APPENDIX B-6

NUMERICAL SIMULATION OF IMPACTS ON OZONE CONCENTRATIONS

A numerical simulation of impacts on ambient ground-level ozone concentrations from the proposed Sumas Energy 2, Inc. power generation facility

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ABSTRACT

Environment Canada, under the auspices of the Lower Fraser Valley Air Quality Co-ordinating Committee, undertook numerical simulations of ambient ground-level ozone concentrations for a select 5-day elevated ozone period. The purpose was to gain insight into the impacts expected from a proposed large gas-fired electric power generating facility, the Sumas Energy 2, Inc. project, in the lower Fraser valley. Environment Canada carried out the simulations using the variable grid Urban Airshed Model. The simulations suggest the project will result in small local increases in ground-level ozone. The results are consistent with unpublished studies of impacts from similar major power generation facilities in the region.

1. Introduction

a. Lower Fraser Valley Air Quality Co-ordinating Committee

The Lower Fraser Valley Air Quality Co-ordinating Committee is an interagency committee charged with co-ordinating action on air quality issues in the lower Fraser valley. Membership includes representatives from the municipal regional districts, the British Columbia Ministry of the Environment, Lands and Parks, Whatcom County in Washington State, and Environment Canada.

In Spring, 1999, the committee (LFVAQCC, 1999) learned about Sumas Energy 2, Inc.'s application to the Washington State Energy Facility Site Evaluation Council to build a large natural gas-fired electric power generating facility. The committee identified a number of potential air quality issues that could arise from the proposed power generating facility. These included fine particulate, visibility, and ground-level ozone. They requested that one particular concern, ground-level ozone, be looked into by its member agencies. This report to the committee details Environment Canada's findings.

b. Sumas Energy 2, Inc. project description

The Washington State Energy Facility Site Evaluation Council web site provided the following description of the project (EFSEC, 2000).

Sumas Energy 2, Inc., of Bellevue, Washington, proposes to build a natural gas-fired electric power generating facility approximately 1 km south of the Canada/US border in the town of Sumas, Washington. See Figure 1. Sumas is in Whatcom County, approximately 30 km northeast of Bellingham. The 15 ha project site lies west of downtown Sumas and includes 11 ha of open fields and approximately 4 ha of open or wooded wetlands and wetland buffers. The site is zoned for industrial use.

The Sumas 2 generation facility is a nominal 660 MW natural gas-fired electrical generation facility. S2GF (Appendix B contains a list of acronyms) is similar to, but much larger than, the company's existing 125 MW facility that adjoins the proposed site. The S2GF design includes two separate but identical combustion turbines, one steam turbine, two generators, and two heat recovery steam generators.

Air emissions will include oxides of nitrogen which the proponent will minimise by using *Best Available Control Technology*[1]. Appendix A details the Sumas Energy 2 emissions estimates (Richmond, 1999). The case 3 estimates are for peak load and are the largest gas-fired emissions forecast. These are the estimates used in this study. The case 4 estimates are for base load, oil-fired winter emissions. Case 4 estimates were not considered because ground-level ozone is not a winter phenomenon.

The projected emissions from S2GF are similar to those from plants of equivalent size. The emissions are a fraction of the total emissions in the lower Fraser valley but are many times that of an automobile. Tables 1a and 1b put the Sumas 2 emissions into context. Table 1a expresses the S2GF emissions relative to an average car using the concept of an 'LDV-equivalent'. An LDV-equivalent emission unit is that amount of pollutant an average light duty vehicle emits. We calculated the LDV-equivalent using the 1995 lower Fraser valley light duty vehicle emissions inventory (GVRD, 1998) and the total number of light duty vehicles inspected in the third year of British Columbia's Air Care Program (BCMOTH, 1996). Table 1b places the S2GF emissions into context with the total valley emissions (GVRD, 1998; Levelton, 1997).

Table 1a. Emissions of the Sumas Energy 2 facility relative to an average light duty vehicle in the lower Fraser valley.

Pollutant	Emissions (expressed as LDV-equivalents)	
	An average car	Case 3 (peak load), Sumas Energy 2 facility
NO_x	1	7,400
CO	1	300
SO_2 or SO_x	1	11,900
VOC	1	4,800
PM_{10}	1	336,000

[1] *Best Available Control Technology* is an emission limitation protocol based upon the maximum reduction for specific air pollutants that is achievable for a particular project. The State of Washington permitting authority determines what is achievable on a case-by-case basis, with due consideration of energy, environmental, and economic impacts.

