

**PEER REVIEW  
BASELINE AIR QUALITY MODELLING  
&  
HUMAN HEALTH RISK ASSESSMENT**

**Current Day Emissions  
NorskeCanada Crofton Division**

**Prepared for:**

**NorskeCanada, Limited  
Crofton, British Columbia**

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## **1.0 INTRODUCTION**

SENES Consultants Limited (SENES) was retained by NorskeCanada Limited to conduct a peer review of the baseline air quality dispersion modelling and human health risk assessment of current day emissions for the NorskeCanada's Crofton Division pulp and paper mill that was prepared by Jacques Whitford (JW) Limited<sup>1</sup>. The peer review, which was based on draft versions of the JW assessment report, focussed on specific aspects of the assessment, including:

- emission factors used to characterize the mill's emission rates;
- the meteorological data used in the dispersion modelling analysis;
- the configuration of the input data files used in the dispersion modelling analysis;
- the interpretation of the modelling results relating to meteorological trends and comparison of modelled air concentrations to established ambient air quality criteria; and,
- the relative significance of predicted air quality impacts with respect to risks to human health.

Due to the relatively short amount of time that was available to SENES for reviewing some parts of the JW assessment, the review has focused on key aspects of the analysis which are most likely to affect the modelling results. Although all aspects of the assessment may not have been reviewed to the extent that SENES would have wished, we believe that the review has addressed the most critical components of the JW assessment.

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<sup>1</sup> Jacques Whitford Limited 2004. (DRAFT) *Baseline Air Quality Modelling and Human Health Risk Assessment of Current Day Emissions from NorskeCanada Crofton Division*. Project No. BCV50396, Burnaby, B.C., September 2004.

## **2.0 EMISSION INPUT DATA**

The review of the emission input files for the air quality dispersion modelling analysis included:

- the air emissions estimates contained in the MS Excel spreadsheet that was provided by Jacques Whitford Limited for the NorskeCanada pulp and paper mill in Crofton, British Columbia;
- the two-volume Jacques Whitford report entitled, “Draft Baseline Air Quality Modelling and Human Health Risk Assessment of Current Day Emissions from NorskeCanada Crofton, Volumes I and II, September 13, 2004”

In general, the air emissions inventory for the NorskeCanada pulp mill is comprehensive and, based upon a review of air emission factors and related reports, is anticipated to reasonably represent air emissions from the facility. However, the air emissions inventory portion of the assessment could be improved with an enhanced review of the range of expected emissions for high priority contaminants. The results from the draft report could be used to assist in identifying a set of critical contaminants for more detailed assessment. The following are specific comments and suggestions for improvement of the emission inventory.

### **2.1 REVIEW OF TECHNICAL BASIS/SUPPORT FOR AIR EMISSIONS INVENTORY**

Emission inventories are used in conjunction with dispersion models to provide predictions of off-site impact from an industrial facility. The air emissions inventory developed for the air quality assessment of the NorskeCanada pulp and paper mill in Crofton, British Columbia is based upon estimates of annual emissions of 106 different compounds as calculated for the National Pollutant Release Inventory (NPRI) for the year 2003. The spread-sheet that summarizes the NPRI data indicates that these annual emission estimates are based upon the a combination of production and process throughput information (air-dried tonnes of bleached pulp produced per year; annual tonnes of black liquor solids processed; and annual wood heat input and annual volume of Bunker C oil used in the power boilers) and air emission factors from the National Council for Air and Stream Improvement Inc. (NCASI). NCASI is an industry-funded organization that conducts environmental research and analysis, whose data has often been cited by the U.S. Environmental Protection Agency in the development of point source emission factors. NCASI emission factors are also used in the preparation of the annual inventory of emissions from the pulp and paper industry sector in British Columbia. Some emission estimates used in preparing the JW inventory for the Crofton mill were also based upon an industry and government co-sponsored emissions study.

The following aspects of the inventory were reviewed:

1. identification of sources and emission scenarios;
2. documentation of emission estimates.

### **2.1.1 Comments on Identification of Sources and Emission Scenarios**

- A. The inventory included a relatively comprehensive array of both point and area sources.
- B. Section 5.4 of the JW report provides an analysis of the anticipated differences between short and long-term average emission rates based upon a review of the variation in production (i.e., median levels of production that range from 68% of the maximum rate for the #4 recovery boiler to 88% of the maximum production rate for lime kilns). This provides a review of a key aspect of the variation in emissions, but the assessment could be enhanced with a review of other source-specific factors through an analysis of the range of available emissions data. The assessment would benefit from the development of a peak emission scenario that reflects worst-case emissions of odorous compounds such as hydrogen sulphide and a total reduced sulphur (TRS) compound grouping, and a maximum emission scenario for contaminants such as sulphur dioxide that have peak threshold air quality criteria (e.g., objectives for 1-hour average concentrations). A review of process upset conditions (i.e., type, frequency and duration) would also be useful.

The assessment would also benefit from the development of a maximum 24-hour average emission scenario for key compounds with health-based air quality criteria (i.e., select the compounds with highest ratio of predicted annual average impact relative to the corresponding health-based air quality criterion).

- C. It is anticipated that fugitive sources of emission discharging closer to grade will be significant contributors to off-site impact. Although Section 5.3 of the JW report apportions some of the NPRI emissions to a site “volume” source, a more detailed discussion of the operations (and process upset conditions – see above) that contribute to fugitive emissions would be beneficial.
- D. It is understood that there may be significant levels of marine, truck and rail traffic that services the NorskeCanada facility in Crofton, and that these sources could be expected to have a significant contribution to facility emissions, and could contribute to the overall pollutant concentrations and affect conclusions regarding the frequency of

exceeding the ambient air quality objectives. The inventory could include, or at least discuss, the contribution of marine, truck, and rail traffic on total facility emissions.

