88	3.6	2.8	4.1	72.7	0.0	20.8	1.2	2.3	3.0	14
2001	297	3	8.97	8.10	0.87	4.2	3.2	4.6	76.0	0.0	18.4	1.1	1.9	2.7	15
2002	35	9	8.56	7.72	0.84	3.2	2.5	3.8	70.2	0.0	22.8	1.2	2.5	3.3	16
2001	114	4	8.42	7.60	0.82	2.8	2.3	3.6	68.2	0.0	24.5	1.4	2.3	3.6	17
2002	222	16	9.12	8.33	0.79	4.9	3.5	5.1	78.8	0.0	16.5	0.9	1.4	2.4	18
2002	28	3	8.58	7.82	0.76	3.4	2.7	4.0	71.9	0.0	21.5	1.2	2.2	3.1	19
2001	279	1	8.87	8.10	0.76	4.2	3.2	4.6	75.9	0.0	18.4	1.0	2.0	2.7	20
2001	220	54	9.09	8.33	0.76	4.9	3.5	5.1	78.5	0.0	16.4	1.0	1.6	2.5	21
2001	111	16	8.33	7.60	0.73	2.8	2.3	3.6	68.1	0.0	24.5	1.4	2.4	3.6	22
2002	107	97	8.32	7.60	0.71	2.8	2.3	3.6	68.0	0.0	24.5	1.4	2.6	3.6	23
2003	178	3	8.79	8.10	0.69	4.2	3.2	4.6	75.8	0.0	18.4	1.0	2.1	2.7	24
2002	207	9	8.89	8.21	0.69	4.5	3.3	4.9	77.3	0.0	17.5	1.0	1.5	2.6	25

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 20 Days Each Year)
Bowen 1-4 Results - Unit 3 Controlled with Agglomerator/Juice Can

						F(RH)			% of Modeled Extinction by Species						
YEAR	**DAY**	**REC**	**DV(Total)**	**DV(BKG)**	**DELTA DV**	**S**	**L**	**SS**	**%_SO4**	**%_NO3**	**%_OC**	**%_EC**	**%_PMC**	**%_PMF**	**Rank**
2001	341	2	9.30	7.94	1.37	3.8	2.9	4.3	73.4	0.0	20.0	1.2	2.3	3.1	1
2001	113	1	8.59	7.60	0.99	2.8	2.3	3.6	67.6	0.0	24.3	1.4	2.9	3.7	2
2001	225	3	9.27	8.33	0.94	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.9	2.5	3
2001	297	3	8.97	8.10	0.87	4.2	3.2	4.6	75.7	0.0	18.3	1.1	2.0	2.9	4
2001	114	4	8.42	7.60	0.82	2.8	2.3	3.6	67.9	0.0	24.4	1.5	2.5	3.7	5
2001	279	1	8.87	8.10	0.77	4.2	3.2	4.6	75.7	0.0	18.3	1.1	2.1	2.7	6
2001	220	54	9.10	8.33	0.76	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.8	2.6	7
2001	111	16	8.34	7.60	0.73	2.8	2.3	3.6	67.8	0.0	24.4	1.5	2.6	3.7	8
2001	294	1	8.79	8.10	0.69	4.2	3.2	4.6	75.5	0.0	18.3	1.2	2.2	2.9	9
2001	51	8	8.39	7.72	0.67	3.2	2.5	3.8	70.1	0.0	22.8	1.3	2.4	3.4	10
2001	102	9	8.20	7.60	0.59	2.8	2.3	3.6	67.8	0.0	24.4	1.5	2.6	3.8	11
2001	229	16	8.88	8.33	0.55	4.9	3.5	5.1	78.6	0.0	16.5	1.0	1.4	2.5	12
2001	110	3	8.12	7.60	0.52	2.8	2.3	3.6	67.8	0.0	24.4	1.5	2.5	3.8	13
2001	142	3	8.34	7.87	0.47	3.6	2.8	4.1	72.8	0.0	20.8	1.3	1.8	3.3	14
2001	112	35	8.07	7.60	0.47	2.8	2.3	3.6	67.8	0.0	24.4	1.5	2.5	3.8	15
2001	343	97	8.40	7.94	0.46	3.8	2.9	4.3	73.3	0.0	20.0	1.3	2.3	3.2	16
2001	158	25	8.56	8.10	0.46	4.2	3.2	4.6	75.8	0.0	18.4	1.1	2.1	2.6	17
2001	126	3	8.31	7.87	0.44	3.6	2.8	4.1	72.6	0.0	20.7	1.2	2.2	3.2	18
2001	236	25	8.77	8.33	0.43	4.9	3.5	5.1	78.2	0.0	16.3	1.0	2.0	2.5	19
2001	198	9	8.62	8.21	0.42	4.5	3.3	4.9	76.9	0.0	17.4	1.1	1.9	2.8	20
2002	224	3	9.66	8.33	1.33	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.9	2.5	1
2002	15	16	9.07	7.82	1.25	3.4	2.7	4.0	71.8	0.0	21.5	1.3	2.3	3.2	2
2002	227	8	9.52	8.33	1.18	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.8	2.5	3
2002	365	16	9.08	7.94	1.14	3.8	2.9	4.3	73.4	0.0	20.0	1.2	2.3	3.1	4
2002	67	3	8.71	7.67	1.04	3.0	2.5	3.7	69.1	0.0	23.3	1.4	2.7	3.6	5
2002	228	97	9.33	8.33	1.00	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.8	2.5	6
2002	230	3	9.31	8.33	0.98	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.9	2.5	7
2002	226	97	9.27	8.33	0.94	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.9	2.5	8
2002	314	2	8.76	7.87	0.88	3.6	2.8	4.1	72.4	0.0	20.7	1.3	2.5	3.2	9
2002	35	9	8.56	7.72	0.84	3.2	2.5	3.8	70.0	0.0	22.7	1.3	2.7	3.3	10
2002	222	16	9.12	8.33	0.79	4.9	3.5	5.1	78.5	0.0	16.4	1.0	1.5	2.5	11
2002	28	3	8.58	7.82	0.77	3.4	2.7	4.0	71.7	0.0	21.5	1.3	2.4	3.2	12
2002	107	97	8.32	7.60	0.72	2.8	2.3	3.6	67.6	0.0	24.3	1.5	2.8	3.8	13
2002	207	9	8.89	8.21	0.69	4.5	3.3	4.9	77.1	0.0	17.4	1.1	1.6	2.8	14
2002	85	97	8.24	7.67	0.57	3.0	2.5	3.7	69.1	0.0	23.3	1.4	2.6	3.6	15
2002	323	3	8.42	7.87	0.55	3.6	2.8	4.1	72.4	0.0	20.7	1.2	2.5	3.2	16
2002	105	8	8.13	7.60	0.52	2.8	2.3	3.6	68.1	0.0	24.5	1.3	2.6	3.5	17
2002	191	16	8.72	8.21	0.51	4.5	3.3	4.9	77.4	0.0	17.5	1.0	1.4	2.7	18
2002	128	3	8.37	7.87	0.50	3.6	2.8	4.1	72.4	0.0	20.7	1.3	2.5	3.2	19
2002	106	8	8.08	7.60	0.47	2.8	2.3	3.6	67.5	0.0	24.3	1.5	2.9	3.8	20
2003	271	3	9.29	8.33	0.96	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.8	2.5	1
2003	270	1	9.28	8.33	0.94	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.8	2.6	2
2003	178	3	8.79	8.10	0.69	4.2	3.2	4.6	75.5	0.0	18.3	1.1	2.3	2.8	3
2003	356	16	8.60	7.94	0.67	3.8	2.9	4.3	73.6	0.0	20.0	1.1	2.3	3.0	4
2003	68	3	8.33	7.67	0.65	3.0	2.5	3.7	68.8	0.0	23.2	1.4	2.9	3.7	5
2003	246	3	8.98	8.33	0.65	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.7	2.7	6
2003	107	1	8.23	7.60	0.63	2.8	2.3	3.6	67.7	0.0	24.4	1.5	2.7	3.8	7
2003	163	3	8.69	8.10	0.59	4.2	3.2	4.6	75.7	0.0	18.3	1.1	2.0	2.9	8
2003	164	97	8.68	8.10	0.58	4.2	3.2	4.6	75.7	0.0	18.3	1.1	2.0	2.9	9
2003	187	3	8.79	8.21	0.58	4.5	3.3	4.9	76.7	0.0	17.4	1.1	2.2	2.7	10
2003	35	10	8.24	7.72	0.53	3.2	2.5	3.8	70.0	0.0	22.8	1.3	2.5	3.4	11
2003	242	16	8.84	8.33	0.50	4.9	3.5	5.1	78.4	0.0	16.4	1.0	1.6	2.6	12
2003	160	3	8.60	8.10	0.49	4.2	3.2	4.6	75.4	0.0	18.2	1.2	2.3	2.9	13
2003	326	1	8.35	7.87	0.48	3.6	2.8	4.1	72.3	0.0	20.7	1.2	2.6	3.2	14
2003	247	97	8.81	8.33	0.48	4.9	3.5	5.1	78.5	0.0	16.5	1.0	1.4	2.6	15
2003	304	1	8.56	8.10	0.46	4.2	3.2	4.6	75.7	0.0	18.4	1.1	2.1	2.7	16
2003	108	3	8.05	7.60	0.45	2.8	2.3	3.6	67.7	0.0	24.4	1.5	2.7	3.8	17
2003	259	3	8.78	8.33	0.45	4.9	3.5	5.1	78.1	0.0	16.3	1.0	2.0	2.5	18
2003	197	9	8.65	8.21	0.44	4.5	3.3	4.9	77.0	0.0	17.4	1.0	2.1	2.5	19
2003	166	46	8.54	8.10	0.43	4.2	3.2	4.6	75.6	0.0	18.3	1.1	2.1	2.9	20