Table 1b. Emissions of the Sumas Energy 2 facility relative to all emissions in the lower Fraser valley.

Pollutant	Case 3 (peak load) S2GF Emissions (expressed as a percentage of all 1995 LFV sources)
NO_X	0.31 %
CO	0.03 %
SO_2 or SO_X	0.09 %
VOC	0.15 %
PM_{10}	1.20 %

c. Background

The Canadian Council of Ministers of Environment identified the lower Fraser valley as one of three areas in Canada where summer ground-level peak ozone concentrations can exceed the Canadian maximum acceptable one-hour objective [2] of 82 ppb (CCME, 1990). Under the aegis of the CCME national management plan for oxides of nitrogen and volatile organic compounds, the precursors for ozone, a number of scientific activities were completed that enhanced the understanding of air quality in the lower Fraser valley.

As part of this plan, Environment Canada took delivery of a computer model that simulates the relevant atmospheric chemical processes needed to understand ground-level ozone in the lower Fraser valley airshed. Concurrently, Environment Canada participated in field studies in the airshed to gain insight into the factors affecting the photochemistry of the airshed (Steyn and Bottenheim, 1997).

The result: Environment Canada is capable of performing sophisticated, objective numerical simulations that can give insight to the impacts new sources of air pollutants may have on ground-level ozone in the lower Fraser valley airshed; a capability that is unique in British Columbia.

2. The question

The LFVAQCC desires to know what impacts on the ambient air concentrations of ground-level ozone can be expected in the lower Fraser valley, should the Sumas Energy 2 facility be built.

Environment Canada undertook to carry out computer simulations of ground-level ozone that would offer some insight into the answer to this question.

[2] The CCME is developing a new standard for ambient ground-level ozone. Recent science supporting the development indicates that ozone-related health impacts may be occurring at levels below 82 ppb.

3. Methodology

a. The variable-grid Urban Airshed Model modelling system

The scientific challenges to use a computer to numerically simulate the atmospheric photochemistry over the lower Fraser valley are substantial. The severe terrain and coastal environment result in complex land-sea breezes and mountain-valley air flows that affect the transport and mixing of precursor pollutants and the production of ozone. Highly urbanised city centres, agricultural tracts, and natural areas lead to complex patterns of pollutant emissions to the atmosphere that affect ozone production. Meeting these challenges requires a modern, state-of-the-art computer model.

Environment Canada contracted with Systems Applications International, Inc. to deliver the variable-grid Urban Airshed Model, known as UAM-V, and to demonstrate that this model met the unique challenges of the lower Fraser valley. SAI implemented the model on computers in Environment Canada's Vancouver office, and demonstrated the robustness of the UAM-V by successfully simulating the July 17-29, 1985 ozone episode (SAI, 1995a).

The UAM-V is an enhanced version of the current U.S. Environmental Protection Agency's regulatory Urban Airshed Model. It is a three-dimensional grid model that numerically simulates the relevant physical and chemical processes affecting the production and transport of tropospheric ozone (SAI, 1995b). One feature of the UAM-V is its 'plume-in-grid' capability that allows the treatment of sub-grid-scale chemistry and plume dynamics from user-selected point sources such as the stacks of a gas-fired turbine. The reactive plume-in-grid algorithm avoids premature dilution and over-dilution of emissions that would arise otherwise.

The UAM-V model accounts for spatial and temporal variations as well as differences in speciation of emissions, making it suited for evaluating the effects of emission change scenarios on ambient ground-level ozone.

b. Meteorology

Environment Canada enjoys an accurate set of mesoscale meteorological fields for the August 01-06, 1993 period. The Pacific '93 field study (Steyn and Bottenheim, 1997) yielded meteorological data not normally available to investigators. These observational data were quality controlled and incorporated into internally consistent numerical fields using a prognostic meteorological model and four-dimensional data assimilation (SAI, 1996).

c. Air emissions

Environment Canada has constructed a detailed air emissions inventory accounting for point, area, mobile, and biogenic emissions of pollutants in the lower Fraser valley airshed (Levelton, 1995) for Canadian and American sources.

