Analysis of air quality data in the Columbia River Gorge during temporary shutdowns at the PGE Boardman plant

Report to the Yakama Nation
by Dr. Dan Jaffe
Northwest Air Quality
NW_airquality@hotmail.com
February 27, 2008

Executive Summary

In an earlier report, I analyzed 12 years of IMPROVE aerosol data from the site located at Wishram, Washington, along with airmass back-trajectories to indicate source region. The data were used to identify the 50 worst air quality days in the Columbia River Gorge (CRG) between 1993-2004. A key result from that work was that the days with the worst air quality in the CRG were associated with transport and sources on the east end of the Gorge, including the PGE coal fired power plant at Boardman, Oregon. I have extended this analysis to consider months when the PGE Boardman plant was temporarily shutdown and therefore had zero emissions. In this way I can more precisely quantify the contribution from the Boardman plant to haze in the CRG.

From this analysis, I find that the PGE Boardman plant has a significant influence on air quality in the CRG. The contribution to fine particle mass (haze) at Wishram from the Boardman plant is 0.90 ug/m^3 for the entire year, 3.94 ug/m^3 if only the month of November is considered and 7.40 ug/m^3 if only November days when the airflow is coming "down-gorge" (from east to west) is considered. In all 3 cases the results are statistically significant at a 95% confidence interval or better. These results indicate a much larger influence from the PGE Boardman plant on air quality in the CRG, compared to results of the Columbia River Gorge Air Quality Study, Science Summary Report (abbreviated here as CRG-AQS). The most likely cause for this discrepancy is that our analysis is based on data collected at Wishram, whereas the CRG-AQS base their conclusions on a computer simulation, and this simulation shows a significant discrepancy with the actual data.

These results have important policy implications regarding pollution controls on the PGE Boardman plant:

1) The PGE Boardman plant has a significant influence on air quality and haze in the CRG. Days with the worst air quality in the CRG occur in the fall and are associated

with "down-gorge" atmospheric transport (east to west). For these days, the average contribution from the PGE Boardman plant is 7.40 ug/m^3. This makes it one of the largest contributors to air quality degradation in the CRG during these days.

2) As emissions from the PGE Boardman plant are reduced, I would expect an approximately linear reduction in its contribution to haze in the CRG. In other words, a 50% reduction in all emissions from the PGE Boardman plant would bring its contribution to fine particle haze in the CRG to 3.70 ug/m^3, which is still a very significant contribution.

Introduction

In my earlier analysis, I found that the worst air quality days were associated with sources in the eastern Columbia River Gorge (CRG) and were much more frequent in the fall, especially the month of November, when 18 of the 50 worst days occurred (Jaffe 2006). At the time that work was conducted, IMPROVE data was available only through 2004. To extend this work, I have incorporated all data through 2006, focusing on a period in late 2005 when the PGE Boardman power plant was shutdown due to a problem with a main turbine unit. Since the plant was almost fully shutdown in November 2005, this presents an ideal opportunity to examine the influence of the PGE Boardman plant during the month when we expect the greatest influence from the plant on air quality in the CRG.

Method

Data for this work come from several sources. Aerosol data from the Wishram site for 1993-2006 is from the IMPROVE program website (http://vista.cira.colostate.edu/improve/). Backward airmass trajectories were calculated using the on-line HYSPLIT model (http://www.arl.noaa.gov/ready.html). I used identical procedures and meteorological data as in my earlier report (Jaffe 2006). Emission data for the PGE Boardman plant were provided by Mark Fisher from the Oregon Department of Environmental Quality (ODEQ). The monthly NOx and SO_2 emissions were determined from continuous emission monitor measurements and reported annually to ODEQ on Form F1106 for the years 1992-2006.

Results

Figure 1 shows the monthly NOx emission for the PGE Boardman plant going back to 1992. In most months, NOx emissions are close to 1000 tons. Over the 15 year timeframe, there have been several periods with extended shutdowns that resulted in significantly lower NOx emissions. Simply put, if no coal is burned then no NOx is generated. These shutdowns have occurred for a variety of reasons, both scheduled and unscheduled. Of the 163 months for which I have data, 33 months have emissions of less than 100 tons/month.