### **2.1.2 Comments on Documentation of Emission Estimates**

- 1) The inventory is well organized and enough data is provided to be able to duplicate emission estimates.
- 2) There are alternate sources of emission factors (i.e., from the United States Environmental Protection Agency) for pulp and paper mills. However, the use of site specific emissions data and the NCASI emission factors is reasonable. The assessment could be improved with an analysis of the range of expected emissions for the following contaminants (selected based upon a review of the key compounds identified in the JW report and identification of compounds where a range of emissions can be anticipated):
  - Fine Particulate Matter (PM<sub>10</sub> and PM<sub>2.5</sub>)
  - Hydrochloric Acid
  - Hydrogen Sulphide
  - Nitrogen Oxides
  - Sulphur Dioxide
- 3) Section 8. of the JW report provides a comparison of the monitored data versus modelled predictions. The assessment could be enhanced with further comparison and validation using ambient air monitoring data for specific compounds such as hydrogen sulphide, sulphur dioxide, and particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>).

### **3.0 DISPERSION MODELLING**

The CALPUFF dispersion model was used to model emissions from the NorskeCanada facility. Currently, CALPUFF is accepted by the B.C. Ministry of Water, Land and Air Protection as a refined model for use in areas experiencing complex meteorological conditions. The U.S. Environmental Protection Agency (USEPA) recommends CALPUFF as a preferred ‘Appendix A’ model for long range transport and (on a case-by-case basis) for near-field impacts in complex terrain. The USEPA also recommends that a minimum three-year period be modelled when using mesoscale meteorological fields within the CALMET meteorological processor. SENES does not agree with this last point, in particular due to the effort and time required to perform a yearly simulation with CALMET, and the ability of CALMET to accurately capture the distribution of meteorological conditions experienced in a region during a single year. In short, the choice of the CALPUFF model, and the length of simulation is appropriate for this air quality study.

#### **3.1 METEOROLOGICAL MODELLING**

In general, SENES approves of the meteorological modelling strategy followed by JW. Acquisition and construction of the meteorological model (CALMET) inputs require a significant amount of time and effort. For all inputs except potentially one, the files were properly constructed, and the choice of CALMET grid spacing (both horizontal and vertical) is sufficient for a coastal region with moderately complex terrain. The one potential exception is the geophysical input file, which specifies the type of vegetation (or lack of) and terrain height for each model grid cell. Although this file is configured properly, all land-based grid cells were set to ‘forest’ category. A higher resolution vegetation dataset may be available, which would allow distinction between types of vegetation cover on land-based grid cells. The actual input data used to construct the geophysical input file (‘geo.dat’) was not provided to SENES, so further comment on this issue is not possible at present. However, SENES does not expect that this issue would have a large effect on the resultant meteorological fields.

Of greater importance, the meteorological data sources that were used within the modelling framework are not ideal. Unfortunately, a more appropriate dataset for the purposes of air quality modelling in this region does not currently exist. Possible weaknesses in the meteorological simulation are largely based on wind predictions.

JW created wind fields within the meteorological CALMET model using the following methodology:

- 1) Numerical mesoscale meteorological model (MC2) fields were used as an ‘initial guess’ wind field. The MC2 fields were produced from operational forecasts compiled at UBC, at a horizontal resolution of 3.3 km.
- 2) Surface station observations were then blended with the initial guess field to produce the final wind field used for air quality modelling in CALPUFF. The blending procedure occurs only in the first atmospheric level (i.e., within 10 metres above the surface). Wind fields at higher elevations are completely unaffected.

### **3.1.1 Comments on Modelled Meteorological Fields**

- A. The MC2 wind fields are likely a very good representation of wind flow in atmospheric layers that experience relatively little effect from the Earth’s surface (i.e., above one or two hundred metres). However, at 3.3 km resolution, the effects of local topography on modelled winds at and near the surface can be somewhat ‘smoothed’ away. The MC2 winds may not represent terrain steering in layers near the surface.
- B. The use of surface station data can correct this weakness in the MC2 winds, but only at locations near the surface stations. This can lead to a ‘bullseye’ effect where initial winds are modified only in those areas surrounding surface station locations; observation data has little influence in other areas of the modelling domain. Reliable station data was not available in the Crofton area for the same period of MC2 data used in the modelling analysis.
- C. The use of higher resolution grid spacing in the CALPUFF model does not significantly modify the wind flow derived from the MC2 model at higher levels, essentially negating any influences of local topography in the vicinity of the mill.
- D. The lack of surface observation data at Crofton to correct the coarse resolution wind fields from MC2 raises concerns about whether the wind fields used in the dispersion modelling analysis are representative of actual wind flow in the vicinity of the mill, and by extension, raises questions about the accuracy of the model predicted pollutant concentrations in the near field (<10 km).
- E. Vertical temperature structure in the CALMET fields is entirely derived from MC2 temperature fields (with the exception of the few missing days of MC2 data, for which

radiosonde data were used). Previous experience with MC2 simulations in B.C. indicates that vertical temperature gradients in the lower atmospheric levels tend to be stronger than observed. This has a direct influence on the determination of CALMET mixing heights. In particular, the expansion of the mixed layer during the day can be slower than actual, with a potential impact on the maximum height of the layer as well. This could affect the timing and magnitude of predicted short-term concentrations due to plume fumigation. Predicted concentrations could be either under- or over-predicting ground level concentrations, depending on the height of plume rise from individual stacks.

### **3.1.2 Comparison of Observed and Modelled Wind Fields at Crofton**

The concerns about whether the wind fields used in the dispersion model are representative of actual wind flow in the vicinity of the plant are based on comparisons between modelled and observed data. SENES conducted the following comparisons:

- CALMET modelled wind fields at Duncan at 30 m above the surface versus observed winds measured at 10 m above the surface for the same time period;
- CALMET modelled wind fields at Crofton, at 30 m elevation, for 2000-2001 versus observed winds at 44m during the same months in 2002-2003;
- observed winds at Crofton in 1999-2001 based on a standard anemometer and wind vane versus the observed winds recorded in 2002-2003 using the current sonic anemometer at the mill.

The comparisons are described below.

#### **Modelled versus Observed Winds at Duncan**

A wind rose (WR) diagram is a representation of the frequency of wind direction and wind speed experienced at a particular location. Figure 1 shows the CALMET Level 1 (10m) WR diagram at Duncan during the first 5 months of 2001. This distribution is virtually identical to that produced directly from the observation station in this area (as one would expect). However, Figure 2 shows that the CALMET winds slightly higher in elevation (30m) are completely different in orientation. Due to the terrain surrounding this area, one would expect the channelling evident at the surface (i.e., outflow winds from the Cowichan Valley) to extend up through several layers, instead of being ‘cut off’ at a height of 20 to 30 m. This shows that the MC2 winds, which were used as input to CALMET, are not realistic near the surface at this location, and are significantly modified by the surface observations introduced as a second step in the CALMET model. This is indicative of the ‘bullseye effect’ described earlier. This

correction within CALMET is not done for the Crofton area, since no acceptable meteorological station data were available for the period modelled (all wind data at Crofton were derived from MC2).