These inventory data were processed for input into the UAM-V system using the U.S. Environmental Protection Agency Emissions Pre-processing System, EPS2.0, and the Biogenic Emission Inventory System, BEIS2. The National Research Council processed the area and mobile source emissions (NRC, 1996). Systems Applications International processed the point source and the biogenic emissions (SAI, 1997).

d. Approach for answering the question

After consultation with the British Columbia Ministry of Environment, Lands and Parks and the Greater Vancouver Regional District, Environment Canada adopted a two-step approach: incorporate the peak load, i.e. case 3, emissions estimates expected from the proposed Sumas facility into its extensive base emissions inventory for 1993; and, evaluate the resulting changes to the numerical simulation of ozone concentrations in the lower Fraser valley airshed for meteorological conditions experienced during August 01-06, 1993. Environment Canada selected this episode because it was the only episode for which there were both appropriate meteorological and emissions data. Two simulations were run: the *base simulation* which used only the base emissions inventory, and the *S2GF simulation* which included the additional case 3 Sumas Energy 2 emissions estimates.

4. Results

a. Ozone episode intensity

The meteorology in the lowest levels of the atmosphere for the period August 01-06, 1993 was typical for a commonplace ozone episode of which we may expect one to three each year (LFVMWG, 1997). The meteorology aloft, however, was not typical, preventing the episode from becoming a major ground-level ozone event (Pottier, 1993).

A brief description of the episode follows. On August 01, peak ozone concentrations ranged from 20 to 40 ppb with a maximum of 56 ppb at Matsqui. August 02 experienced a similar range but with more locations having peaks in the fifties. By August 03, the light winds and strong insolation conditions produced episodic values edging into the low eighties with peak values centred near Abbotsford. A similar pattern redeveloped on August 04 and 05 before breaking down in the later afternoon of August 05. By August 06 stratus cloud and cool marine air completely destroyed conditions favourable for low-level ozone formation. Note that the peak ozone concentrations occurred in the same general portion of the valley in which the S2GF will be located. Other reports describe the episode in detail (SAI, 1997; Steyn et al, 1997).

The base simulation performed well. In general, there was a tendency to under-predict afternoon ozone maximums and over-predict overnight minimum ozone concentrations. This tendency is typical for ozone models. The root mean square error, a statistical measure of performance, ranged from 7 ppb to 19 ppb – a good result. Validation using this and a variety of other measures indicated that UAM-V can be used reliably to investigate the effects of emissions changes on ground-level ozone in the lower Fraser valley (SAI, 1997).

The simulation used an horizontal grid-cell resolution of 5 km. An output ozone concentration should thus be interpreted as the most representative value likely to occur anywhere within its 5 km grid-square.

The precision of, or noise in, a simulation is dependent on the grid resolution. For the horizontal resolution of 5 km used in these simulations, the precision is 4-6 ppb (SAI, 2000). This means that model simulations giving values less than this will be indistinguishable from the model noise. However, due to the high correlations between the base simulation and the S2GF simulation, the noise when the former is subtracted from the latter is smaller.

The S2GF simulation when compared to the base simulation showed a small increase in ambient ozone concentrations for each day of the episode. The peak changes range in value from 0.7 to 3.8 ppb and all occurred in the afternoon near the time of peak ozone values. See Table 2.

Table 2. Peak changes in ambient ozone concentrations that resulted from incorporating forecasted peak load emissions estimates from Sumas Energy 2 plant. Note that times are in Pacific Standard Time and that the meteorological data correspond to the end of the interval, for example, the temperature observed at 1500 h PST is attributed to the interval 1400-1500 h.

Date	August 01	August 02	August 03	August 04	August 05
Peak Change (ppb)	1.1 ±0.4	0.7 ±0.2	1.1 ±0.4	1.9 ±0.6	3.8 ±1.3
Resultant ozone concentration at location of peak change (ppb)	42	41	45	90	52
Time of Peak Change (h PST)	1400-1500	1500 -1600	1400-1500	1400-1500	1300-1400

Figure 2 shows the areal extent of the peak changes predicted. The August 04 day is the most interesting day at which to look because meteorologically it most resembles a day on which you would expect to see high ozone values. The simulation shows a peak increase in ambient ground-level ozone concentrations of 1.9 ppb between 1500 and 1600 PDT. The location of the peak is in the same grid-cell as the Sumas Energy 2 site. Beyond one model grid-square, or 5 km, from the site, the change in ozone concentrations decreased to less than one-quarter of this value. See Figure 2d.