<u>I assume that if NOx emissions are essentially zero, than all other emissions will be near zero. It is important to note that I am using the PGE Boardman NOx emissions as a surrogate for all plant emissions.</u>

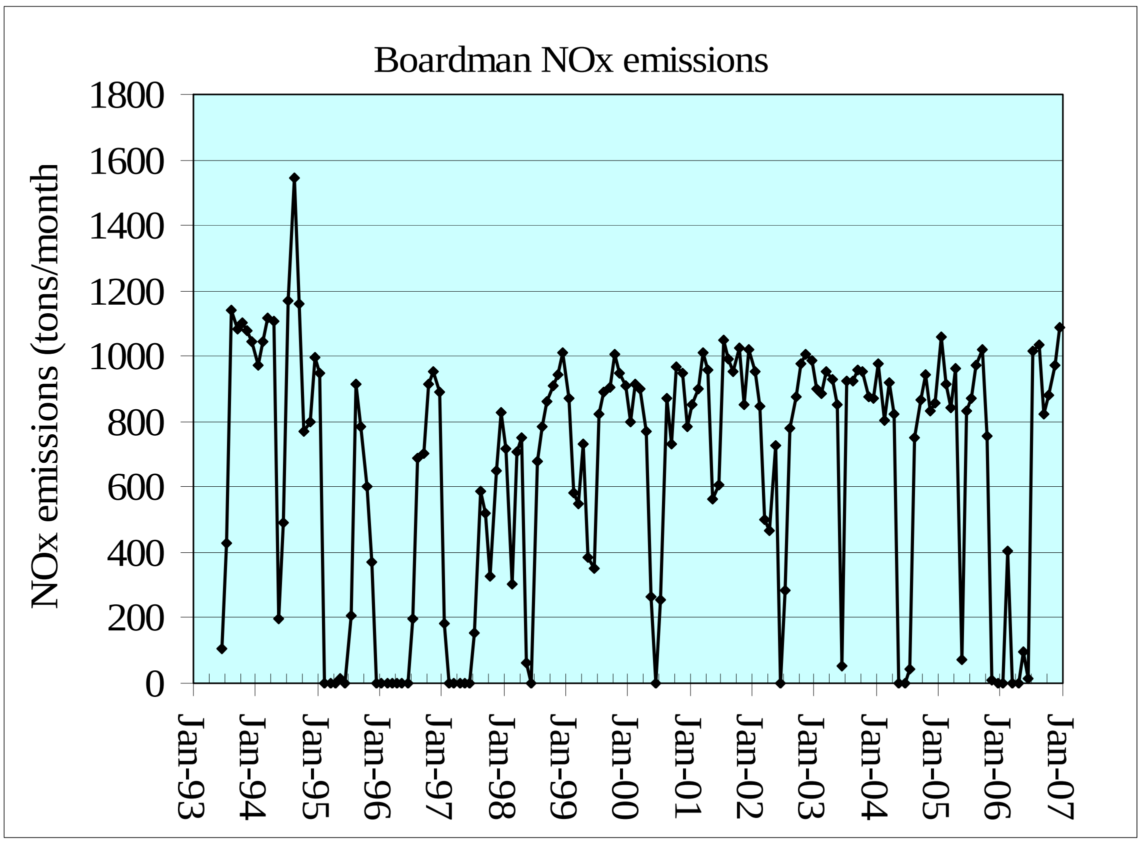

Figure 1. NOx emissions (tons/month) for the PGE Boardman plant.

I examined all of the Wishram IMPROVE data to see if I could identify an improvement in air quality in those months when the PGE plant had zero or insignificant emissions. Figure 2 shows the monthly average fine mass concentration (PM2.5) measured at Wishram vs the PGE Boardman NOx emissions.