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 25 Days for 3 Years)
Bowen 1-4 Results - Unit 3 Controlled with Agglomerator/Juice Can

						F(RH)			% of Modeled Extinction by Species						
YEAR	DAY	REC	DV(Total)	DV(BKG)	DELTA DV	S	L	SS	%_SO4	%_NO3	%_OC	%_EC	%_PMC	%_PMF	Rank
2001	341	2	9.30	7.94	1.37	3.8	2.9	4.3	73.4	0.0	20.0	1.2	2.3	3.1	1
2002	224	3	9.66	8.33	1.33	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.9	2.5	2
2002	15	16	9.07	7.82	1.25	3.4	2.7	4.0	71.8	0.0	21.5	1.3	2.3	3.2	3
2002	227	8	9.52	8.33	1.18	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.8	2.5	4
2002	365	16	9.08	7.94	1.14	3.8	2.9	4.3	73.4	0.0	20.0	1.2	2.3	3.1	5
2002	67	3	8.71	7.67	1.04	3.0	2.5	3.7	69.1	0.0	23.3	1.4	2.7	3.6	6
2002	228	97	9.33	8.33	1.00	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.8	2.5	7
2001	113	1	8.59	7.60	0.99	2.8	2.3	3.6	67.6	0.0	24.3	1.4	2.9	3.7	8
2002	230	3	9.31	8.33	0.98	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.9	2.5	9
2003	271	3	9.29	8.33	0.96	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.8	2.5	10
2003	270	1	9.28	8.33	0.94	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.8	2.6	11
2002	226	97	9.27	8.33	0.94	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.9	2.5	12
2001	225	3	9.27	8.33	0.94	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.9	2.5	13
2002	314	2	8.76	7.87	0.88	3.6	2.8	4.1	72.4	0.0	20.7	1.3	2.5	3.2	14
2001	297	3	8.97	8.10	0.87	4.2	3.2	4.6	75.7	0.0	18.3	1.1	2.0	2.9	15
2002	35	9	8.56	7.72	0.84	3.2	2.5	3.8	70.0	0.0	22.7	1.3	2.7	3.3	16
2001	114	4	8.42	7.60	0.82	2.8	2.3	3.6	67.9	0.0	24.4	1.5	2.5	3.7	17
2002	222	16	9.12	8.33	0.79	4.9	3.5	5.1	78.5	0.0	16.4	1.0	1.5	2.5	18
2002	28	3	8.58	7.82	0.77	3.4	2.7	4.0	71.7	0.0	21.5	1.3	2.4	3.2	19
2001	279	1	8.87	8.10	0.77	4.2	3.2	4.6	75.7	0.0	18.3	1.1	2.1	2.7	20
2001	220	54	9.10	8.33	0.76	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.8	2.6	21
2001	111	16	8.34	7.60	0.73	2.8	2.3	3.6	67.8	0.0	24.4	1.5	2.6	3.7	22
2002	107	97	8.32	7.60	0.72	2.8	2.3	3.6	67.6	0.0	24.3	1.5	2.8	3.8	23
2003	178	3	8.79	8.10	0.69	4.2	3.2	4.6	75.5	0.0	18.3	1.1	2.3	2.8	24
2002	207	9	8.89	8.21	0.69	4.5	3.3	4.9	77.1	0.0	17.4	1.1	1.6	2.8	25

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 20 Days Each Year)
Bowen 1-4 Results - Unit 4 Controlled with Agglomerator/Juice Can

							F(RH)			% of Modeled Extinction by Species					
YEAR	**DAY**	**REC**	**DV(Total)**	**DV(BKG)**	**DELTA DV**	**S**	**L**	**SS**	**%_SO4**	**%_NO3**	**%_OC**	**%_EC**	**%_PMC**	**%_PMF**	**Rank**
2001	341	2	9.30	7.94	1.37	3.8	2.9	4.3	73.4	0.0	20.0	1.2	2.3	3.0	1
2001	113	1	8.59	7.60	0.99	2.8	2.3	3.6	67.7	0.0	24.3	1.4	2.9	3.7	2
2001	225	3	9.27	8.33	0.94	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.9	2.5	3
2001	297	3	8.97	8.10	0.87	4.2	3.2	4.6	75.7	0.0	18.3	1.1	2.0	2.9	4
2001	114	4	8.42	7.60	0.82	2.8	2.3	3.6	67.9	0.0	24.4	1.4	2.5	3.7	5
2001	279	1	8.87	8.10	0.76	4.2	3.2	4.6	75.8	0.0	18.4	1.0	2.1	2.7	6
2001	220	54	9.09	8.33	0.76	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.8	2.6	7
2001	111	16	8.34	7.60	0.73	2.8	2.3	3.6	67.9	0.0	24.4	1.5	2.6	3.7	8
2001	294	1	8.79	8.10	0.68	4.2	3.2	4.6	75.6	0.0	18.3	1.1	2.2	2.9	9
2001	51	8	8.39	7.72	0.67	3.2	2.5	3.8	70.2	0.0	22.8	1.3	2.4	3.3	10
2001	102	9	8.20	7.60	0.59	2.8	2.3	3.6	67.9	0.0	24.4	1.4	2.6	3.7	11
2001	229	16	8.88	8.33	0.55	4.9	3.5	5.1	78.6	0.0	16.5	0.9	1.4	2.5	12
2001	110	3	8.12	7.60	0.52	2.8	2.3	3.6	67.8	0.0	24.4	1.5	2.5	3.8	13
2001	142	3	8.34	7.87	0.47	3.6	2.8	4.1	72.8	0.0	20.8	1.3	1.8	3.3	14
2001	112	35	8.07	7.60	0.47	2.8	2.3	3.6	68.0	0.0	24.4	1.4	2.5	3.7	15
2001	343	97	8.40	7.94	0.46	3.8	2.9	4.3	73.3	0.0	20.0	1.3	2.3	3.2	16
2001	158	25	8.56	8.10	0.45	4.2	3.2	4.6	75.9	0.0	18.4	1.0	2.2	2.6	17
2001	126	3	8.31	7.87	0.44	3.6	2.8	4.1	72.6	0.0	20.7	1.2	2.2	3.2	18
2001	236	25	8.77	8.33	0.43	4.9	3.5	5.1	78.2	0.0	16.3	1.0	2.0	2.5	19
2001	198	9	8.62	8.21	0.42	4.5	3.3	4.9	76.9	0.0	17.4	1.1	1.9	2.8	20
2002	224	3	9.66	8.33	1.33	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.9	2.5	1
2002	15	16	9.06	7.82	1.25	3.4	2.7	4.0	71.8	0.0	21.5	1.2	2.3	3.2	2
2002	227	8	9.52	8.33	1.18	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.8	2.5	3
2002	365	16	9.08	7.94	1.14	3.8	2.9	4.3	73.4	0.0	20.0	1.2	2.3	3.1	4
2002	67	3	8.71	7.67	1.04	3.0	2.5	3.7	69.1	0.0	23.3	1.4	2.7	3.5	5
2002	228	97	9.33	8.33	1.00	4.9	3.5	5.1	78.4	0.0	16.4	1.0	1.8	2.5	6
2002	230	3	9.31	8.33	0.98	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.9	2.5	7
2002	226	97	9.27	8.33	0.94	4.9	3.5	5.1	78.3	0.0	16.4	0.9	1.9	2.5	8
2002	314	2	8.76	7.87	0.88	3.6	2.8	4.1	72.5	0.0	20.7	1.2	2.5	3.1	9
2002	35	9	8.56	7.72	0.84	3.2	2.5	3.8	70.0	0.0	22.7	1.3	2.7	3.3	10
2002	222	16	9.12	8.33	0.79	4.9	3.5	5.1	78.6	0.0	16.4	1.0	1.5	2.5	11
2002	28	3	8.58	7.82	0.77	3.4	2.7	4.0	71.7	0.0	21.5	1.2	2.4	3.2	12
2002	107	97	8.32	7.60	0.71	2.8	2.3	3.6	67.7	0.0	24.3	1.4	2.8	3.8	13
2002	207	9	8.89	8.21	0.69	4.5	3.3	4.9	77.1	0.0	17.5	1.1	1.6	2.7	14
2002	85	97	8.24	7.67	0.57	3.0	2.5	3.7	69.1	0.0	23.3	1.4	2.6	3.6	15
2002	323	3	8.42	7.87	0.55	3.6	2.8	4.1	72.5	0.0	20.7	1.2	2.5	3.1	16
2002	105	8	8.13	7.60	0.52	2.8	2.3	3.6	68.1	0.0	24.5	1.3	2.6	3.5	17
2002	191	16	8.72	8.21	0.51	4.5	3.3	4.9	77.4	0.0	17.5	1.0	1.4	2.7	18
2002	128	3	8.37	7.87	0.50	3.6	2.8	4.1	72.4	0.0	20.7	1.3	2.5	3.2	19
2002	106	8	8.08	7.60	0.47	2.8	2.3	3.6	67.5	0.0	24.3	1.5	2.9	3.8	20
2003	271	3	9.29	8.33	0.96	4.9	3.5	5.1	78.4	0.0	16.4	1.0	1.8	2.5	1
2003	270	1	9.28	8.33	0.94	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.8	2.5	2
2003	178	3	8.79	8.10	0.69	4.2	3.2	4.6	75.5	0.0	18.3	1.1	2.3	2.8	3
2003	356	16	8.60	7.94	0.67	3.8	2.9	4.3	73.6	0.0	20.0	1.1	2.3	3.0	4
2003	68	3	8.33	7.67	0.65	3.0	2.5	3.7	68.8	0.0	23.2	1.4	2.9	3.7	5
2003	246	3	8.98	8.33	0.65	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.7	2.6	6
2003	107	1	8.23	7.60	0.62	2.8	2.3	3.6	67.8	0.0	24.4	1.4	2.6	3.7	7
2003	163	3	8.69	8.10	0.59	4.2	3.2	4.6	75.9	0.0	18.3	1.1	2.0	2.8	8
2003	164	97	8.68	8.10	0.58	4.2	3.2	4.6	75.7	0.0	18.3	1.1	2.0	2.9	9
2003	187	3	8.79	8.21	0.58	4.5	3.3	4.9	76.7	0.0	17.4	1.1	2.2	2.7	10
2003	35	10	8.24	7.72	0.53	3.2	2.5	3.8	70.0	0.0	22.8	1.3	2.5	3.4	11
2003	242	16	8.84	8.33	0.50	4.9	3.5	5.1	78.5	0.0	16.4	0.9	1.6	2.6	12
2003	160	3	8.60	8.10	0.49	4.2	3.2	4.6	75.5	0.0	18.2	1.1	2.3	2.9	13
2003	326	1	8.35	7.87	0.48	3.6	2.8	4.1	72.3	0.0	20.7	1.2	2.5	3.2	14
2003	247	97	8.81	8.33	0.48	4.9	3.5	5.1	78.5	0.0	16.5	1.0	1.4	2.6	15
2003	304	1	8.56	8.10	0.46	4.2	3.2	4.6	75.7	0.0	18.4	1.1	2.1	2.7	16
2003	108	3	8.05	7.60	0.45	2.8	2.3	3.6	67.7	0.0	24.4	1.5	2.7	3.8	17
2003	259	3	8.78	8.33	0.45	4.9	3.5	5.1	78.1	0.0	16.3	1.0	2.0	2.5	18
2003	197	9	8.65	8.21	0.44	4.5	3.3	4.9	77.0	0.0	17.4	1.0	2.1	2.5	19
2003	166	46	8.54	8.10	0.43	4.2	3.2	4.6	75.7	0.0	18.3	1.1	2.1	2.8	20