The August 05 day is also of interest. If the meteorological pattern had not changed significantly in the later afternoon with the intrusion of cooler air and stratus, this day would have qualified as an ozone episode day. Again the simulations show that the maximum change in ozone concentrations will be an increase in the same grid-cell as the plant site. The peak change value is 3.8 ppb. And again, beyond 5 km from the site, the change in ozone concentrations decreased by more than 75 per cent. See Figure 2e.

Overall, considering Table 2 and Figure 2, the simulation indicates that increases in ozone episode intensity as a result of the Sumas Energy 2 project will be small and localised.

b. Ozone episode duration

Figure 3 shows a time series plot of simulated (and observed) ozone concentrations for Abbotsford and Custer. Software restrictions limit time series simulations to observation sites. Abbotsford and Custer are the closest locations to the Sumas Energy 2 site for which there are observations. Abbotsford is 6 km north of Sumas and Custer is 22 km west-southwest of Sumas.

Figure 3a shows results from the base simulation. Figure 3b shows results from the S2GF simulation. Overlaying the figures, no discernible change in the duration of the ozone episode, either intra-day or over the episode is apparent. This is not surprising because Custer and Abbotsford were infrequently within ozone change areas larger than 0.2 ppb. However, even when they were well within change areas, there was indiscernible duration change.

5. Conclusions

The increases in emissions in the lower Fraser valley as estimated by the proponent for the peak load case will result in a small increase in ozone episode intensity and no increase in ozone episode duration for commonplace ozone episodes similar to August 1993.

The conclusions are based on computer model simulations using a select ozone episode. Different modelling conditions may result in different findings. The conclusions found are consistent with unpublished studies of similar power generating facilities in the region.

The conclusions are restricted to ambient ozone concentrations. The impacts on ambient concentrations of other common pollutants such as fine particulate matter were not investigated.

ACKNOWLEDGEMENTS

The authors wish to express thanks to their manager, Bruce Thomson, and to the members of the Sumas Energy 2 Technical Committee (Ali Ergudenler, Domenic Mignacca, and Ken Reid, all of the Greater Vancouver Regional District office; and, Steve Sakiyama and Natalie Suzuki, both of the Ministry of Environment, Lands and Parks) for providing advice with decisions contained in this report and for providing valuable suggestions on content and organisation.

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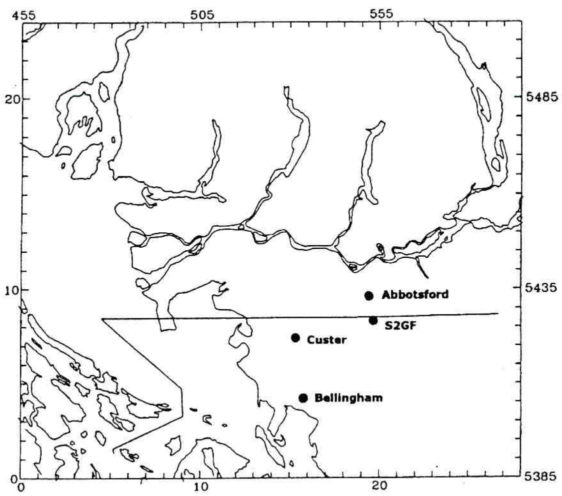

Figure 1. Location of the proposed Sumas Energy 2 power generating facility, S2GF, in Sumas, Washington.

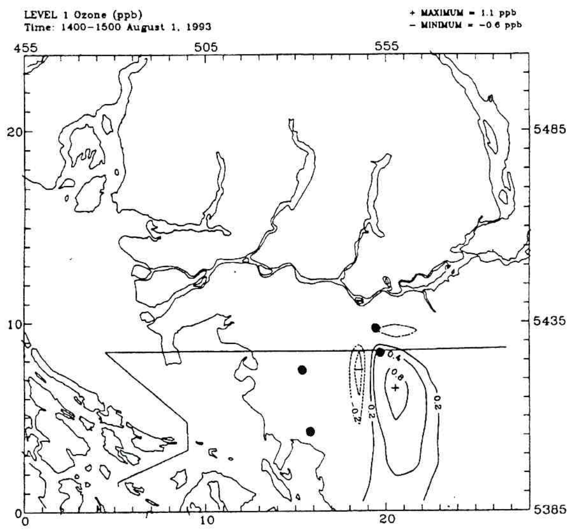

Figure 2a. Simulated surface ozone concentration differences between the S2GF and base simulations for 1993 Aug 01. The contour intervals are -0.4, -0.2, +0.2, +0.4, +0.8, +1.6, +3.2.