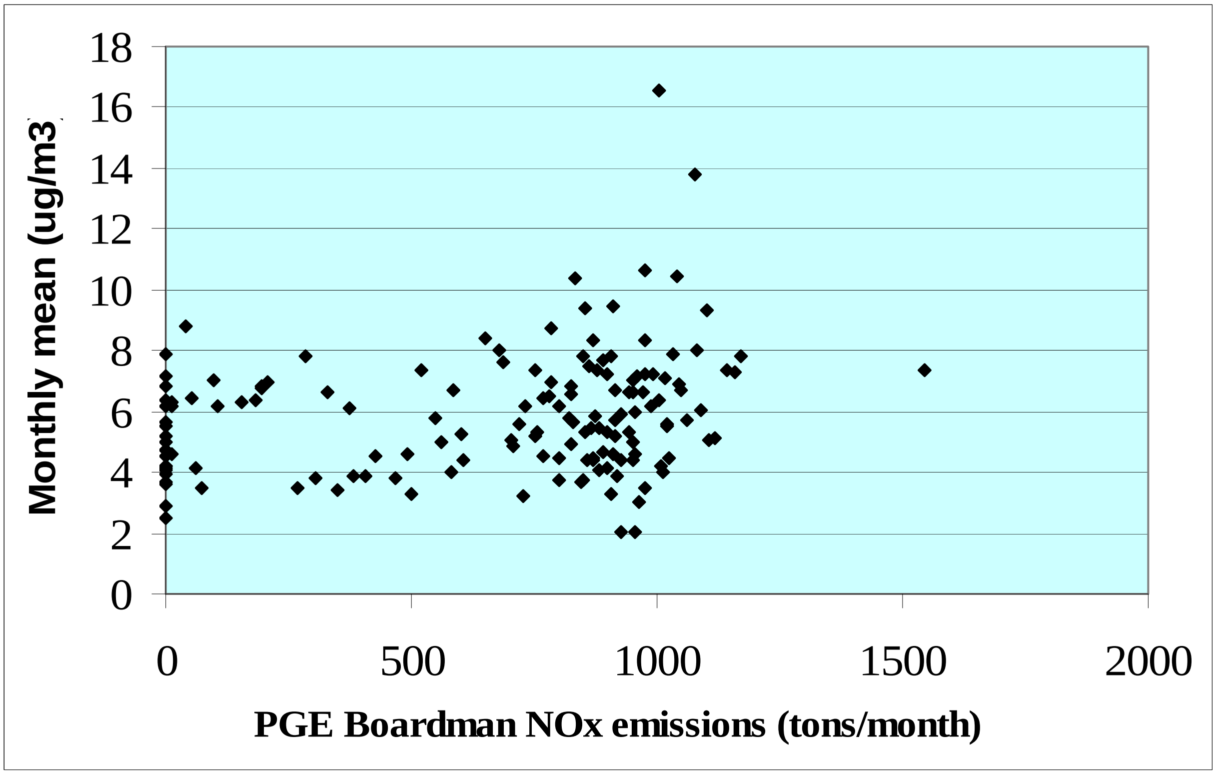

Figure 2. Monthly mean fine mass concentration (PM2.5) measured at Wishram vs PGE Boardman NOx emissions (tons/month).

Figure 2 does not show an obvious relationship, but this is not surprising given the large seasonal and daily variations in meteorology and transport. On the other hand if we examine Figure 2 closely we see that only when the emissions are high, do we get high PM concentrations in the CRG.

If I segregate the data to compare months with low emissions vs months with high (or normal) emissions, I find there is a significant difference. Comparing months that have emissions of less than 100 tons, I find that the difference is 0.90 ug/m^3. Using a t-test to compare months with emissions above and below 100 tons, this difference is statistically significant with a confidence of 95% or greater. Choosing a slightly different segregation criteria (e.g. 200 tons/month or 300 tons/month) has no impact on this conclusion. Table 1 shows details on the data above and below 100 tons/month.

	Months with emissions >100 tons	Months with emissions <100 tons
Number	122	30
Average fine mass (ug/m^3)	6.06	5.16
S.D.	2.10	1.50

Table 1. Comparison of fine mass data (PM2.5) for months with greater than, and less than, 100 tons. The difference (0.90 ug/m^3) is statistically significant at a confidence of 95% or better.

Based on our earlier findings (Jaffe 2006) I expect to identify an even larger influence on air quality from the PGE Boardman plant during the fall, especially November. Of the months with very low NOx emissions, one period occurred in November 2005, when the plant suffered an extended shutdown (November 2005-June 2006) due to a turbine failure. I will therefore evaluate the November 2005 data in more detail. Figure 2 shows a time series of just the November data for all years.