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 25 Days for 3 Years)
Bowen 1-4 Results - Unit 4 Controlled with Agglomerator/Juice Can

						F(RH)			% of Modeled Extinction by Species						
YEAR	DAY	REC	DV(Total)	DV(BKG)	DELTA DV	S	L	SS	% SO4	% NO3	% OC	% EC	% PMC	% PMF	Rank
2001	341	2	9.30	7.94	1.37	3.8	2.9	4.3	73.4	0.0	20.0	1.2	2.3	3.0	1
2002	224	3	9.66	8.33	1.33	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.9	2.5	2
2002	15	16	9.06	7.82	1.25	3.4	2.7	4.0	71.8	0.0	21.5	1.2	2.3	3.2	3
2002	227	8	9.52	8.33	1.18	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.8	2.5	4
2002	365	16	9.08	7.94	1.14	3.8	2.9	4.3	73.4	0.0	20.0	1.2	2.3	3.1	5
2002	67	3	8.71	7.67	1.04	3.0	2.5	3.7	69.1	0.0	23.3	1.4	2.7	3.5	6
2002	228	97	9.33	8.33	1.00	4.9	3.5	5.1	78.4	0.0	16.4	1.0	1.8	2.5	7
2001	113	1	8.59	7.60	0.99	2.8	2.3	3.6	67.7	0.0	24.3	1.4	2.9	3.7	8
2002	230	3	9.31	8.33	0.98	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.9	2.5	9
2003	271	3	9.29	8.33	0.96	4.9	3.5	5.1	78.4	0.0	16.4	1.0	1.8	2.5	10
2003	270	1	9.28	8.33	0.94	4.9	3.5	5.1	78.3	0.0	16.4	1.0	1.8	2.5	11
2002	226	97	9.27	8.33	0.94	4.9	3.5	5.1	78.3	0.0	16.4	0.9	1.9	2.5	12
2001	225	3	9.27	8.33	0.94	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.9	2.5	13
2002	314	2	8.76	7.87	0.88	3.6	2.8	4.1	72.5	0.0	20.7	1.2	2.5	3.1	14
2001	297	3	8.97	8.10	0.87	4.2	3.2	4.6	75.7	0.0	18.3	1.1	2.0	2.9	15
2002	35	9	8.56	7.72	0.84	3.2	2.5	3.8	70.0	0.0	22.7	1.3	2.7	3.3	16
2001	114	4	8.42	7.60	0.82	2.8	2.3	3.6	67.9	0.0	24.4	1.4	2.5	3.7	17
2002	222	16	9.12	8.33	0.79	4.9	3.5	5.1	78.6	0.0	16.4	1.0	1.5	2.5	18
2002	28	3	8.58	7.82	0.77	3.4	2.7	4.0	71.7	0.0	21.5	1.2	2.4	3.2	19
2001	279	1	8.87	8.10	0.76	4.2	3.2	4.6	75.8	0.0	18.4	1.0	2.1	2.7	20
2001	220	54	9.09	8.33	0.76	4.9	3.5	5.1	78.2	0.0	16.4	1.0	1.8	2.6	21
2001	111	16	8.34	7.60	0.73	2.8	2.3	3.6	67.9	0.0	24.4	1.5	2.6	3.7	22
2002	107	97	8.32	7.60	0.71	2.8	2.3	3.6	67.7	0.0	24.3	1.4	2.8	3.8	23
2003	178	3	8.79	8.10	0.69	4.2	3.2	4.6	75.5	0.0	18.3	1.1	2.3	2.8	24
2002	207	9	8.89	8.21	0.69	4.5	3.3	4.9	77.1	0.0	17.5	1.1	1.6	2.7	25

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 20 Days Each Year)
Bowen 1-4 Results - Unit 1 Controlled with WESP