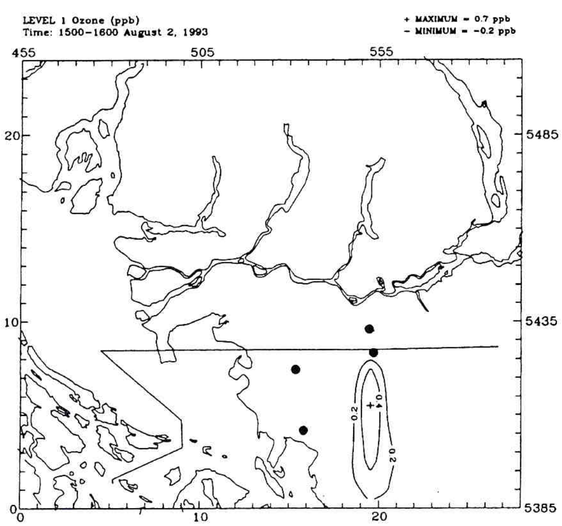

Figure 2b. Simulated surface ozone concentration differences between the S2GF and base simulations for 1993 Aug 02.

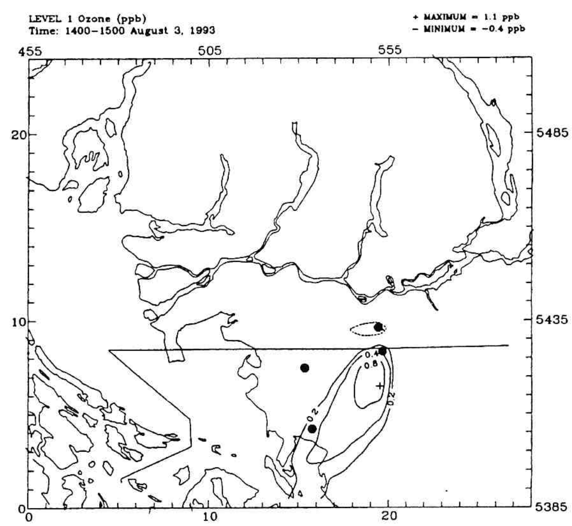

Figure 2c. Simulated surface ozone concentration differences between the S2GF and base simulations for 1993 Aug 03.

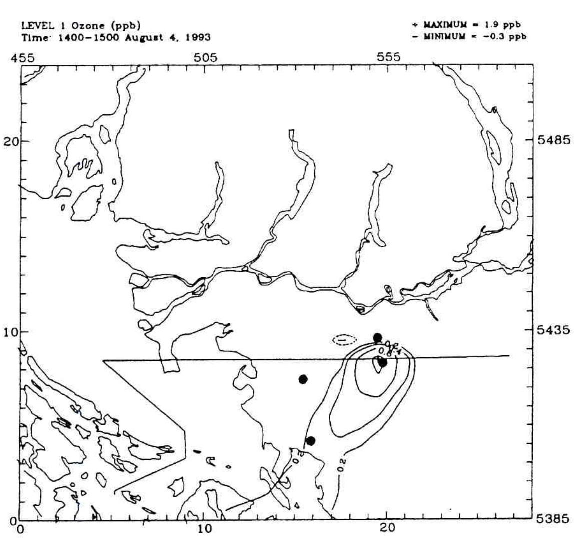

Figure 2d. Simulated surface ozone concentration differences between the S2GF and base simulations for 1993 Aug 04.

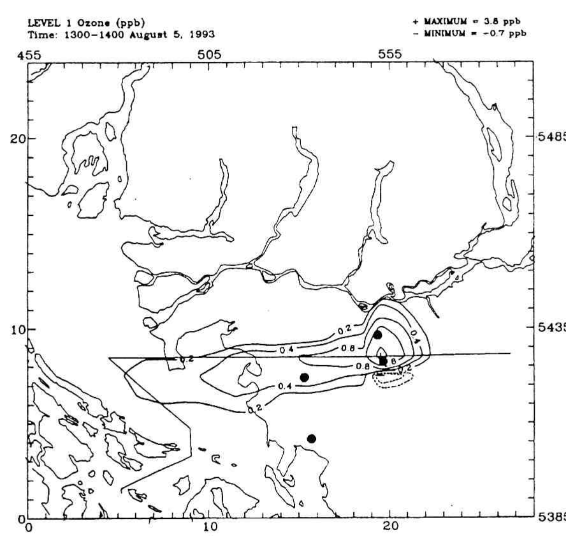

Figure 2e. Simulated surface ozone concentration differences between the S2GF and base simulations for 1993 Aug 05.