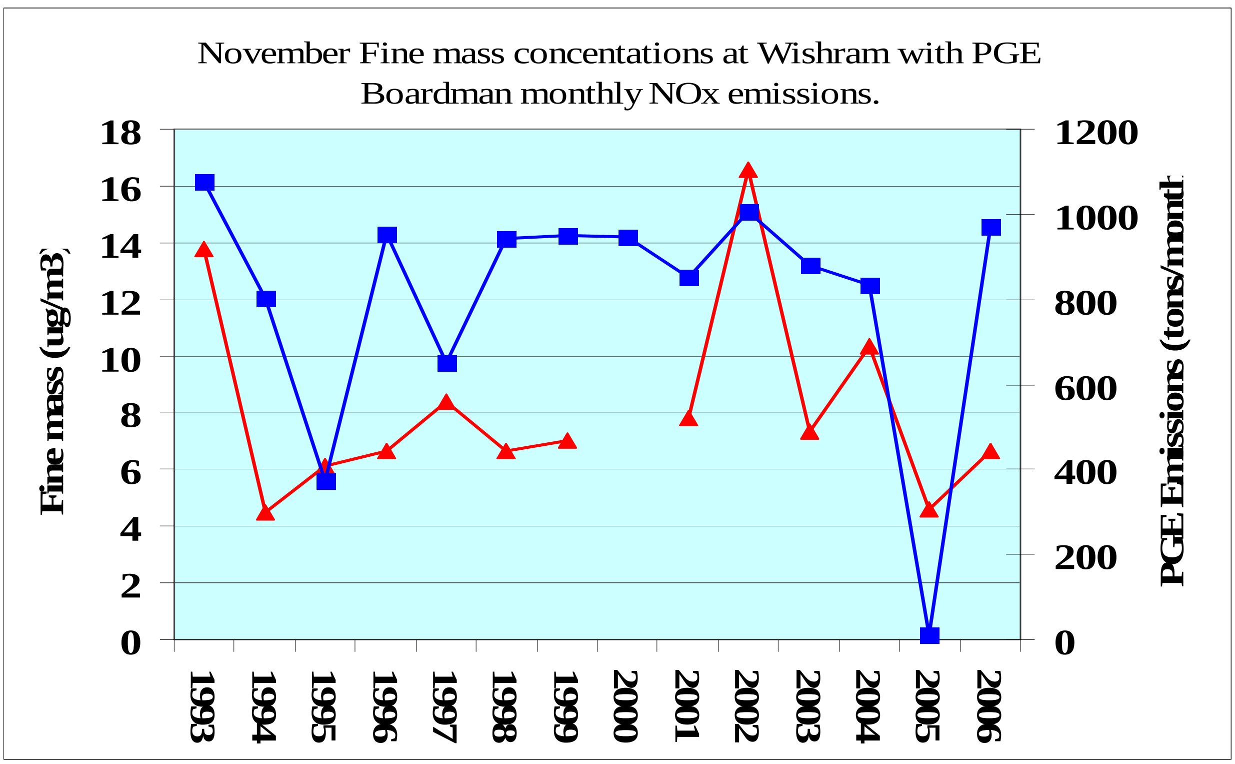

Figure 3. Average fine mass (PM2.5) concentrations for November 1993-2006 at Wishram (red triangles) and PGE Boardman NOx emission (blue squares). In November 2005 the PGE Boardman plant was essentially shut down due to a turbine problem so NOx emissions were near zero for that month.

From an air quality point of view, the cleanest November on record was in 2005, with an average fine mass concentration of 4.61 ug/m^3. I compared the mean concentration for November 2005 with all other November data. A bar graph comparison is shown in Figure 4 and a summary of the results is shown in Table 2.