						F(RH)			% of Modeled Extinction by Species						
YEAR	**DAY**	**REC**	**DV(Total)**	**DV(BKG)**	**DELTA DV**	**S**	**L**	**SS**	**%_SO4**	**%_NO3**	**%_OC**	**%_EC**	**%_PMC**	**%_PMF**	**Rank**
2001	341	2	9.12	7.94	1.18	3.8	2.9	4.3	70.4	0.0	23.5	1.1	2.1	2.9	1
2001	113	1	8.46	7.60	0.86	2.8	2.3	3.6	64.3	0.0	28.2	1.3	2.6	3.5	2
2001	225	3	9.13	8.33	0.80	4.9	3.5	5.1	75.5	0.0	19.4	0.9	1.8	2.4	3
2001	297	3	8.84	8.10	0.74	4.2	3.2	4.6	72.6	0.0	21.8	1.0	1.8	2.7	4
2001	114	4	8.31	7.60	0.71	2.8	2.3	3.6	64.6	0.0	28.4	1.3	2.2	3.5	5
2001	279	1	8.77	8.10	0.67	4.2	3.2	4.6	73.2	0.0	21.2	1.0	1.9	2.6	6
2001	111	16	8.24	7.60	0.64	2.8	2.3	3.6	64.5	0.0	28.3	1.3	2.4	3.5	7
2001	220	54	8.97	8.33	0.64	4.9	3.5	5.1	75.2	0.0	19.7	0.9	1.7	2.4	8
2001	51	8	8.31	7.72	0.59	3.2	2.5	3.8	67.3	0.0	26.0	1.3	2.3	3.2	9
2001	294	1	8.68	8.10	0.58	4.2	3.2	4.6	72.4	0.0	21.9	1.0	2.0	2.8	10
2001	102	9	8.12	7.60	0.51	2.8	2.3	3.6	64.4	0.0	28.3	1.4	2.4	3.6	11
2001	229	16	8.80	8.33	0.47	4.9	3.5	5.1	76.0	0.0	19.4	0.9	1.3	2.4	12
2001	110	3	8.05	7.60	0.45	2.8	2.3	3.6	64.2	0.0	28.5	1.4	2.3	3.6	13
2001	112	35	8.01	7.60	0.41	2.8	2.3	3.6	64.6	0.0	28.4	1.3	2.2	3.5	14
2001	142	3	8.27	7.87	0.40	3.6	2.8	4.1	69.4	0.0	24.6	1.1	1.7	3.1	15
2001	158	25	8.50	8.10	0.40	4.2	3.2	4.6	73.4	0.0	20.9	1.0	2.0	2.7	16
2001	343	97	8.32	7.94	0.39	3.8	2.9	4.3	69.8	0.0	23.9	1.2	2.1	3.0	17
2001	126	3	8.24	7.87	0.37	3.6	2.8	4.1	69.3	0.0	24.5	1.1	2.0	3.1	18
2001	236	25	8.70	8.33	0.37	4.9	3.5	5.1	75.6	0.0	19.2	0.9	1.9	2.4	19
2001	198	9	8.56	8.21	0.35	4.5	3.3	4.9	74.0	0.0	20.7	1.0	1.8	2.5	20
2002	224	3	9.47	8.33	1.13	4.9	3.5	5.1	75.5	0.0	19.4	0.9	1.7	2.4	1
2002	15	16	8.91	7.82	1.09	3.4	2.7	4.0	68.9	0.0	24.8	1.2	2.1	3.1	2
2002	227	8	9.35	8.33	1.01	4.9	3.5	5.1	75.7	0.0	19.3	0.9	1.7	2.4	3
2002	365	16	8.92	7.94	0.98	3.8	2.9	4.3	70.3	0.0	23.6	1.1	2.1	2.9	4
2002	67	3	8.58	7.67	0.90	3.0	2.5	3.7	65.8	0.0	27.2	1.3	2.4	3.4	5
2002	228	97	9.19	8.33	0.85	4.9	3.5	5.1	75.7	0.0	19.4	0.9	1.7	2.4	6
2002	230	3	9.17	8.33	0.83	4.9	3.5	5.1	75.5	0.0	19.4	0.9	1.8	2.4	7
2002	226	97	9.14	8.33	0.80	4.9	3.5	5.1	75.6	0.0	19.3	0.9	1.8	2.4	8
2002	314	2	8.63	7.87	0.76	3.6	2.8	4.1	69.4	0.0	24.2	1.1	2.2	3.0	9
2002	35	9	8.46	7.72	0.75	3.2	2.5	3.8	67.2	0.0	25.8	1.2	2.5	3.3	10
2002	28	3	8.48	7.82	0.66	3.4	2.7	4.0	68.6	0.0	24.9	1.2	2.2	3.1	11
2002	222	16	9.01	8.33	0.67	4.9	3.5	5.1	75.9	0.0	19.4	0.9	1.4	2.4	12
2002	107	97	8.22	7.60	0.62	2.8	2.3	3.6	64.1	0.0	28.4	1.4	2.5	3.6	13
2002	207	9	8.79	8.21	0.58	4.5	3.3	4.9	74.0	0.0	20.9	1.0	1.5	2.6	14
2002	85	97	8.16	7.67	0.49	3.0	2.5	3.7	65.7	0.0	27.2	1.2	2.4	3.4	15
2002	323	3	8.35	7.87	0.48	3.6	2.8	4.1	69.5	0.0	24.1	1.2	2.2	3.0	16
2002	105	8	8.07	7.60	0.47	2.8	2.3	3.6	65.3	0.0	27.6	1.3	2.4	3.4	17
2002	191	16	8.65	8.21	0.44	4.5	3.3	4.9	74.6	0.0	20.5	1.0	1.3	2.6	18
2002	128	3	8.30	7.87	0.43	3.6	2.8	4.1	69.2	0.0	24.4	1.2	2.3	3.0	19
2002	313	8	8.29	7.87	0.42	3.6	2.8	4.1	70.1	0.0	23.7	1.1	2.1	3.0	20
2003	271	3	9.15	8.33	0.82	4.9	3.5	5.1	75.7	0.0	19.4	0.9	1.6	2.4	1
2003	270	1	9.14	8.33	0.80	4.9	3.5	5.1	75.6	0.0	19.4	0.9	1.6	2.4	2
2003	178	3	8.69	8.10	0.59	4.2	3.2	4.6	72.7	0.0	21.5	1.0	2.1	2.7	3
2003	356	16	8.52	7.94	0.58	3.8	2.9	4.3	70.9	0.0	23.1	1.1	2.1	2.9	4
2003	68	3	8.23	7.67	0.56	3.0	2.5	3.7	65.2	0.0	27.5	1.3	2.6	3.4	5
2003	107	1	8.14	7.60	0.54	2.8	2.3	3.6	64.3	0.0	28.4	1.3	2.3	3.6	6
2003	246	3	8.87	8.33	0.54	4.9	3.5	5.1	75.2	0.0	19.8	1.0	1.5	2.5	7
2003	163	3	8.60	8.10	0.50	4.2	3.2	4.6	73.0	0.0	21.6	1.0	1.8	2.7	8
2003	164	97	8.60	8.10	0.49	4.2	3.2	4.6	72.7	0.0	21.8	1.0	1.8	2.7	9
2003	187	3	8.70	8.21	0.49	4.5	3.3	4.9	73.8	0.0	20.7	1.0	2.0	2.6	10
2003	35	10	8.18	7.72	0.46	3.2	2.5	3.8	67.0	0.0	26.3	1.2	2.2	3.3	11
2003	242	16	8.76	8.33	0.43	4.9	3.5	5.1	75.6	0.0	19.5	0.9	1.5	2.4	12
2003	326	1	8.29	7.87	0.41	3.6	2.8	4.1	69.3	0.0	24.3	1.1	2.3	3.0	13
2003	160	3	8.52	8.10	0.41	4.2	3.2	4.6	72.3	0.0	21.9	1.1	2.1	2.7	14
2003	304	1	8.50	8.10	0.40	4.2	3.2	4.6	73.3	0.0	21.1	1.0	2.0	2.7	15
2003	247	97	8.73	8.33	0.40	4.9	3.5	5.1	75.5	0.0	19.8	0.9	1.3	2.5	16
2003	108	3	7.99	7.60	0.39	2.8	2.3	3.6	64.3	0.0	28.4	1.3	2.4	3.5	17
2003	197	9	8.59	8.21	0.39	4.5	3.3	4.9	74.7	0.0	19.9	0.9	1.9	2.5	18
2003	320	25	8.25	7.87	0.38	3.6	2.8	4.1	69.9	0.0	23.7	1.1	2.3	2.9	19
2003	259	3	8.71	8.33	0.38	4.9	3.5	5.1	75.3	0.0	19.5	0.9	1.9	2.4	20

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 25 Days for 3 Years)
Bowen 1-4 Results - Unit 1 Controlled with WESP

						F(RH)			% of Modeled Extinction by Species						
YEAR	DAY	REC	DV(Total)	DV(BKG)	DELTA DV	S	L	SS	%_SO4	%_NO3	%_OC	%_EC	%_PMC	%_PMF	Rank
2001	341	2	9.12	7.94	1.18	3.8	2.9	4.3	70.4	0.0	23.5	1.1	2.1	2.9	1
2002	224	3	9.47	8.33	1.13	4.9	3.5	5.1	75.5	0.0	19.4	0.9	1.7	2.4	2
2002	15	16	8.91	7.82	1.09	3.4	2.7	4.0	68.9	0.0	24.8	1.2	2.1	3.1	3
2002	227	8	9.35	8.33	1.01	4.9	3.5	5.1	75.7	0.0	19.3	0.9	1.7	2.4	4
2002	365	16	8.92	7.94	0.98	3.8	2.9	4.3	70.3	0.0	23.6	1.1	2.1	2.9	5
2002	67	3	8.58	7.67	0.90	3.0	2.5	3.7	65.8	0.0	27.2	1.3	2.4	3.4	6
2001	113	1	8.46	7.60	0.86	2.8	2.3	3.6	64.3	0.0	28.2	1.3	2.6	3.5	7
2002	228	97	9.19	8.33	0.85	4.9	3.5	5.1	75.7	0.0	19.4	0.9	1.7	2.4	8
2002	230	3	9.17	8.33	0.83	4.9	3.5	5.1	75.5	0.0	19.4	0.9	1.8	2.4	9
2003	271	3	9.15	8.33	0.82	4.9	3.5	5.1	75.7	0.0	19.4	0.9	1.6	2.4	10
2003	270	1	9.14	8.33	0.80	4.9	3.5	5.1	75.6	0.0	19.4	0.9	1.6	2.4	11
2002	226	97	9.14	8.33	0.80	4.9	3.5	5.1	75.6	0.0	19.3	0.9	1.8	2.4	12
2001	225	3	9.13	8.33	0.80	4.9	3.5	5.1	75.5	0.0	19.4	0.9	1.8	2.4	13
2002	314	2	8.63	7.87	0.76	3.6	2.8	4.1	69.4	0.0	24.2	1.1	2.2	3.0	14
2002	35	9	8.46	7.72	0.75	3.2	2.5	3.8	67.2	0.0	25.8	1.2	2.5	3.3	15
2001	297	3	8.84	8.10	0.74	4.2	3.2	4.6	72.6	0.0	21.8	1.0	1.8	2.7	16
2001	114	4	8.31	7.60	0.71	2.8	2.3	3.6	64.6	0.0	28.4	1.3	2.2	3.5	17
2002	222	16	9.01	8.33	0.67	4.9	3.5	5.1	75.9	0.0	19.4	0.9	1.4	2.4	18
2001	279	1	8.77	8.10	0.67	4.2	3.2	4.6	73.2	0.0	21.2	1.0	1.9	2.6	19
2002	28	3	8.48	7.82	0.66	3.4	2.7	4.0	68.6	0.0	24.9	1.2	2.2	3.1	20
2001	220	54	8.97	8.33	0.64	4.9	3.5	5.1	75.2	0.0	19.7	0.9	1.7	2.4	21
2001	111	16	8.24	7.60	0.64	2.8	2.3	3.6	64.5	0.0	28.3	1.3	2.4	3.5	22
2002	107	97	8.22	7.60	0.62	2.8	2.3	3.6	64.1	0.0	28.4	1.4	2.5	3.6	23
2001	51	8	8.31	7.72	0.59	3.2	2.5	3.8	67.3	0.0	26.0	1.3	2.3	3.2	24
2003	178	3	8.69	8.10	0.59	4.2	3.2	4.6	72.7	0.0	21.5	1.0	2.1	2.7	25

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 20 Days Each Year)
Bowen 1-4 Results - Unit 2 Controlled with WESP