### **Modelled Winds versus Observation Data at Crofton**

A new sonic anemometer was installed at the Crofton mill during 2002<sup>2</sup>. A comparison can be made with the CALMET modelled surface winds at Crofton to the observed winds during the same months of 2002-2003. SENES has previously made comparisons of yearly WR diagrams at several other station locations on Vancouver Island (including Saturna Island, Victoria Topaz and Royal Roads University) which clearly indicate that the annual distribution of wind direction and speed at a surface location changes very little from year to year. Therefore, the winds at Crofton from June of 2000 to June of 2001 should be very similar in overall pattern to the winds of June 2002 to June 2003. Figures 3 and 4 show that the CALMET winds at a similar height to the observed surface winds are missing much of the easterly flow and over-emphasize south-westerly and north-westerly flow when compared to 2002-2003 data.

### **Observation Data at Crofton using Different Wind Sensors**

Figures 5 and 6 show the WR diagrams for the Crofton meteorological station from June 1999-June 2000 and June 2000 to March 2001 (the last three months of monitoring data is missing), respectively. These data were considered untrustworthy by NorskeCanada due to reported problems with the wind direction sensor, which is why the station equipment was eventually replaced by the Ministry of Water, Land and Air Protection in 2002 with a sonic anemometer. The distribution of wind direction from this dataset for the 1999-2000 period (Figure 5) has some similarity with the distribution from CALMET for the 2000-2001 period (depicted in Figure 3), but the distribution of observed wind data for 2000-2001 in Figure 6 is entirely different. Figure 6 appears to support the conclusion that the data from the station was unreliable by 2000. However, the differences in observed data between the standard anemometer in Figure 5 and the new sonic anemometer in Figure 4, in conjunction with the similarities between modelled data in Figure 3 versus observed data in Figure 5, raise concerns about the accuracy of the new sonic anemometer as well.

The net result of these comparisons is that SENES cannot conclude that the MC2 data used in the dispersion modelling analysis are in fact representative of actual wind speed and direction in the vicinity of the Crofton mill. The use of the MC2 data may have introduced an unknown degree

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<sup>2</sup> Communication with Warren McCormick, BC Ministry of Water, Land and Air Protection (WLAP) meteorologist.

of uncertainty into the modelling analysis, which would affect predicted short term and long term pollutant concentrations at locations within a few kilometres of the plant. In particular, pollutants such as SO<sub>2</sub>, NO<sub>2</sub>, CO, TRS and particulate matter, which have established ambient air quality criteria for averaging periods from 1-to-24 hours, may not have been accurately modelled (i.e., either under-or over-predicted) at some locations. This may affect conclusions related to whether the ambient air quality objectives could be exceeded, as well as the potential frequency of any exceedences.

SENES has not viewed the meteorological station at the Crofton mill site, and therefore cannot comment on its ability to accurately represent local winds. SENES has been informed that the instrument is mounted on the roof of a long, low building, but we have no information on the overall instrument exposure with respect to the height above ground and above roof height, or about the distance to nearby structures. In addition, we have some concerns about the use of a sonic anemometer at an industrial location due to possible susceptibility of the instrument to noise interference in high noise environments. Therefore, we cannot comment on whether the current monitoring station provides representative wind data for this site.

Even if the existing meteorological station at the site does provide representative data for modelling purposes, it must also be recognized that a 'best-practices' CALMET simulation (or that from any other meteorological model) cannot completely represent all characteristics of the meteorological conditions surrounding the Crofton area, due to the considerable complexities in atmospheric circulation. However, analysis of the CALMET wind fields suggests the following weaknesses in the 2000-2001 simulation:

- Correction of the modelled surface and near-surface wind flow (as derived from MC2 winds) at Crofton within the CALMET model is not possible, due to lack of reliable station data at this location during 2000-2001. Since the pollutant sources are sited in this area, this is where the correction is most desirable. A simple analysis of CALMET winds in this area suggests that low level winds may not be wholly representative.
- Level 2, Level 3 and Level 4 winds (30m to 120m in height) are entirely derived from the MC2 winds. The MC2 winds may not be representative of air flow near the surface in regions of complex terrain. The highest quality of data available to the model (i.e., surface observations) has very little influence on the wind fields as a whole. The implications of this are that only the lowest level emission sources (i.e., fugitive emissions)<sup>3</sup> at the pulp mill would be influenced by surface observation meteorological

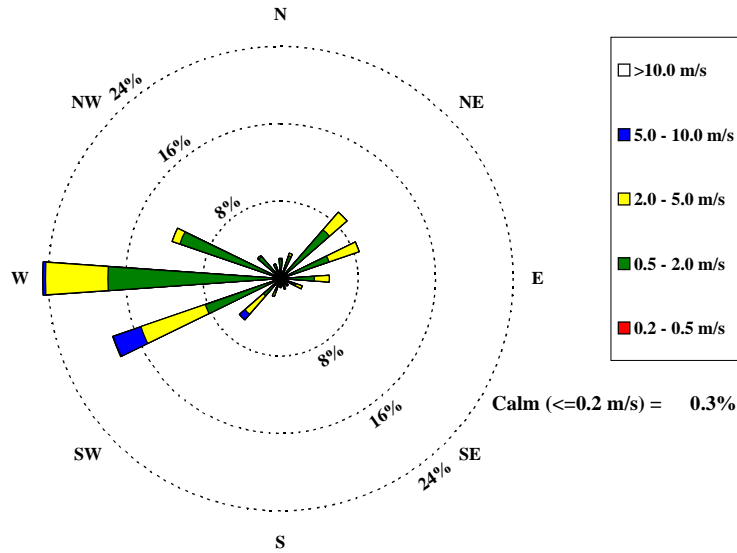
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<sup>3</sup>Based on the available CALPUFF input files, the only fugitive emission sources that appear to have been modelled include emissions from the bleach plant and one tank.

data. All thermally buoyant plumes from stacks greater than 30 m would be steered by the MC2-derived winds.