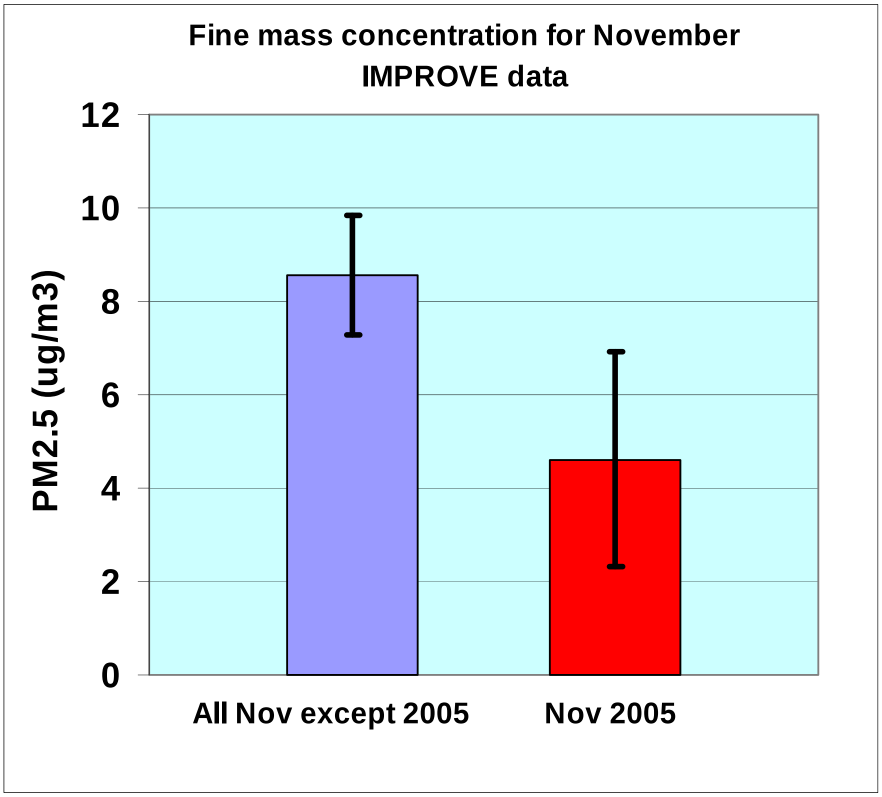

Figure 4: Comparison of IMPROVE data from Wishram for November 2005 data (red bar on right) with all other Novembers data (blue bar on left). The error bars show the 95% confidence interval for each dataset and these do not overlap. A t-test confirms that the difference (3.94 ug/m^3) is statistically significant with a confidence of greater than 95%. More detailed data are shown in Table 2.

	All November data except 2005	**November 2005**
Number of IMPROVE observations	108	10
Mean fine mass concentration (ug/m^3)	8.55	4.61
S.D.	6.76	3.74

Table 2. Comparison of November 2005 IMPROVE observations with all other November observations. A t-test confirms that the difference (3.94 ug/m^3) is statistically significant with a confidence of greater than 95%.

So far I have analyzed the impacts of the PGE Boardman emissions on all data and on only November data. Again, referring to our previous work, I found that the influence from sources in the Eastern end of the CRG was strongest when airmass trajectories indicated strong transport from the east end of the Gorge. So I have further segregated our analysis by only looking at the data when back trajectories indicated this transport. As I reported earlier (Jaffe 2006), these days are associated with the highest fine mass concentrations in the CRG. Example trajectories can be found in our earlier report.

Figure 5 compares the fine mass concentration from November 2005 with all other November data, but in both cases, only days with airmass transport from the eastern CRG are included. While this significantly reduces the number of data points, it points out the strong influence from the PGE Boardman emissions. For dates with transport from the eastern CRG, the average fine mass concentration in November 2005 is 5.94 ug/m^3, compared to 13.34 ug/m^3 for all other November data with similar transport patterns.