						F(RH)			% of Modeled Extinction by Species						
YEAR	DAY	REC	DV(Total)	DV(BKG)	DELTA DV	S	L	SS	% SO4	% NO3	% OC	% EC	% PMC	% PMF	Rank
2001	341	2	9.11	7.94	1.17	3.8	2.9	4.3	70.3	0.0	23.7	1.1	2.1	2.8	1
2001	113	1	8.46	7.60	0.85	2.8	2.3	3.6	64.2	0.0	28.5	1.3	2.6	3.4	2
2001	225	3	9.12	8.33	0.79	4.9	3.5	5.1	75.3	0.0	19.6	0.9	1.7	2.4	3
2001	297	3	8.83	8.10	0.73	4.2	3.2	4.6	72.5	0.0	22.0	1.0	1.8	2.7	4
2001	114	4	8.31	7.60	0.71	2.8	2.3	3.6	64.4	0.0	28.6	1.3	2.2	3.4	5
2001	279	1	8.76	8.10	0.66	4.2	3.2	4.6	73.0	0.0	21.4	1.0	1.9	2.6	6
2001	111	16	8.24	7.60	0.63	2.8	2.3	3.6	64.4	0.0	28.5	1.3	2.3	3.5	7
2001	220	54	8.96	8.33	0.63	4.9	3.5	5.1	75.2	0.0	19.9	0.9	1.6	2.4	8
2001	51	8	8.30	7.72	0.59	3.2	2.5	3.8	67.2	0.0	26.2	1.2	2.2	3.2	9
2001	294	1	8.67	8.10	0.57	4.2	3.2	4.6	72.3	0.0	22.1	1.0	1.9	2.6	10
2001	102	9	8.11	7.60	0.51	2.8	2.3	3.6	64.3	0.0	28.6	1.3	2.3	3.5	11
2001	229	16	8.80	8.33	0.46	4.9	3.5	5.1	75.9	0.0	19.5	0.9	1.3	2.3	12
2001	110	3	8.05	7.60	0.44	2.8	2.3	3.6	64.1	0.0	28.8	1.3	2.2	3.5	13
2001	112	35	8.01	7.60	0.40	2.8	2.3	3.6	64.4	0.0	28.6	1.3	2.2	3.5	14
2001	142	3	8.27	7.87	0.40	3.6	2.8	4.1	69.3	0.0	24.9	1.2	1.6	3.0	16
2001	158	25	8.50	8.10	0.40	4.2	3.2	4.6	73.4	0.0	21.1	1.0	1.9	2.6	15
2001	343	97	8.32	7.94	0.38	3.8	2.9	4.3	69.8	0.0	24.2	1.1	2.0	2.9	17
2001	126	3	8.24	7.87	0.37	3.6	2.8	4.1	69.2	0.0	24.8	1.1	1.9	3.0	18
2001	236	25	8.70	8.33	0.37	4.9	3.5	5.1	75.4	0.0	19.4	1.0	1.8	2.4	19
2001	198	9	8.55	8.21	0.35	4.5	3.3	4.9	73.8	0.0	20.9	1.0	1.7	2.6	20
2002	224	3	9.46	8.33	1.12	4.9	3.5	5.1	75.5	0.0	19.6	0.9	1.7	2.4	1
2002	15	16	8.90	7.82	1.09	3.4	2.7	4.0	68.8	0.0	25.0	1.2	2.1	3.0	2
2002	227	8	9.34	8.33	1.00	4.9	3.5	5.1	75.6	0.0	19.5	0.9	1.6	2.4	3
2002	365	16	8.91	7.94	0.97	3.8	2.9	4.3	70.1	0.0	23.8	1.1	2.1	2.9	4
2002	67	3	8.57	7.67	0.90	3.0	2.5	3.7	65.7	0.0	27.4	1.2	2.4	3.3	5
2002	228	97	9.18	8.33	0.84	4.9	3.5	5.1	75.5	0.0	19.6	0.9	1.6	2.4	6
2002	230	3	9.16	8.33	0.82	4.9	3.5	5.1	75.4	0.0	19.6	0.9	1.8	2.4	7
2002	226	97	9.13	8.33	0.80	4.9	3.5	5.1	75.5	0.0	19.5	0.9	1.7	2.4	8
2002	314	2	8.63	7.87	0.76	3.6	2.8	4.1	69.2	0.0	24.5	1.1	2.2	3.0	9
2002	35	9	8.46	7.72	0.74	3.2	2.5	3.8	67.1	0.0	26.1	1.2	2.5	3.2	10
2002	28	3	8.47	7.82	0.66	3.4	2.7	4.0	68.5	0.0	25.2	1.2	2.1	3.0	12
2002	222	16	9.00	8.33	0.67	4.9	3.5	5.1	75.8	0.0	19.5	0.9	1.4	2.4	11
2002	107	97	8.22	7.60	0.61	2.8	2.3	3.6	64.1	0.0	28.7	1.3	2.5	3.4	13
2002	207	9	8.78	8.21	0.57	4.5	3.3	4.9	73.9	0.0	21.1	1.0	1.5	2.5	14
2002	85	97	8.16	7.67	0.48	3.0	2.5	3.7	65.6	0.0	27.5	1.3	2.3	3.4	15
2002	323	3	8.34	7.87	0.47	3.6	2.8	4.1	69.3	0.0	24.3	1.2	2.2	3.0	16
2002	105	8	8.07	7.60	0.46	2.8	2.3	3.6	65.1	0.0	27.8	1.3	2.3	3.4	17
2002	191	16	8.64	8.21	0.43	4.5	3.3	4.9	74.6	0.0	20.7	0.9	1.2	2.5	18
2002	128	3	8.29	7.87	0.42	3.6	2.8	4.1	69.1	0.0	24.6	1.1	2.2	2.9	19
2002	313	8	8.28	7.87	0.41	3.6	2.8	4.1	70.1	0.0	23.9	1.1	2.0	2.9	20
2003	271	3	9.15	8.33	0.81	4.9	3.5	5.1	75.6	0.0	19.5	0.9	1.6	2.4	1
2003	270	1	9.13	8.33	0.80	4.9	3.5	5.1	75.5	0.0	19.6	0.9	1.6	2.4	2
2003	178	3	8.69	8.10	0.58	4.2	3.2	4.6	72.6	0.0	21.7	1.0	2.0	2.7	3
2003	356	16	8.51	7.94	0.58	3.8	2.9	4.3	70.7	0.0	23.3	1.1	2.1	2.8	4
2003	68	3	8.22	7.67	0.55	3.0	2.5	3.7	65.0	0.0	27.8	1.3	2.5	3.4	5
2003	107	1	8.14	7.60	0.54	2.8	2.3	3.6	64.2	0.0	28.7	1.3	2.4	3.5	6
2003	246	3	8.87	8.33	0.53	4.9	3.5	5.1	75.1	0.0	20.0	0.9	1.5	2.4	7
2003	163	3	8.60	8.10	0.50	4.2	3.2	4.6	72.8	0.0	21.7	1.0	1.8	2.7	8
2003	164	97	8.59	8.10	0.49	4.2	3.2	4.6	72.5	0.0	22.0	1.0	1.8	2.6	9
2003	187	3	8.69	8.21	0.49	4.5	3.3	4.9	73.7	0.0	20.9	1.0	1.9	2.5	10
2003	35	10	8.17	7.72	0.45	3.2	2.5	3.8	66.8	0.0	26.5	1.2	2.2	3.3	11
2003	242	16	8.76	8.33	0.42	4.9	3.5	5.1	75.5	0.0	19.7	0.9	1.5	2.4	12
2003	326	1	8.28	7.87	0.41	3.6	2.8	4.1	69.0	0.0	24.5	1.1	2.3	3.0	13
2003	160	3	8.51	8.10	0.41	4.2	3.2	4.6	72.1	0.0	22.1	1.0	2.1	2.7	14
2003	304	1	8.50	8.10	0.40	4.2	3.2	4.6	73.3	0.0	21.2	1.0	1.9	2.6	15
2003	247	97	8.73	8.33	0.39	4.9	3.5	5.1	75.4	0.0	20.0	0.9	1.2	2.4	16
2003	108	3	7.99	7.60	0.39	2.8	2.3	3.6	64.2	0.0	28.7	1.4	2.3	3.4	17
2003	197	9	8.59	8.21	0.38	4.5	3.3	4.9	74.6	0.0	20.1	0.9	2.0	2.4	18
2003	320	25	8.25	7.87	0.37	3.6	2.8	4.1	69.8	0.0	23.9	1.1	2.2	3.0	19
2003	259	3	8.71	8.33	0.37	4.9	3.5	5.1	75.3	0.0	19.7	0.9	1.8	2.3	20

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 25 Days for 3 Years)
Bowen 1-4 Results - Unit 2 Controlled with WESP