**Figure 1: CALMET Level 1 Winds at Duncan**

Level 1 Winds (10m) at Duncan, January - June 2001



**Figure 2: CALMET Level 2 Winds At Duncan**

Level 2 Winds (30m) at Duncan, January - June 2001

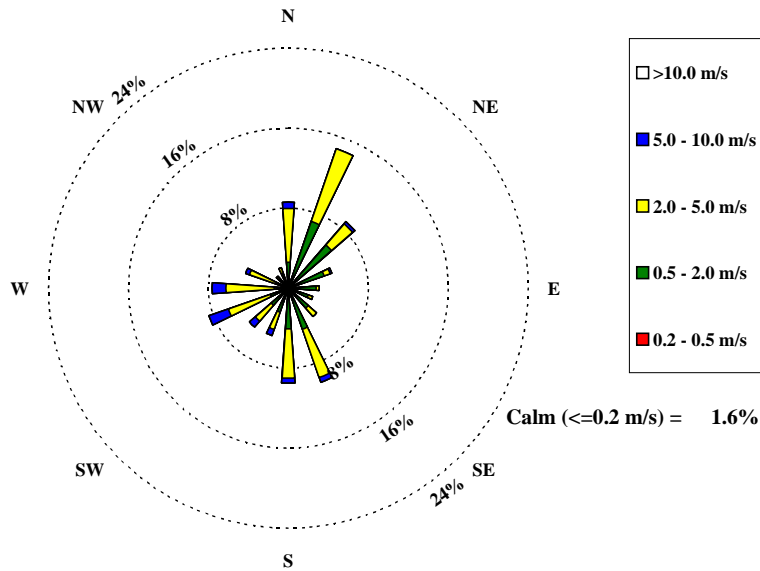


Figure 3: CALMET (Level 2) Winds at Crofton, June 2000-June 2001

CALMET Level 2 Winds (30m) at Crofton, June 2000 - June 2001

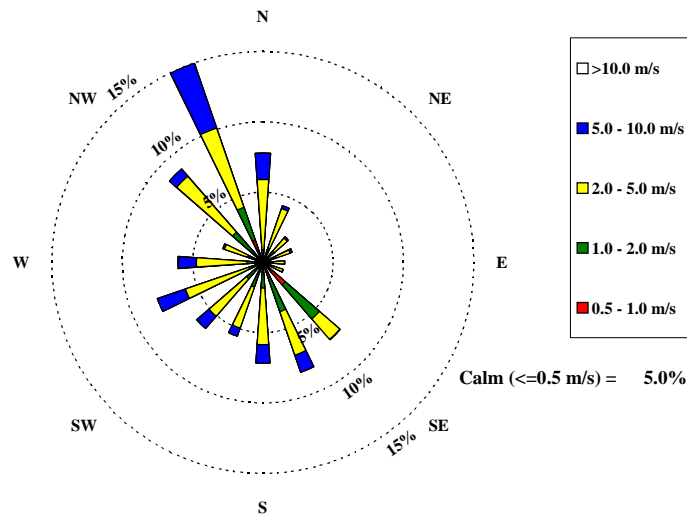
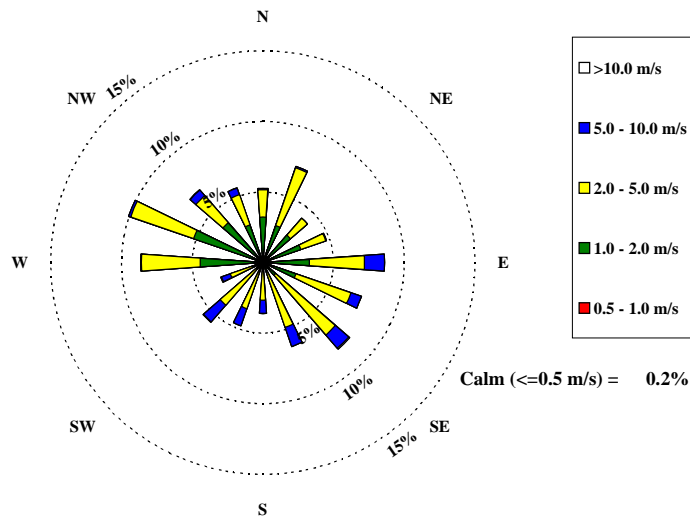


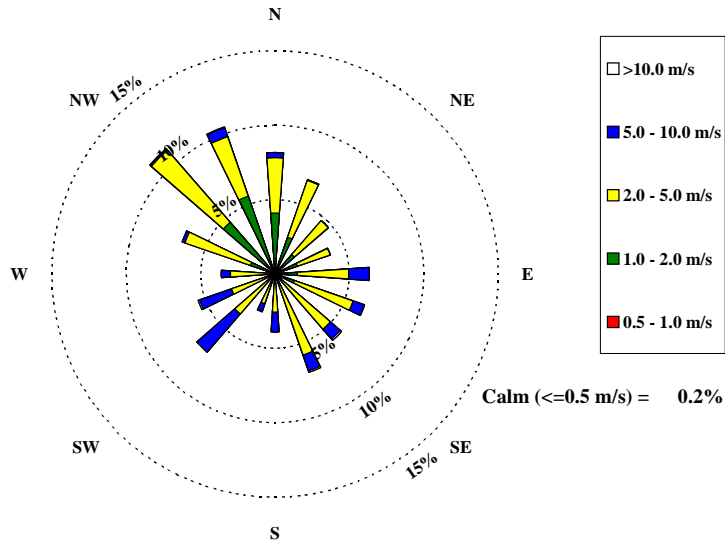
Figure 4: Observed Surface Winds at Crofton, June 2002 – June 2003