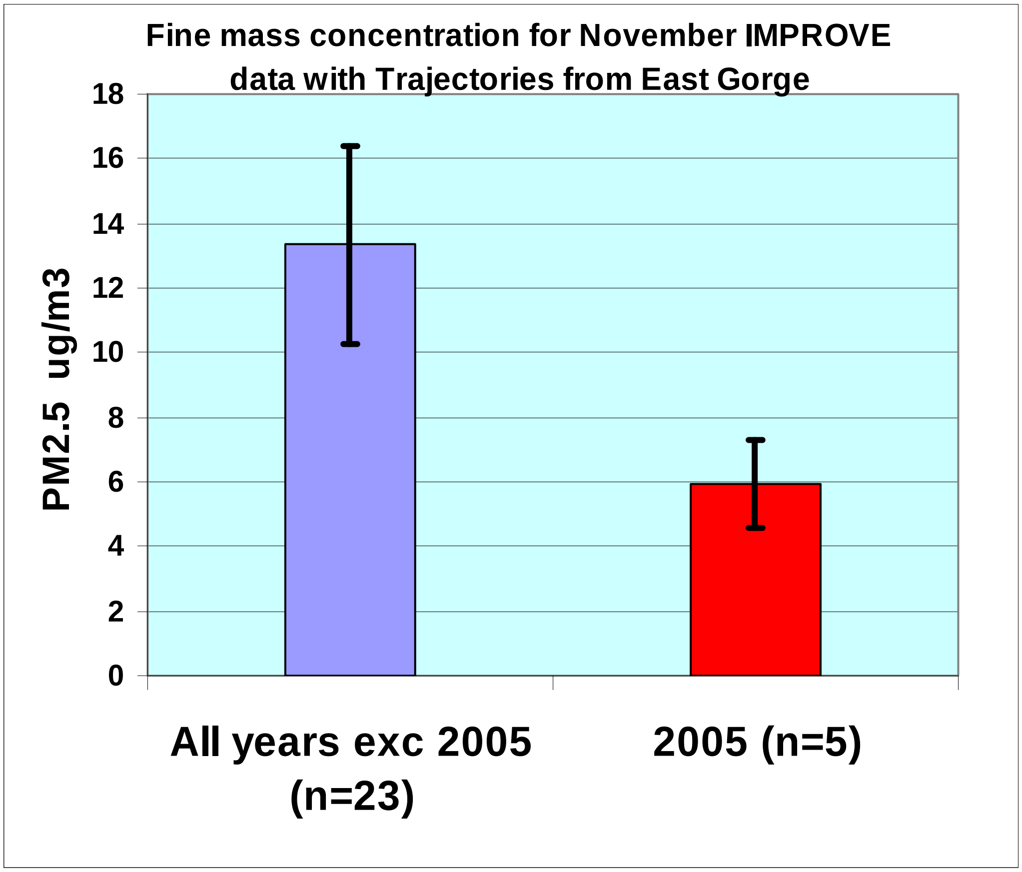

Figure 5. Fine mass (PM2.5) concentration for all November IMPROVE data (1993-2006) for days with trajectories arriving at Wishram from the eastern end of the CRG. In November 2005 the PGE Boardman plant was essentially shut down due to a turbine problem. As a result, concentrations at Wishram were significantly reduced. Each bar shows the mean and the error bars show the 95% confidence interval around each mean. A t-test confirms that the difference (7.40 ug/m^3) is statistically significant at a confidence of greater than 95%. Table 3 shows the detailed data.

	All November data except 2005 with East Gorge trajectories	**November 2005 data with East Gorge trajectories**
Count	23	5
Mean fine mass concentration (ug/m^3)	13.34	5.94
S.D.	8.33	1.51

Table 3. Comparison of November 2005 IMPROVE observations with all other November observations, that exhibit airmass transport from the eastern CRG. A t-test confirms that the difference (7.40 ug/m^3) is statistically significant with a confidence of greater than 95%.

Taken together, these three analyses present a consistent picture of the influence from the PGE Boardman plant on air quality in the CRG. Using the analysis for all months, I find that the

PGE Boardman influence is, on average, 0.90 ug/m^3. Comparing only November data, I find that the influence is significantly larger at 3.94 ug/m^3. Comparing only November data for days with likely transport from the eastern CRG, I find the influence is greatest at 7.40 ug/m^3. Table 4 summarizes the results and also derives the % contribution at Wishram due to the PGE Boardman emissions.

Table 4. Summary of fine mass concentrations at Wishram (ug/m^3) with and without PGE Boardman influence.

	With Boardman influence (ug/m^3)	Without Boardman influence (ug/m^3)	Difference (ug/m^3)	Fine mass due to PGE Boardman (%)
All months[1]	**6.06**	**5.16**	**0.90**	**14.9**
All November data[2]	**8.55**	**4.61**	**3.94**	**46.1**
All November data w/ trajectories from East Gorge[3]	**13.34**	**5.94**	**7.40**	**55.5**

[1]This row compares months where PGE Boardman emissions are less than 100 tons vs all other months.
[2]This row compares the November 2005 data (plant shutdown) with all other November data.
[3]This row compares November 2005 data with east gorge trajectories with all other November data with east gorge trajectories.

Comparison with other studies

A number of agencies have been involved in a significant air quality study in the CRG between 2000-2007. Only data from one year was considered (2004) and the primary conclusions were derived from analysis of a regional air quality model. The Columbia River Gorge Air Quality Study, Science Summary Report (abbreviated here as CRG-AQS) was released on February 8th, 2008. I will compare our results to those in this report.

As part of the observations and modeling that was conducted for the CRG-AQS report, attention focused on one air pollution episode, which occurred between November 8-14, 2004. The CRG-AQS report, as well as our earlier work (Jaffe et al., 2006) found that emissions in the east end of the CRG were largely responsible for this episode. Thus it is reasonable to compare the results from this November episode with our results for November when trajectories are coming from the eastern CRG. By reference to the bottom line of Table 4 (above), we see that the PGE Boardman plant is responsible for approximately 55% of the fine mass during these episodes. In contrast the CRG-AQS report states that Electric Generation Units (EGUs) east of the CRG (essentially only the PGE Boardman plant) were responsible for 32% of the fine mass at Wishram (CRG-AQS, pg 87), a significant discrepancy with our results.