						F(RH)			% of Modeled Extinction by Species						
YEAR	DAY	REC	DV(Total)	DV(BKG)	DELTA DV	S	L	SS	% SO4	% NO3	% OC	% EC	% PMC	% PMF	Rank
2001	341	2	9.11	7.94	1.17	3.8	2.9	4.3	70.3	0.0	23.7	1.1	2.1	2.8	1
2002	224	3	9.46	8.33	1.12	4.9	3.5	5.1	75.5	0.0	19.6	0.9	1.7	2.4	2
2002	15	16	8.90	7.82	1.09	3.4	2.7	4.0	68.8	0.0	25.0	1.2	2.1	3.0	3
2002	227	8	9.34	8.33	1.00	4.9	3.5	5.1	75.6	0.0	19.5	0.9	1.6	2.4	4
2002	365	16	8.91	7.94	0.97	3.8	2.9	4.3	70.1	0.0	23.8	1.1	2.1	2.9	5
2002	67	3	8.57	7.67	0.90	3.0	2.5	3.7	65.7	0.0	27.4	1.2	2.4	3.3	6
2001	113	1	8.46	7.60	0.85	2.8	2.3	3.6	64.2	0.0	28.5	1.3	2.6	3.4	7
2002	228	97	9.18	8.33	0.84	4.9	3.5	5.1	75.5	0.0	19.6	0.9	1.6	2.4	8
2002	230	3	9.16	8.33	0.82	4.9	3.5	5.1	75.4	0.0	19.6	0.9	1.8	2.4	9
2003	271	3	9.15	8.33	0.81	4.9	3.5	5.1	75.6	0.0	19.5	0.9	1.6	2.4	10
2003	270	1	9.13	8.33	0.80	4.9	3.5	5.1	75.5	0.0	19.6	0.9	1.6	2.4	11
2002	226	97	9.13	8.33	0.80	4.9	3.5	5.1	75.5	0.0	19.5	0.9	1.7	2.4	12
2001	225	3	9.12	8.33	0.79	4.9	3.5	5.1	75.3	0.0	19.6	0.9	1.7	2.4	13
2002	314	2	8.63	7.87	0.76	3.6	2.8	4.1	69.2	0.0	24.5	1.1	2.2	3.0	14
2002	35	9	8.46	7.72	0.74	3.2	2.5	3.8	67.1	0.0	26.1	1.2	2.5	3.2	15
2001	297	3	8.83	8.10	0.73	4.2	3.2	4.6	72.5	0.0	22.0	1.0	1.8	2.7	16
2001	114	4	8.31	7.60	0.71	2.8	2.3	3.6	64.4	0.0	28.6	1.3	2.2	3.4	17
2002	222	16	9.00	8.33	0.67	4.9	3.5	5.1	75.8	0.0	19.5	0.9	1.4	2.4	18
2001	279	1	8.76	8.10	0.66	4.2	3.2	4.6	73.0	0.0	21.4	1.0	1.9	2.6	19
2002	28	3	8.47	7.82	0.66	3.4	2.7	4.0	68.5	0.0	25.2	1.2	2.1	3.0	20
2001	111	16	8.24	7.60	0.63	2.8	2.3	3.6	64.4	0.0	28.5	1.3	2.3	3.5	21
2001	220	54	8.96	8.33	0.63	4.9	3.5	5.1	75.2	0.0	19.9	0.9	1.6	2.4	22
2002	107	97	8.22	7.60	0.61	2.8	2.3	3.6	64.1	0.0	28.7	1.3	2.5	3.4	23
2001	51	8	8.30	7.72	0.59	3.2	2.5	3.8	67.2	0.0	26.2	1.2	2.2	3.2	24
2003	178	3	8.69	8.10	0.58	4.2	3.2	4.6	72.6	0.0	21.7	1.0	2.0	2.7	25

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 20 Days Each Year)
Bowen 1-4 Results - Unit 3 Controlled with WESP

						F(RH)			% of Modeled Extinction by Species						
YEAR	DAY	REC	DV(Total)	DV(BKG)	DELTA DV	S	L	SS	%_SO4	%_NO3	%_OC	%_EC	%_PMC	%_PMF	Rank
2001	341	1	9.10	7.94	1.16	3.8	2.9	4.3	69.2	0.0	23.8	1.3	2.4	3.3	1
2001	113	1	8.45	7.60	0.84	2.8	2.3	3.6	62.9	0.0	28.7	1.5	3.0	3.9	2
2001	225	3	9.12	8.33	0.79	4.9	3.5	5.1	74.5	0.0	19.6	1.1	2.0	2.8	3
2001	297	3	8.84	8.10	0.74	4.2	3.2	4.6	71.9	0.0	21.7	1.2	2.1	3.1	4
2001	114	4	8.30	7.60	0.70	2.8	2.3	3.6	63.2	0.0	28.8	1.5	2.5	4.0	5
2001	220	54	8.98	8.33	0.65	4.9	3.5	5.1	74.9	0.0	19.3	1.1	1.9	2.8	6
2001	279	4	8.74	8.10	0.64	4.2	3.2	4.6	71.5	0.0	22.2	1.2	2.2	3.0	7
2001	111	16	8.23	7.60	0.63	2.8	2.3	3.6	63.1	0.0	28.8	1.5	2.6	4.0	8
2001	294	1	8.69	8.10	0.59	4.2	3.2	4.6	71.9	0.0	21.5	1.2	2.3	3.1	9
2001	51	8	8.28	7.72	0.56	3.2	2.5	3.8	65.0	0.0	27.6	1.4	2.4	3.6	10
2001	102	9	8.11	7.60	0.51	2.8	2.3	3.6	63.1	0.0	28.7	1.6	2.7	4.0	11
2001	229	16	8.79	8.33	0.46	4.9	3.5	5.1	74.8	0.0	19.9	1.0	1.5	2.8	12
2001	110	3	8.05	7.60	0.45	2.8	2.3	3.6	63.2	0.0	28.5	1.6	2.7	4.0	13
2001	142	3	8.28	7.87	0.40	3.6	2.8	4.1	68.8	0.0	24.4	1.4	1.9	3.5	14
2001	112	35	8.00	7.60	0.40	2.8	2.3	3.6	63.2	0.0	28.7	1.5	2.5	4.0	15
2001	343	97	8.33	7.94	0.40	3.8	2.9	4.3	69.5	0.0	23.3	1.4	2.4	3.4	16
2001	126	3	8.25	7.87	0.38	3.6	2.8	4.1	68.5	0.0	24.4	1.3	2.2	3.6	17
2001	158	25	8.47	8.10	0.37	4.2	3.2	4.6	71.1	0.0	22.7	1.1	2.2	2.9	18
2001	236	25	8.70	8.33	0.36	4.9	3.5	5.1	74.4	0.0	19.7	1.1	2.1	2.8	19
2001	198	9	8.56	8.21	0.35	4.5	3.3	4.9	73.3	0.0	20.6	1.1	1.9	3.0	20
2002	224	3	9.45	8.33	1.12	4.9	3.5	5.1	74.5	0.0	19.7	1.1	2.0	2.7	1
2002	15	16	8.87	7.82	1.05	3.4	2.7	4.0	67.1	0.0	25.8	1.3	2.3	3.4	2
2002	227	8	9.33	8.33	0.99	4.9	3.5	5.1	74.5	0.0	19.8	1.1	1.9	2.7	3
2002	365	16	8.91	7.94	0.97	3.8	2.9	4.3	69.3	0.0	23.7	1.3	2.4	3.3	4
2002	67	2	8.57	7.67	0.89	3.0	2.5	3.7	64.5	0.0	27.5	1.5	2.7	3.8	5
2002	228	97	9.17	8.33	0.84	4.9	3.5	5.1	74.6	0.0	19.7	1.1	1.9	2.7	6
2002	230	3	9.15	8.33	0.82	4.9	3.5	5.1	74.5	0.0	19.7	1.0	2.0	2.8	7
2002	226	97	9.12	8.33	0.79	4.9	3.5	5.1	74.6	0.0	19.8	1.0	2.0	2.7	8
2002	314	2	8.62	7.87	0.75	3.6	2.8	4.1	68.1	0.0	24.6	1.3	2.5	3.4	9
2002	35	9	8.42	7.72	0.70	3.2	2.5	3.8	64.8	0.0	27.5	1.4	2.7	3.5	10
2002	222	16	8.99	8.33	0.66	4.9	3.5	5.1	74.8	0.0	19.8	1.0	1.6	2.7	11
2002	28	3	8.46	7.82	0.65	3.4	2.7	4.0	67.1	0.0	25.6	1.3	2.4	3.5	12
2002	107	97	8.22	7.60	0.62	2.8	2.3	3.6	63.1	0.0	28.5	1.5	2.8	4.0	13
2002	207	9	8.79	8.21	0.59	4.5	3.3	4.9	73.5	0.0	20.7	1.1	1.7	3.0	14
2002	85	97	8.16	7.67	0.48	3.0	2.5	3.7	64.5	0.0	27.5	1.4	2.7	3.9	15
2002	323	3	8.34	7.87	0.47	3.6	2.8	4.1	68.1	0.0	24.7	1.3	2.6	3.4	16
2002	105	16	8.04	7.60	0.44	2.8	2.3	3.6	62.7	0.0	29.3	1.5	2.7	3.9	17
2002	191	16	8.63	8.21	0.43	4.5	3.3	4.9	73.4	0.0	21.1	1.1	1.5	2.9	18
2002	128	3	8.30	7.87	0.42	3.6	2.8	4.1	68.2	0.0	24.5	1.3	2.6	3.5	19
2002	106	8	8.01	7.60	0.41	2.8	2.3	3.6	63.0	0.0	28.6	1.5	2.9	4.0	20
2003	271	3	9.14	8.33	0.80	4.9	3.5	5.1	74.6	0.0	19.8	1.1	1.9	2.7	1
2003	270	1	9.13	8.33	0.79	4.9	3.5	5.1	74.6	0.0	19.7	1.1	1.9	2.7	2
2003	178	3	8.68	8.10	0.58	4.2	3.2	4.6	71.5	0.0	21.9	1.1	2.4	3.1	3
2003	68	3	8.24	7.67	0.57	3.0	2.5	3.7	64.7	0.0	26.9	1.5	3.0	3.9	4
2003	356	16	8.49	7.94	0.56	3.8	2.9	4.3	69.0	0.0	24.2	1.2	2.4	3.3	5
2003	246	3	8.88	8.33	0.55	4.9	3.5	5.1	75.1	0.0	19.3	1.1	1.6	2.8	6
2003	107	1	8.14	7.60	0.54	2.8	2.3	3.6	63.1	0.0	28.6	1.6	2.7	4.0	7
2003	164	97	8.60	8.10	0.50	4.2	3.2	4.6	71.9	0.0	21.7	1.2	2.1	3.1	8
2003	163	3	8.60	8.10	0.49	4.2	3.2	4.6	71.7	0.0	22.0	1.2	2.1	3.1	9
2003	187	3	8.70	8.21	0.49	4.5	3.3	4.9	73.0	0.0	20.6	1.2	2.2	3.0	10
2003	35	10	8.16	7.72	0.45	3.2	2.5	3.8	65.3	0.0	27.1	1.5	2.5	3.7	11
2003	242	16	8.76	8.33	0.42	4.9	3.5	5.1	74.8	0.0	19.6	1.0	1.7	2.8	12
2003	160	3	8.52	8.10	0.42	4.2	3.2	4.6	71.8	0.0	21.4	1.2	2.4	3.2	13
2003	326	1	8.28	7.87	0.41	3.6	2.8	4.1	68.0	0.0	24.5	1.3	2.7	3.5	14
2003	247	97	8.74	8.33	0.41	4.9	3.5	5.1	75.3	0.0	19.4	1.1	1.4	2.8	15
2003	108	1	7.99	7.60	0.39	2.8	2.3	3.6	63.2	0.0	28.4	1.6	2.7	4.0	16
2003	304	25	8.48	8.10	0.38	4.2	3.2	4.6	71.3	0.0	22.4	1.2	2.1	3.0	17
2003	259	3	8.71	8.33	0.38	4.9	3.5	5.1	74.6	0.0	19.5	1.0	2.1	2.8	18
2003	316	97	8.24	7.87	0.37	3.6	2.8	4.1	68.4	0.0	24.3	1.4	2.5	3.5	19
2003	166	46	8.47	8.10	0.37	4.2	3.2	4.6	71.8	0.0	21.9	1.2	2.1	3.1	20