Crofton Surface Meteorological Data, June 2002 - June 2003



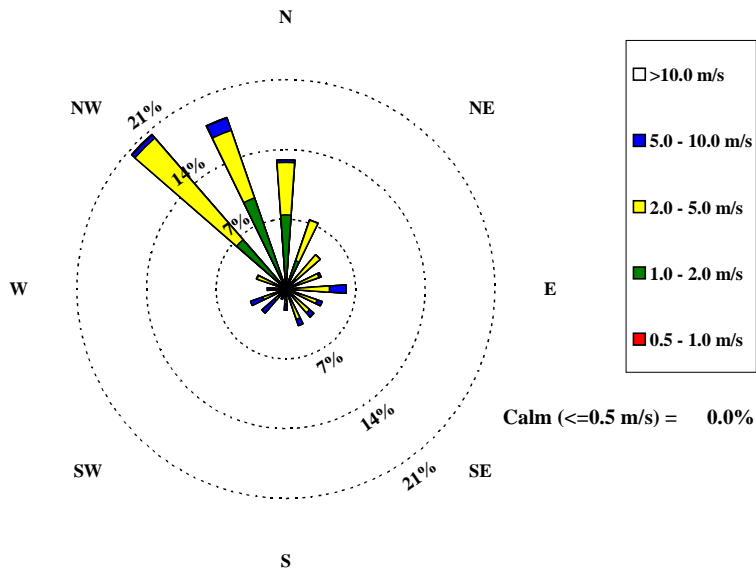
**Figure 5: Observed Surface Winds at Crofton, June 1999 – June 2000**

Crofton Surface Meteorological Data, June 1999 - June 2000



**Figure 6: Observed Surface Winds at Crofton, June 2000 – March 2001\***

Crofton Surface Meteorological Data, June 2000 - March 2001



\* Problems were identified with the meteorological station during this period

### **3.1.3 Discussion of Meteorological Trends**

Meteorological assessments in the JW report are based on characteristics of the CALMET meteorological fields. Some of the JW discussion in Section 2.2 (p12-15) is misleading and superfluous in that it provides information that is not used in the modelling assessment. An assessment is provided for the frequency of atmospheric stability regimes over Crofton (and other locations). This assessment is based on the rather simplistic Pasquill-Gifford (PG) Stability classes, which derive from cloud cover and wind speed data. The PG classes are **not** used in the CALPUFF modelling. JW chose the modelling approach (which SENES agrees with) of using micrometeorological scaling parameters to internally calculate dispersion coefficients, instead of the option of using the PG stability classes. Therefore, the rate that emitted pollutants dilute in the atmosphere may have little to do with the frequency of PG classes reported by JW. Mixing heights, which are also discussed, have particular significance in the CALPUFF configuration chosen. The discussion should be centered on mixing heights, with the potential addition of other significant parameters CALPUFF uses. In this regard, some of the discussion in the report is superfluous. SENES is unable to comment on the analysis of mixing heights, due to difficulty interpreting the black and white figures provided in the PDF version of the report provided by JW.

A misleading comment is made on page 16 of the report. On this page it is stated that there is 'very good agreement' between CALMET winds and measured data at the Victoria Airport and the Duncan stations. This must occur, since data from the stations are used by CALMET to correct its wind predictions at these two locations. This is no indication of model performance at any location away from the meteorological stations. A valid assessment of CALMET performance must use observation data of the same time period that were not used to drive the model.

### **3.1.4 CALMET Stability Regimes**

Earlier work with MC2 fields conducted by SENES has shown that vertical temperature gradients from the MC2 model tend to be stronger than observations indicate<sup>4</sup>. This can lead to the CALMET model predicting stable conditions more frequently than they actually occur, although other meteorological parameters such as surface temperature and cloud cover also have significance. SENES was not able to extract temperature data from the CALMET fields used in the modelling analysis, due to difficulties dealing with the binary meteorological files supplied

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<sup>4</sup> SENES Consultants Ltd, 2004. *Use of High Resolution Numerical Fields with the CALPUFF Modelling System: An Analysis of RAMS and MC2 Fields over Kamloops, B.C.* <http://wlapwww.gov.bc.ca/air/airquality/index.html>.

by JW. In CALMET, growth of the mixed layer is governed partly by the vertical temperature gradient above the previous hours' mixing height<sup>5</sup>.

The JW report states that the meteorological conditions that lead to high ground-level concentrations from elevated point sources "are typically either convective atmospheric stability with light winds or neutral conditions with high wind speeds" (pg. 6). An increased frequency of stable conditions results in a decrease of other stability regimes. Therefore, a higher frequency of modelled stable conditions than what is actually experienced would have an effect on maximum CALPUFF predicted pollutant concentrations, and the potential frequency of exceeding ambient air quality objectives.

### **3.1.5 Suggestions for Alternative Modelling Analysis**

If the modelled winds at the surface in Crofton, derived from the MC2 model, are not representative of actual winds at this location, it is difficult to determine the degree of uncertainty introduced to the analysis by the use of this data without the ability to make direct comparisons between predicted and observed pollutant concentrations. There currently is very little air quality monitoring data available to validate the CALPUFF predictions. There are two monitoring stations in Crofton, but the only parameter monitored at these sites is total reduced sulphur (TRS) compounds. As TRS is an aggregate measure of various sulphur compounds, it is difficult to make direct comparisons between predicted concentrations of individual compounds derived from dispersion modelling with observations of ambient TRS concentrations. Consequently, the available monitoring data are not particularly well suited to validating the accuracy of the current dispersion modelling analysis.

It is very difficult to estimate the effect of stronger-than-actual temperature gradients in the CALMET fields on CALPUFF predictions. However, SENES suggests that a simple test be conducted, looking at MC2 temperatures at two different vertical levels for different hours of the day (for example, 4 a.m. and 4 p.m.) for a period of at least a month. This can be realized by taking CALMET temperatures from Level 3 and Level 5 (for example). With these parameters, an estimate of the vertical temperature gradient near the surface can be determined and used as a comparison to gradients experienced in similar coastal locations (Port Hardy for example).

The following suggestions are possible improvements that can be made to the CALPUFF simulation:

- 1) The same modelling strategy could be followed for a different period (i.e., 2002-2003)

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<sup>5</sup> A User's Guide for the CALMET Meteorological Model, <http://www.src.com/calpuff/calpuff1.htm>.

during which Crofton surface meteorological data are available. This would require the acquisition of a new numerical dataset from MC2 or some other mesoscale meteorological model.