In addition, our analysis indicates that for the November episodes with down-gorge transport, the PGE Boardman contribution is 7.40 ug/m^3 at Wishram, whereas in the CRG-AQS report they conclude that EGUs are responsible for only 3.17 ug/m^3 (2.64 ug/m^3 + 0.53 ug/m^3, Table 5-7, pg 85). Thus the CRG-AQS study appears to significantly under-estimate the influence from the PGE Boardman plant. A likely source of this discrepancy is that our analysis was based on analysis of the IMPROVE data collected at the Wishram site, whereas the CRG-AQS conclusions were based largely on a computer simulation of air quality in the CRG. In Figure 5-1 of the CRG-AQS (pg 74) there is one graph comparing the computer simulation with observations from several sites in the CRG. For the November cases (right side of Figure 5-1) the model is performing very poorly. For example, for the worst air quality days the observed scattering coefficients is up to 250 Mm^{-1}, however the "predicted" (i.e. modeled) value is low by about a factor of 3. In short, this simulation does a poor job of reproducing the observational data and appears to significantly underestimate the contribution to haze from sources in the CRG for the worst air quality days of the year.

The report goes on to estimate the influence from EGUs in the east of the CRG in 2018. It does this by assuming a “presumptive BART" control level for the Boardman power plant. This limit is assumed to be 0.23 lbs of NOx per million BTU or 1323 lbs NOx per hour (CRG-AQS, pg 92). This translates into annual NOx emissions of 5790 tons/year. Given that the current emissions are 800-1000 tons/month during normal operations (see Figure 1), the 5790 tons/year limit is approximately a 50% reduction in NOx emissions from current levels. The "presumptive BART" control also results in a 70% reduction in SOx emissions (CRG-AQS, pg 92). For the November episode considered, and using these assumed emissions in 2018, the resulting influence from PGE Boardman is 0.95 ug/m^3 (CRG-AQS, Table 7-9, pg 108). Our results suggest a much larger level of influence. Referring to the bottom line of Table 4 (above), for the November episode, I estimate the current influence from PGE Boardman at 7.40 ug/m^3. Even if all emissions were reduced by 70% in 2018 emissions, then the influence would still be approximately 2.22 ug/m^3, much larger than the value reported in the CRG-AQS report.

In addition, the CRG-AQS compares the 2018 base case with 5 alternate emission scenarios. Case 1, represents a total zero out of the PGE Boardman emissions. From this analysis the authors state:

"Since major SO2 and NOx emission reductions at the Boardman Power Plant are already reflected in the 2018 inventory (i.e., presumptive BART controls), practically zero sensitivity to Case 1 is seen." (CRG-AQS, pg 97).

This statement is inconsistent with their own results and certainly inconsistent with the results of our study. It is very puzzling how the study could conclude that by reducing Boardman emissions to 50-70% of current levels brings the influence at Wishram to 0.95 ug/m^3, and then to claim that zeroing out of these emissions will have no further influence. Our results indicate that the current PGE Boardman influence during these November episodes is 7.40 ug/m^3 and I would expect a linear relationship between this influence and the degree of emission control, assuming all pollutants were reduced a similar %.

In summary, our analysis of times when the PGE Boardman plant was temporarily shutdown indicate a much larger influence on air quality in the CRG, compared to the CRG-AQS study. I believe the primary cause for this discrepancy is that the CRG-AQS result is based on a computer simulation, which does a poor job of reproducing the actual data for the worst air quality days of the year.

References

Pitchford M.L, Green M.C. Morris R., Emery C., Sakata R., Swab C., and Mairose P.T. Columbia River Gorge Air Quality Study, Final Science Summary Report. February 8th, 2008.

Jaffe D.A. Who is polluting the Columbia River Gorge? Final report to the Yakama Nation. Northwest Air Quality, Inc., Seattle, Wash., December 31, 2006.

Appendix: Summary of data used. More detailed data can be obtained from the IMPROVE website or from the author. ND indicates no data.

Month	Boardman NOx emissions (tons)	Average fine mass at Wishram (ug/m3)
June-93	104.5	6.18
July-93	426.2	4.53
August-93	1141	7.33
September-93	1082.4	8.01
October-93	1103	9.34
November-93	1076.7	13.77
December-93	1042.6	10.45
January-94	973.9	8.36
February-94	1046.38	6.89
March-94	1116.08	5.13
April-94	1106.32	5.05
May-94	195.99	6.79
June-94	492.68	4.57
July-94	1169.02	7.82
August-94	1542.76	7.35
September-94	1159.65	7.31
October-94	767.9	6.46
November-94	801.2	4.48
December-94	994.5	ND
January-95	949.4	ND
February-95	0	ND
March-95	0	ND
April-95	0	7.17
May-95	12.8	6.20
June-95	0	5.65
July-95	206.5	6.96
August-95	913.4	5.19
September-95	785.1	8.74
October-95	600.8	5.23
November-95	372.8	6.13
December-95	0	6.35
January-96	0	4.11
February-96	0	7.90
March-96	0	5.18
April-96	0	2.89
May-96	0	4.16
June-96	0	5.00
July-96	195	6.84
August-96	687	7.64
September-96	702	5.08
October-96	915	5.73
November-96	952	6.64
December-96	889	4.70
January-97	184	6.39
February-97	0	4.18
March-97	0	4.52
April-97	0	5.55
May-97	0	6.16
June-97	0	3.95
July-97	153	6.32
August-97	586	6.72
September-97	519	7.39