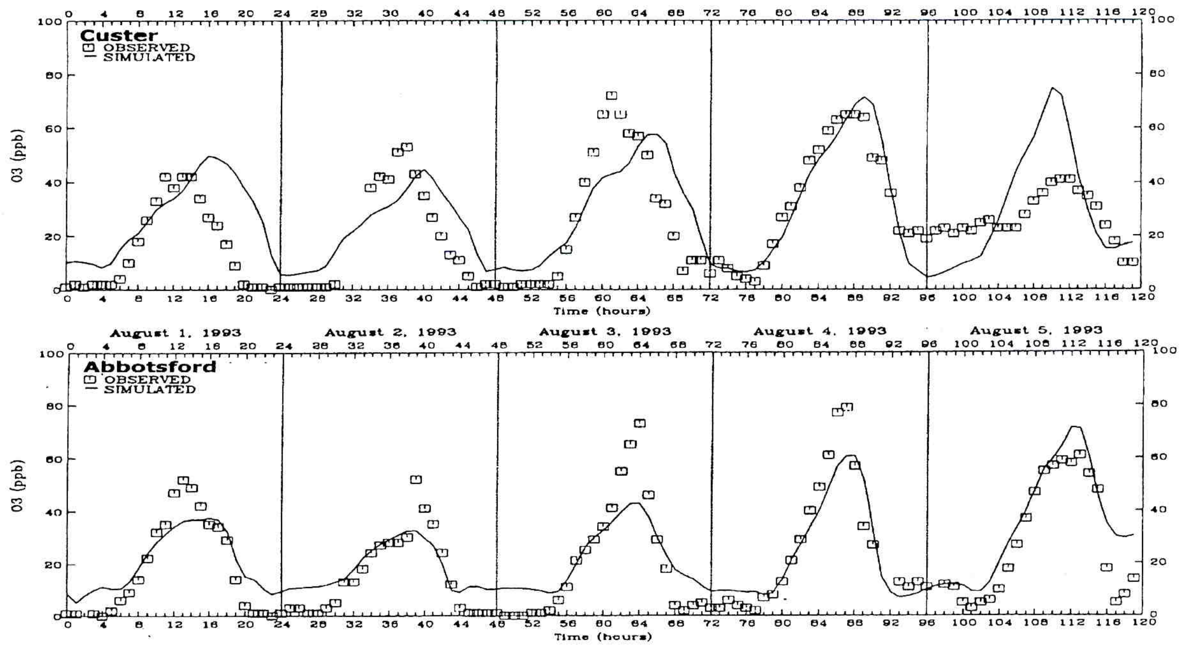

Figure 3a. Time series of the base simulation (and observed) ambient ozone concentrations (ppb) at Custer and Abbotsford. At any ozone value, the width of each peak indicates the duration at that value.