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 25 Days for 3 Years)
Bowen 1-4 Results - Unit 3 Controlled with WESP

						F(RH)			% of Modeled Extinction by Species						
YEAR	**DAY**	**REC**	**DV(Total)**	**DV(BKG)**	**DELTA DV**	**S**	**L**	**SS**	**%_SO4**	**%_NO3**	**%_OC**	**%_EC**	**%_PMC**	**%_PMF**	**Rank**
2001	341	1	9.10	7.94	1.16	3.8	2.9	4.3	69.2	0.0	23.8	1.3	2.4	3.3	1
2002	224	3	9.45	8.33	1.12	4.9	3.5	5.1	74.5	0.0	19.7	1.1	2.0	2.7	2
2002	15	16	8.87	7.82	1.05	3.4	2.7	4.0	67.1	0.0	25.8	1.3	2.3	3.4	3
2002	227	8	9.33	8.33	0.99	4.9	3.5	5.1	74.5	0.0	19.8	1.1	1.9	2.7	4
2002	365	16	8.91	7.94	0.97	3.8	2.9	4.3	69.3	0.0	23.7	1.3	2.4	3.3	5
2002	67	2	8.57	7.67	0.89	3.0	2.5	3.7	64.5	0.0	27.5	1.5	2.7	3.8	6
2001	113	1	8.45	7.60	0.84	2.8	2.3	3.6	62.9	0.0	28.7	1.5	3.0	3.9	7
2002	228	97	9.17	8.33	0.84	4.9	3.5	5.1	74.6	0.0	19.7	1.1	1.9	2.7	8
2002	230	3	9.15	8.33	0.82	4.9	3.5	5.1	74.5	0.0	19.7	1.0	2.0	2.8	9
2003	271	3	9.14	8.33	0.80	4.9	3.5	5.1	74.6	0.0	19.8	1.1	1.9	2.7	10
2003	270	1	9.13	8.33	0.79	4.9	3.5	5.1	74.6	0.0	19.7	1.1	1.9	2.7	11
2001	225	3	9.12	8.33	0.79	4.9	3.5	5.1	74.5	0.0	19.6	1.1	2.0	2.8	12
2002	226	97	9.12	8.33	0.79	4.9	3.5	5.1	74.6	0.0	19.8	1.0	2.0	2.7	13
2002	314	2	8.62	7.87	0.75	3.6	2.8	4.1	68.1	0.0	24.6	1.3	2.5	3.4	14
2001	297	3	8.84	8.10	0.74	4.2	3.2	4.6	71.9	0.0	21.7	1.2	2.1	3.1	15
2002	35	9	8.42	7.72	0.70	3.2	2.5	3.8	64.8	0.0	27.5	1.4	2.7	3.5	16
2001	114	4	8.30	7.60	0.70	2.8	2.3	3.6	63.2	0.0	28.8	1.5	2.5	4.0	17
2002	222	16	8.99	8.33	0.66	4.9	3.5	5.1	74.8	0.0	19.8	1.0	1.6	2.7	18
2001	220	54	8.98	8.33	0.65	4.9	3.5	5.1	74.9	0.0	19.3	1.1	1.9	2.8	19
2002	28	3	8.46	7.82	0.65	3.4	2.7	4.0	67.1	0.0	25.6	1.3	2.4	3.5	20
2001	279	4	8.74	8.10	0.64	4.2	3.2	4.6	71.5	0.0	22.2	1.2	2.2	3.0	21
2001	111	16	8.23	7.60	0.63	2.8	2.3	3.6	63.1	0.0	28.8	1.5	2.6	4.0	22
2002	107	97	8.22	7.60	0.62	2.8	2.3	3.6	63.1	0.0	28.5	1.5	2.8	4.0	23
2001	294	1	8.69	8.10	0.59	4.2	3.2	4.6	71.9	0.0	21.5	1.2	2.3	3.1	24
2002	207	9	8.79	8.21	0.59	4.5	3.3	4.9	73.5	0.0	20.7	1.1	1.7	3.0	25

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 20 Days Each Year)
Bowen 1-4 Results - Unit 4 Controlled with WESP