- 2) The potential weaknesses of the existing meteorological (wind) simulation occur at the lowest atmospheric levels. At higher levels, the simulation is likely a very good representation of wind flow (i.e., far field air quality impacts are likely to be more accurately determined than near field impacts). A second CALMET simulation, for the same period, could be conducted using surface station data and upper-air radiosonde data from Port Hardy (*without* use of MC2 data). Such a simulation puts much more emphasis on surface observations, and allows the station data to be extrapolated both horizontally and vertically to higher levels (i.e., up to several hundred metres) within CALMET. This second simulation may produce a better representation of wind flow near the surface. Whichever of the two resulting air quality simulations produces the highest air concentrations at a location could then be chosen as a more conservative estimate of pollutant concentrations for that point than is provided by the current simulation in the draft JW report. This modelling approach has already been used by JW in the current modelling analysis for those short intervals during which no MC2 data was available.

In addition, NorskeCanada may want to consider establishing ambient monitoring stations for a specific pollutant(s) that would be suitable for validating future dispersion modelling. For example, monitoring of H<sub>2</sub>S and/or SO<sub>2</sub>, as opposed to TRS.

### **3.2 AIR QUALITY MODELLING**

SENES believes that the CALPUFF modelling configuration used by JW is appropriate. However, the comparison of the CALPUFF modelled estimates of pollutant ground level concentrations to provincial ambient air quality objectives is another matter. There are three primary concerns identified in this review, namely:

1. although day-to-day variability in mill production rates are discussed in Section 5.4, the modelling of emissions is based on average production rates and is not incorporated into the comparison between predicted pollutant concentrations and ambient air quality objectives;
2. contributions from other sources in the area are discussed but not quantified, such that the comparison between predicted pollutant concentrations and ambient air quality objectives is made without considering the impact of other emission sources on overall background concentrations; and,

3. potential impacts on vegetation are considered with respect to SO<sub>2</sub> emissions alone, without considering the emerging evidence for adverse effects of NO<sub>x</sub> on natural vegetation as well.

These issues are discussed in more detail below.

### **3.2.1 Variability in Daily Production and Emission Rates**

Table 5-4 in Section 5.4 of the JW report provides a statistical summary of the variability in daily mill production rates for various process streams. The report states that *“median production rates for the parameters presented in this table vary from 68% of the maximum rate for the #4 Recovery Boiler to 88% for the lime kilns (CaO production). These data suggest that typically, the mill operated near capacity and therefore the variability between long-term and short-term emission rates would be from 12-31% of the median.”*

SENES agrees with JW that the average emission rates are appropriate for estimating long term impacts (annual averages) and are suitable for evaluating long term human health risks for potentially toxic pollutants. However, SENES disagrees with JW on two matters:

1. since the modelling analysis was based on the average emission rates, the measure of production variability should have been made between the average and maximum production rates rather than the median and maximum production rates; and,
2. depending on the emission source, the range of variability in daily production rates could significantly impact short term pollutant concentrations, affecting conclusions about the potential for operations at the plant to exceed ambient air quality objectives for some pollutants.

The range in production variability provided by JW is summarized below. The data indicate that, at least 10% of the time, production rates on various process streams can be above average production rates by amounts ranging from 19-33%, and 20% of the time the production rates are as much as 16-26% above average. It is not possible to say how these differences would affect predicted pollutant concentrations without re-modelling emissions at the higher rates because the modelling results represent an aggregate of emissions from all sources at the mill. However, these differences raise questions about whether the data on predicted pollutant concentrations presented in the summary Table I of the Executive Summary of the JW report are representative of the true impacts of the plant.

*Peer Review of Baseline Air Quality Modelling and  
Human Health Risk Assessment, NorskeCanda Crofton Division*

	Kraft Slush Production (ADt/day)	Groundwood Production (ADt/day)	Kilns CaO Production (tons)	ClO <sub>2</sub> Production (tons)	#3 Rec Solids Fired (tonne/day)	#4 Solids Fired (tonne/day)
Maximum	1361	861	396	42	1220	2155
Minimum	0	0	0	0	0	0
Average	1021	647	316	31	725	1362
Median	1133	700	350	34	861	1475
90th Percentile	1240	796	375	39	961	1664
80th Percentile	1219	764	367	38	915	1595
	Production Variability					
Max. vs. Median	20.1%	23.0%	13.1%	23.5%	41.7%	46.1%
Max. vs. Average	33.3%	33.1%	25.3%	35.5%	68.3%	58.2%
90th %tile vs. Average	21.4%	23.0%	18.7%	25.8%	32.6%	22.2%
80th %tile vs. Average	19.4%	18.1%	16.1%	22.6%	26.2%	17.1%

These differences in emission rates could also affect conclusions about the frequency of exceedence for SO<sub>2</sub> emissions presented in Table III of the Executive Summary, as well as the potential for SO<sub>2</sub> concentrations to exceed threshold concentration for acute foliar injury in vegetation.

### 3.2.2 Background Concentrations

In general, the comparison of predicted pollutant concentrations for facility emissions to ambient air quality objectives or standards usually involves adding modelled concentrations to estimates of background concentrations before representative values are determined. Other sources of emission in the area are discussed in Section 3.4 of the JW report, but it is stated that the quantitative assessment of the cumulative impact of these sources in conjunction with emissions from the mill are beyond the scope of the JW study. That being the case, no definitive conclusions can be reached with regard to whether current levels of common air pollutants such as SO<sub>2</sub>, NO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> currently meet the provincial ambient air quality objectives and standards, as well as the potential frequency with which those objectives/standards may or may not be exceeded.

For example, initial modelling results for the near-source impacts of NO<sub>2</sub> led JW to apply an ‘ozone limiting method’ (OLM) to more accurately represent the conversion of NO (which is directly emitted from the stacks) to NO<sub>2</sub>. Based on the OLM analysis, JW concluded that the BC ambient NO<sub>2</sub> guidelines were not exceeded.

However, there are numerous other sources of NO<sub>x</sub> emission in the area which could contribute to total NO<sub>2</sub> concentrations including marine, rail and truck sources servicing the mill itself,

general traffic along the Island Highway, and residential space heating, especially in winter. Marine vessel emissions are significant contributors to both SO<sub>2</sub> and NO<sub>2</sub> concentrations in the Georgia Strait region, while wood burning for space heating in winter is a major contributor to concentrations of PM<sub>10</sub> in many small communities in B.C. Without knowing the magnitude of the contribution to local concentrations from these emission sources, it is premature to state conclusively that the ambient air quality objectives for SO<sub>2</sub>, NO<sub>2</sub> and PM<sub>10</sub> are currently being met in the area, how often they may be exceeded, or to what degree emissions from the Crofton mill contribute to any exceedences of objectives.