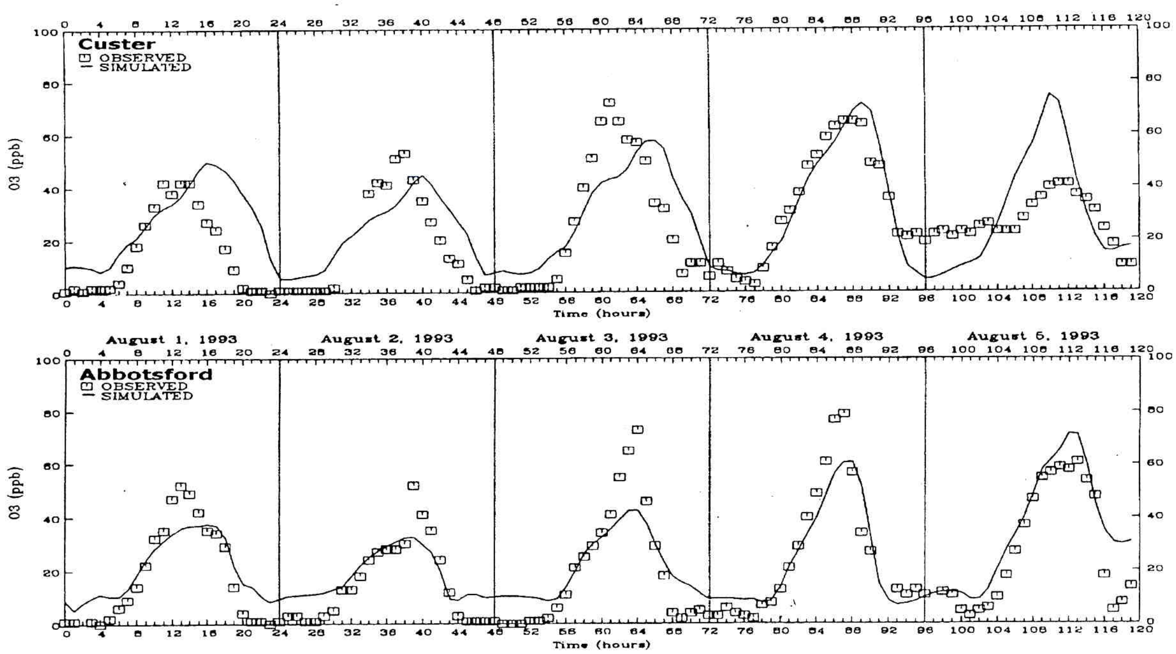

Figure 3b. Time series of the S2GF simulation (and observed) ambient ozone concentrations (ppb) at Custer and Abbotsford. The differences between these time series and base time series from Figure 3a are not discernible.

APPENDIX A

Sumas 2 Energy, Inc. projected emissions

Environment Canada, in its numerical simulations, used emission estimates extracted from the following email:

From: Ken Richmond [krichmond@mfgsea.com]
Sent: 1999 November 16 10:42
To: Steve Sakiyama; Bruce Thomson - Env Canada; Colin di Cenzo - Env Canada
Cc: Eric Hansen; Bruce Thompson - SE2; Dave Eaden - NESCO

Subject: emissions for o3 modeling

Revised design for the Sumas Energy 2 facility has been completed. The revised facility will have smaller turbines & lower NO_X limits. Also the revised facility will have the capability of oil backup during winter NG curtailment and use duct-firing for peaking in the summer. For O3 modeling the duct-firing case should probably be used. Stack parameters and emissions rates are as follows:

Emissions & Stack parameters per turbine

Case	1	2	3	4
Exh flow(m3/s)	401.6	484.0	482.4	545.9
exh temp(K)	364.3	366.0	360.6	412.3
Exh diam(m)	5.87	5.87	5.87	5.87
Exh vel(m/s)	14.85	17.90	17.84	20.19
Stack Ht(m)	45.7	45.7	45.7	45.7
NOx(kg/hr)	6.8	9.0	11.2	36.0
CO(kg/hr)	2.8	3.6	4.5	22.0
SO2(kg/hr)	0.4	0.5	0.7	41.0
VOC(kg/hr)	2.3	1.6	8.0	11.2
PM10(kg/hr)	7.3	8.7	10.8	28.9

Case 1: Gas-fired 70% Load
Case 2: Gas-fired Base Load
Case 3: Gas-Fired Peak Load with Duct-firing
Case 4: Oil-Fired Base Load (up to 15 days during winter)

Location (x(m),y(m),z(m)) UTM Zone 10, NAV27 Projection

Turbine Unit 1: 553129 5426944 12.
Turbine Unit 2: 553159 5426944 12.

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APPENDIX B

List of acronyms and abbreviations

BCMOTH	British Columbia Ministry of Transportation and Highways
CCME	Canadian Council of Ministers of Environment
EFSEC	Washington State Energy Facility Site Evaluation Council
GVRD	Greater Vancouver Regional District
h	hour(s)
ha	hectare, approximately 2.5 acres to 1 hectare
km	kilometre(s)
LDV	Light Duty Vehicle
LFV	lower Fraser valley
LFVAQCC	Lower Fraser Valley Air Quality Co-ordinating Committee
LFVMWG	Lower Fraser Valley Modelling and Measurement Working Group
MW	megawatt(s)
NO_X	oxides of nitrogen
ppb	parts per billion
PDT	Pacific Daylight Time
PST	Pacific Standard Time
S2GF	Sumas 2 Generation Facility as proposed by Sumas Energy 2, Inc.
SAI	Systems Applications International, Inc.
SO_2	sulphur dioxide
SO_X	oxides of sulphur
UAM-V	Urban Airshed Model - Variable grid