						F(RH)			% of Modeled Extinction by Species						
YEAR	**DAY**	**REC**	**DV(Total)**	**DV(BKG)**	**DELTA DV**	**S**	**L**	**SS**	**% SO4**	**% NO3**	**% OC**	**% EC**	**% PMC**	**% PMF**	**Rank**
2001	341	1	9.09	7.94	1.15	3.8	2.9	4.3	69.0	0.0	24.1	1.3	2.4	3.3	1
2001	113	1	8.44	7.60	0.84	2.8	2.3	3.6	62.7	0.0	29.0	1.5	2.9	3.9	2
2001	225	3	9.11	8.33	0.78	4.9	3.5	5.1	74.4	0.0	19.8	1.0	2.0	2.7	3
2001	297	3	8.83	8.10	0.73	4.2	3.2	4.6	71.8	0.0	21.9	1.2	2.0	3.1	4
2001	114	4	8.30	7.60	0.69	2.8	2.3	3.6	63.0	0.0	29.1	1.5	2.5	3.9	5
2001	220	54	8.98	8.33	0.64	4.9	3.5	5.1	74.8	0.0	19.5	1.1	1.8	2.8	6
2001	279	4	8.73	8.10	0.63	4.2	3.2	4.6	71.3	0.0	22.5	1.1	2.1	3.0	7
2001	111	16	8.22	7.60	0.62	2.8	2.3	3.6	62.9	0.0	29.1	1.5	2.6	3.9	8
2001	294	1	8.68	8.10	0.58	4.2	3.2	4.6	71.6	0.0	21.7	1.2	2.3	3.1	9
2001	51	8	8.27	7.72	0.55	3.2	2.5	3.8	64.8	0.0	27.9	1.3	2.4	3.5	10
2001	102	9	8.11	7.60	0.50	2.8	2.3	3.6	62.9	0.0	29.0	1.5	2.6	3.9	11
2001	229	16	8.79	8.33	0.45	4.9	3.5	5.1	74.7	0.0	20.1	1.1	1.4	2.7	12
2001	110	3	8.04	7.60	0.44	2.8	2.3	3.6	63.1	0.0	28.9	1.5	2.6	4.0	13
2001	142	3	8.27	7.87	0.40	3.6	2.8	4.1	68.7	0.0	24.6	1.4	1.8	3.4	14
2001	112	35	8.00	7.60	0.40	2.8	2.3	3.6	63.0	0.0	29.0	1.6	2.5	3.9	15
2001	343	97	8.33	7.94	0.39	3.8	2.9	4.3	69.5	0.0	23.5	1.3	2.3	3.4	16
2001	126	3	8.24	7.87	0.37	3.6	2.8	4.1	68.3	0.0	24.6	1.4	2.2	3.5	17
2001	158	25	8.47	8.10	0.37	4.2	3.2	4.6	70.9	0.0	23.0	1.1	2.2	2.8	18
2001	236	25	8.69	8.33	0.36	4.9	3.5	5.1	74.2	0.0	19.9	1.1	2.1	2.7	19
2001	198	9	8.56	8.21	0.35	4.5	3.3	4.9	73.2	0.0	20.9	1.1	1.9	2.9	20
2002	224	3	9.44	8.33	1.11	4.9	3.5	5.1	74.4	0.0	19.9	1.1	1.9	2.7	1
2002	15	16	8.86	7.82	1.04	3.4	2.7	4.0	66.9	0.0	26.2	1.3	2.3	3.4	2
2002	227	8	9.31	8.33	0.98	4.9	3.5	5.1	74.4	0.0	20.1	1.0	1.9	2.7	3
2002	365	16	8.90	7.94	0.97	3.8	2.9	4.3	69.1	0.0	23.9	1.3	2.4	3.3	4
2002	67	2	8.56	7.67	0.88	3.0	2.5	3.7	64.3	0.0	27.8	1.5	2.6	3.8	5
2002	228	97	9.16	8.33	0.83	4.9	3.5	5.1	74.4	0.0	20.0	1.0	1.9	2.7	6
2002	230	3	9.15	8.33	0.81	4.9	3.5	5.1	74.3	0.0	19.9	1.1	2.0	2.7	7
2002	226	97	9.11	8.33	0.78	4.9	3.5	5.1	74.4	0.0	20.0	1.0	1.9	2.7	8
2002	314	2	8.61	7.87	0.74	3.6	2.8	4.1	67.9	0.0	24.9	1.3	2.5	3.3	9
2002	35	9	8.41	7.72	0.70	3.2	2.5	3.8	64.6	0.0	27.8	1.3	2.7	3.5	10
2002	222	16	8.98	8.33	0.65	4.9	3.5	5.1	74.6	0.0	20.1	1.1	1.5	2.7	11
2002	28	3	8.46	7.82	0.64	3.4	2.7	4.0	66.9	0.0	25.9	1.4	2.3	3.5	12
2002	107	97	8.21	7.60	0.61	2.8	2.3	3.6	62.8	0.0	28.8	1.5	2.8	4.0	13
2002	207	9	8.79	8.21	0.58	4.5	3.3	4.9	73.4	0.0	20.9	1.1	1.7	2.9	14
2002	85	97	8.15	7.67	0.48	3.0	2.5	3.7	64.3	0.0	27.8	1.5	2.6	3.8	15
2002	323	3	8.33	7.87	0.46	3.6	2.8	4.1	67.9	0.0	25.0	1.3	2.5	3.4	16
2002	105	16	8.04	7.60	0.44	2.8	2.3	3.6	62.5	0.0	29.6	1.5	2.6	3.8	17
2002	191	16	8.63	8.21	0.42	4.5	3.3	4.9	73.3	0.0	21.4	1.2	1.4	2.8	18
2002	128	3	8.29	7.87	0.42	3.6	2.8	4.1	68.1	0.0	24.7	1.3	2.5	3.4	19
2002	106	8	8.00	7.60	0.40	2.8	2.3	3.6	62.8	0.0	28.9	1.5	2.8	3.9	20
2003	271	3	9.13	8.33	0.79	4.9	3.5	5.1	74.4	0.0	20.0	1.0	1.8	2.7	1
2003	270	1	9.12	8.33	0.79	4.9	3.5	5.1	74.5	0.0	19.9	1.0	1.8	2.7	2
2003	178	3	8.68	8.10	0.57	4.2	3.2	4.6	71.4	0.0	22.1	1.2	2.3	3.0	3
2003	68	3	8.24	7.67	0.56	3.0	2.5	3.7	64.5	0.0	27.2	1.5	3.0	3.9	4
2003	356	16	8.49	7.94	0.55	3.8	2.9	4.3	68.7	0.0	24.5	1.2	2.4	3.2	5
2003	246	3	8.88	8.33	0.55	4.9	3.5	5.1	74.9	0.0	19.5	1.1	1.7	2.8	6
2003	107	1	8.14	7.60	0.53	2.8	2.3	3.6	62.9	0.0	28.9	1.5	2.7	4.0	7
2003	164	97	8.59	8.10	0.49	4.2	3.2	4.6	71.8	0.0	22.0	1.2	2.0	3.1	8
2003	163	3	8.59	8.10	0.49	4.2	3.2	4.6	71.6	0.0	22.2	1.2	2.0	3.0	9
2003	187	3	8.69	8.21	0.49	4.5	3.3	4.9	72.9	0.0	20.9	1.1	2.2	2.9	10
2003	35	10	8.16	7.72	0.44	3.2	2.5	3.8	65.1	0.0	27.4	1.4	2.4	3.6	11
2003	242	16	8.75	8.33	0.42	4.9	3.5	5.1	74.7	0.0	19.9	1.0	1.7	2.7	12
2003	160	3	8.52	8.10	0.42	4.2	3.2	4.6	71.7	0.0	21.7	1.2	2.3	3.1	13
2003	326	1	8.28	7.87	0.41	3.6	2.8	4.1	67.8	0.0	24.8	1.4	2.6	3.4	14
2003	247	97	8.74	8.33	0.40	4.9	3.5	5.1	75.1	0.0	19.6	1.1	1.4	2.8	15
2003	108	1	7.99	7.60	0.38	2.8	2.3	3.6	63.1	0.0	28.8	1.5	2.7	4.0	16
2003	304	25	8.48	8.10	0.37	4.2	3.2	4.6	71.2	0.0	22.7	1.1	2.2	2.9	17
2003	259	3	8.70	8.33	0.37	4.9	3.5	5.1	74.4	0.0	19.7	1.1	2.1	2.7	18
2003	316	97	8.24	7.87	0.37	3.6	2.8	4.1	68.1	0.0	24.5	1.4	2.5	3.5	19
2003	166	46	8.46	8.10	0.36	4.2	3.2	4.6	71.6	0.0	22.2	1.1	2.1	3.0	20

New IMPROVE/Virtual Temp - Ranked Daily Visibility Change for Cohutta (Top 25 Days for 3 Years)
Bowen 1-4 Results - Unit 4 Controlled with WESP

						F(RH)			% of Modeled Extinction by Species						
YEAR	**DAY**	**REC**	**DV(Total)**	**DV(BKG)**	**DELTA DV**	**S**	**L**	**SS**	**% SO4**	**% NO3**	**% OC**	**% EC**	**% PMC**	**% PMF**	**Rank**
2001	341	1	9.09	7.94	1.15	3.8	2.9	4.3	69.0	0.0	24.1	1.3	2.4	3.3	1
2002	224	3	9.44	8.33	1.11	4.9	3.5	5.1	74.4	0.0	19.9	1.1	1.9	2.7	2
2002	15	16	8.86	7.82	1.04	3.4	2.7	4.0	66.9	0.0	26.2	1.3	2.3	3.4	3
2002	227	8	9.31	8.33	0.98	4.9	3.5	5.1	74.4	0.0	20.1	1.0	1.9	2.7	4
2002	365	16	8.90	7.94	0.97	3.8	2.9	4.3	69.1	0.0	23.9	1.3	2.4	3.3	5
2002	67	2	8.56	7.67	0.88	3.0	2.5	3.7	64.3	0.0	27.8	1.5	2.6	3.8	6
2001	113	1	8.44	7.60	0.84	2.8	2.3	3.6	62.7	0.0	29.0	1.5	2.9	3.9	7
2002	228	97	9.16	8.33	0.83	4.9	3.5	5.1	74.4	0.0	20.0	1.0	1.9	2.7	8
2002	230	3	9.15	8.33	0.81	4.9	3.5	5.1	74.3	0.0	19.9	1.1	2.0	2.7	9
2003	271	3	9.13	8.33	0.79	4.9	3.5	5.1	74.4	0.0	20.0	1.0	1.8	2.7	10
2003	270	1	9.12	8.33	0.79	4.9	3.5	5.1	74.5	0.0	19.9	1.0	1.8	2.7	11
2001	225	3	9.11	8.33	0.78	4.9	3.5	5.1	74.4	0.0	19.8	1.0	2.0	2.7	12
2002	226	97	9.11	8.33	0.78	4.9	3.5	5.1	74.4	0.0	20.0	1.0	1.9	2.7	13
2002	314	2	8.61	7.87	0.74	3.6	2.8	4.1	67.9	0.0	24.9	1.3	2.5	3.3	14
2001	297	3	8.83	8.10	0.73	4.2	3.2	4.6	71.8	0.0	21.9	1.2	2.0	3.1	15
2002	35	9	8.41	7.72	0.70	3.2	2.5	3.8	64.6	0.0	27.8	1.3	2.7	3.5	16
2001	114	4	8.30	7.60	0.69	2.8	2.3	3.6	63.0	0.0	29.1	1.5	2.5	3.9	17
2002	222	16	8.98	8.33	0.65	4.9	3.5	5.1	74.6	0.0	20.1	1.1	1.5	2.7	18
2001	220	54	8.98	8.33	0.64	4.9	3.5	5.1	74.8	0.0	19.5	1.1	1.8	2.8	19
2002	28	3	8.46	7.82	0.64	3.4	2.7	4.0	66.9	0.0	25.9	1.4	2.3	3.5	20
2001	279	4	8.73	8.10	0.63	4.2	3.2	4.6	71.3	0.0	22.5	1.1	2.1	3.0	21
2001	111	16	8.22	7.60	0.62	2.8	2.3	3.6	62.9	0.0	29.1	1.5	2.6	3.9	22
2002	107	97	8.21	7.60	0.61	2.8	2.3	3.6	62.8	0.0	28.8	1.5	2.8	4.0	23
2001	294	1	8.68	8.10	0.58	4.2	3.2	4.6	71.6	0.0	21.7	1.2	2.3	3.1	24
2002	207	9	8.79	8.21	0.58	4.5	3.3	4.9	73.4	0.0	20.9	1.1	1.7	2.9	25