### **3.2.3 Ecosystem Effects**

The JW report compares predicted 1-hour, 2-hour and 3-hour average SO<sub>2</sub> concentrations to threshold concentrations for acute foliar injury to vegetation. It should be noted that the World Health Organization (WHO) has also issued guidelines for the protection of ecosystems that includes annual average concentrations for SO<sub>2</sub>, as well as both 24-hour average and annual average guidelines for NO<sub>x</sub> and NH<sub>3</sub>. For consistency, the JW assessment should not be limited to SO<sub>2</sub> alone, and should include comparisons with the WHO guidelines.

## **4.0 HUMAN HEALTH RISK ASSESSMENT**

The review of the human health assessment document was carried out under the assumption that the predicted concentrations presented in the report were correct. As discussed above, there are some concerns with the predicted concentrations which may potentially result in some recalculations. This review does not consider any results relating to any potential recalculations.

As indicated in Section 1, the review of the risk assessment document was carried out within a very short time frame which did not allow for verification of all the values used in the document, especially the toxicity reference values.

The purpose of a peer review is to offer an opinion as to whether the risk assessment has been undertaken competently in accordance with published frameworks for risk assessment as outlined by Health Canada or the U.S. Environmental Protection Agency. The peer review also comments on whether or not the conclusions that have been reached are appropriate and defensible.

Thus, this peer review examines the information presented in the human health assessment report that describes the problem formulation, the rationale for identification of the chemicals of interest, the fate and toxicological characteristics of those chemicals, the rationale for selection of the appropriate exposure scenarios, the equations and/or models used to estimate the potential for receptors to be exposed to the chemicals, the interpretation of exposure estimates, and the subsequent conclusions and recommendations.

The following sections follow the general format presented by Jacques Whitford Limited.

### **4.1 INTRODUCTION**

This section of the report provides a brief description of the issues surrounding the NorskeCanada Crofton Division. It also summarizes the risk assessment framework and the air quality modeling framework. The objectives of the risk assessment were summarized and are adequate.

### **4.2 STUDY BACKGROUND**

This section includes a brief description of the history of the facility complete with relevant figures. It provides a description of the regional setting which includes a discussion of industrial development, residential and recreational areas, First Nations and climate in the study area.

The discussion provided is appropriate.

On a minor note, in this section and throughout the report there is reference to the “Air Modelling Report”. There is no consistent referencing to this report. It is suggested that a consistent reference to this report should be made.

### **4.3 PROBLEM FORMULATION**

This section presents the key steps to problem formulation and discusses the emissions from the facility, the air modelling methodology, the model inputs, model validation, selection of substances of potential concern, exposure pathways, receptor characteristics and conceptual model.

In the first part of this section, there is a large amount of overlap from the air quality modelling report. Since it has been indicated throughout the risk assessment that the “Air Modelling Report” provides the detailed analysis, it is suggested that the first parts of this section pertaining to the modelling methods be substantially reduced to provide only the information necessary for the risk assessment report. The model validation section raises a number of questions that have been discussed in the previous sections and should be provided only in the “Air Modelling Report”. Similarly the detailed discussions on the CALPUFF and CALMET models should be left to the “Air Modelling Report”.

The sections of the report from Section 3.4 onwards are appropriate for the risk assessment and follow the risk assessment framework; however, it is suggested that Section 3.4 is not the Selection of Substances of Potential Concern (SoPCs) but rather the Methodology for the selection as a list of SoPCs is not provided in this section.

In the exposure pathways section, the report indicates that there are “*numerous pathways by which human receptors could be affected by the emissions*” and then indicate that the report only considers inhalation pathways. While it is acknowledged that the inhalation pathway is the major pathway for SO<sub>x</sub>, NO<sub>x</sub> and H<sub>2</sub>S, some discussion should be provided on the indirect pathways with a rationale for not considering them.

The discussion of the receptor characteristics and conceptual model are adequate. On a minor note, the conceptual model (Figure 3-5) shows routes of exposure and not exposure pathways.

#### 4.4 TOXICITY ASSESSMENT

In this section of the report different toxicity reference values are discussed. First, Canadian Ambient Air Quality Objectives were discussed, specifically, B.C. Air Quality Objectives, National Ambient Air Quality Objectives, Canada Wide Standards for Particulate Matter and Ontario Ambient Air Quality Criteria.

It is our opinion that comparisons to the Ontario air quality criteria should be presented in the air quality document and that only the B.C and Federal air quality objectives should be used to screen for SoPCs. In addition, it is our opinion that the World Health Organization health based TRVs may be more appropriate for the B.C. context than the Ontario Ambient Air Quality Objectives.

A quick spot check between Appendix B and Table 4-2 indicates that some of the numbers in the table are not the exact value reported in Appendix B. For example, the TRV for acute exposure to hydrogen sulphide is reported to be 97.6  $\mu\text{g}/\text{m}^3$  in Appendix B and is provided as 100  $\mu\text{g}/\text{m}^3$  in Table 4-2. Differences between Appendix B and Table 4-2 should be resolved to ensure consistency in the numbers and so that there is no confusion. In addition, in Appendix B, the intermediate duration TRV from the WHO could not be found. An intermediate value of 40  $\mu\text{g}/\text{m}^3$  was obtained from ATSDR. It should be highlighted that all the values presented in Tables 4-1, 4-2 and Appendix B were not verified; only spot checks were carried out.

In discussing short-term exposure limits, JW indicates that longer term health based concentrations can be derived using scaling factors provided the Ontario Ministry of the Environment. We agree with the approach but suggest that the report should indicate that these factors have also been validated by the U.S. EPA and that an empirical relationship has been derived. It is suggested that the discussion that air quality objectives at shorter averaging times were derived using these empirical factors should be changed to indicate that shorter term health based limits were derived using these empirical values since indicating that the shorter term values are air quality objectives is misleading.