October-97	329	6.63
November-97	651	8.39
December-97	826	6.83
January-98	719	5.59
February-98	304	3.81
March-98	708	4.83
April-98	752	7.38
May-98	62	4.14
June-98	0	4.74
July-98	678	8.00
August-98	784	6.97
September-98	861	7.47
October-98	909	9.49
November-98	942	6.64
December-98	1012	4.01
January-99	870	4.39
February-99	583	4.01
March-99	547.9	5.81
April-99	731.8	6.16
May-99	383.6	3.87
June-99	349.8	3.42
July-99	823.8	6.55
August-99	891.3	7.69
September-99	904.5	7.81
October-99	1005.6	6.38
November-99	949.7	7.04
December-99	907.8	3.28
January-00	799.9	3.72
February-00	912.2	4.59
March-00	898.8	4.11
April-00	770.3	4.53
May-00	266.3	3.51
June-00	0	ND
July-00	255.6	ND
August-00	871.6	ND
September-00	731	ND
October-00	969	ND
November-00	947.7	ND
December-00	782.9	ND

January-01	853.7	9.40
February-01	898.2	7.26
March-01	1009.2	4.18
April-01	957.1	4.63
May-01	560.9	4.99
June-01	604.1	4.43
July-01	1048.7	6.73
August-01	993.1	7.25
September-01	950.7	4.98
October-01	1023.1	4.44
November-01	851.5	7.79
December-01	1019.3	5.54
January-02	951.1	4.43
February-02	849.4	3.76
March-02	499	3.30
April-02	465.9	3.80
May-02	726.8	3.25
June-02	0	4.72
July-02	286.1	7.81
August-02	779.5	6.52
September-02	873.8	5.82
October-02	976.9	7.23
November-02	1005.5	16.58
December-02	988.3	6.20
January-03	899	5.31
February-03	883.8	4.09
March-03	953.7	2.02
April-03	926.5	2.01
May-03	853.2	5.34
June-03	51.4	6.43
July-03	925.8	4.41
August-03	926.2	5.90
September-03	958.5	7.13
October-03	954.2	5.98
November-03	878.3	7.36
December-03	870.4	4.48
January-04	975.9	3.47
February-04	802.4	6.15
March-04	918.3	3.89

April-04	823.7	4.92
May-04	0	3.71
June-04	0	4.18
July-04	41.4	8.83
August-04	750.1	5.21
September-04	864.9	5.43
October-04	944	5.33
November-04	835	10.35
December-04	857.1	4.42
January-05	1061	5.71
February-05	913.2	6.68
March-05	844.1	3.68
April-05	962.4	3.04
May-05	72.5	3.49
June-05	830.3	5.65
July-05	868.8	8.36
August-05	973.7	10.61

September-05	1020.8	5.59
October-05	756.4	5.29
November-05	10.3	4.61
December-05	0	6.80
January-06	0	2.48
February-06	405	3.86
March-06	0	3.61
April-06	0	4.70
May-06	97.5	7.03
June-06	13.2	6.33
July-06	1016.6	7.07
August-06	1033.7	7.89
September-06	821.8	5.80
October-06	882	5.47
November-06	970.6	6.65
December-06	1087.5	6.07

IMPROVE sample dates in November with airmass trajectories suggesting transport from the east end of the CRG.

19-Nov-2006	14-Nov-2003	1-Nov-1995
1-Nov-2006	25-Nov-2002	24-Nov-1993
24-Nov-2005	4-Nov-2002	28-Nov-2006
21-Nov-2005	1-Nov-2002	7-Nov-2002
18-Nov-2005	18-Nov-2001	24-Nov-2001
15-Nov-2005	12-Nov-2001	9-Nov-2001
9-Nov-2005	17-Nov-2000	29-Nov-2000
14-Nov-2004	14-Nov-2000	20-Nov-2000
1-Nov-2004	7-Nov-1998	15-Nov-1997
8-Nov-2004	12-Nov-1997	10-Nov-1993