In the discussion relating to PAH compounds, JW indicate that the U.S.EPA toxic equivalency factors are used because “ the justification for the benzo(a)pyrene OMOE value could not be found”. We would direct JW to the OMOE document entitled “ *Scientific Criteria Document for Multimedia Standards Development Polycyclic Aromatic Hydrocarbons (PAH): Hazard Identification and Dose-Response Assessment*”(1997) for the rationale for the inhalation TRV. This statement should be removed from the report.

This section would benefit from a final summary table of all the TRVs to be used in the assessment which includes SO<sub>2</sub>, NO<sub>2</sub>, H<sub>2</sub>S and all the organics.

#### **4.5 EXPOSURE ASSESSMENT AND RISK CHARACTERIZATION**

This section combines the measured and predicted concentrations of SoPCs to TRVs.

Section 5.2 of the report provides a discussion on ambient air monitoring, it is our opinion that this section is not appropriate in this part of the report and in fact should be provided in the “Air Quality Modelling Report”. The only information that should be presented in this section is the measured values with all reference to the details back to the air quality stating all the values in the Table are MOE Health Based AAQ criteria (since this is not the case). The table needs to be clarified to indicate which values are the AAQC and which values have been derived using the empirical values provided by the MOE report. It is suggested that the measured values be presented before a discussion of the % exceedances (Table 5-1).

Table 5-4 provides a table that summarizes which of the substances are carried forward as SoPCs based on the modelling results. Caution needs to be exercised when indicating that the adjusted short term values are standards.

We agree with the SoPCs that are carried through for more detailed consideration but suggest that some discussion should be provided for particulate matter since the public are more aware of health issues related to particulate and it would be beneficial to indicate that PM was screened out. A detailed discussion was provided for PAHs which are measured at extremely low concentrations compared to a TRV whereas for PM there is no discussion.

The section discussing evaluation of SoPC with no TRV (Section 5.3.4) may be better presented under the uncertainty section since this is a gap in the assessment.

#### **4.6 FURTHER RISK EVALUATION OF SELECTED SoPCs**

This section focussed on a discussion of HCl, NO<sub>x</sub>, SO<sub>2</sub>, and H<sub>2</sub>S. In this section comparisons are made to OMOE AAQCs. It is recommended that in this section Health based values presented in Health Canada, U.S. EPA or WHO documents be used rather than the OMOE AAQCs. It is our opinion that these comparisons would be more rigorous and have a better basis as studies from the U.S.EPA and WHO provide the basis (i.e. health related endpoints) associated with the TRV values. There are some inconsistencies in the assessment and each SoPC is handled differently. It is suggested that a standardized approach be used for SoPCs that have federal guidelines (i.e. NO<sub>x</sub>, SO<sub>2</sub>, and H<sub>2</sub>S) where both the federal AAQO is used as well as other TRVs. This would make the section a lot easier to follow and understand. The approach

for HCl would be the only assessment that would not be standard. The following paragraphs provide other points relating to this section.

Section 6.1 provided a discussion on H<sub>2</sub>S which was somewhat confusing especially the paragraph starting “*Given that the OMOE 24 hour AAQC...*”, it is suggested that this section be clarified. A table is provided in this section which has a Figure 6-1 title. This appears to be a typographical error. In this table, the health based TRVs are CalEPA and OMOE AAQC where as the discussion in the section relates to CalEPA and U.S.EPA values. Since an RfC value of 20 µg/m<sup>3</sup> is provided. This should be used in the table with a discussion and rationale indicating whether this value is considered to be a 24-hour or annual value. The table must also indicate that any other values relating to this RfC have been derived from the OMOE empirical factors. Units should also be provided in the table. There is a value of 9 provided in the CalEPA row, it is unclear where this value is from.

Section 6.2 provides a discussion on NO<sub>2</sub> and outlines a Tier approach as presented by the U.S.EPA. This approach seems reasonable. The text refers to Table 6-2 whereas the information is presented in Table 6-1. Predicted values were presented in the table, however, no TRVs are presented. This table and discussion would benefit from including the appropriate TRVs in the table.

Section 6.3 provides a discussion of SO<sub>2</sub>. In this section only OMOE and the federal health based guidelines are presented. The discussion focuses on the OMOE standards and then indicated that the federal values are higher. This does not provide confidence in the assessment. It is suggested that the federal standards be used in this discussion with the WHO TRV values provided for a context. Again in this section, the table should indicate which TRV values have been adjusted using the OMOE factors.

Section 6.4 discusses hydrogen sulphide and provides an RfC value for H<sub>2</sub>S. There are TRS measurements that are referred to in this section. It may be more appropriate to provide a comparison between the modelled and measured values to show how the model is performing and with this as a basis then provide a comparison to the TRVs. This would make this section easier to follow. The same comments apply as to the use of the OMOE factors.

#### **4.7 UNCERTAINTY ANALYSIS**

This section provides a discussion on the uncertainties in various assumptions in the assessment. A section is provided which discusses the uncertainty in the TRVs and indicates that uncertainty factors are used in the derivation of many of the numbers. We agree that uncertainty factors are used in TRVs derived by Health Canada and U.S. EPA but are less certain of the uncertainty

factors used in the development of AAQC values which are used throughout this report. Some discussion about the different TRV values used in the report should be provided. As well, it would seem that JW uses an RfC as an annual TRV. We agree with this approach; however, some regulatory agencies such as the OMOE use this value as a 24-hour TRV and then use the scaling factors to adjust to lower values on an annual basis. This should be acknowledged in this section and thus the conclusion that the risk assessment is highly conservative may not be entirely correct.

The section on sensitive subpopulations is related to TRVs and should be included as a subsection in the TRV discussion. JW indicates that most of the AQO's are based on epidemiological studies; a reference should be provided for this statement as it may only relate to the combustion gases and not all the other substances that were assessed in this report.

#### **4.8 SUMMARY AND RECOMMENDATIONS**

In this section, it is indicated that there are some residual issues relating to all four of the SOPCs (HCl, NO<sub>x</sub>, SO<sub>2</sub> and H<sub>2</sub>S). We agree with these findings and agree that a followup monitoring program is necessary to validate the conclusions of the risk assessment.

## **5.0 CONCLUSIONS**

The overall conclusion of the review of the draft baseline air quality modelling and human health risk assessment of the current day emissions from the NorskeCanada mill at Crofton is that the current assessment represents a comprehensive initial evaluation of the mill's emissions and impacts, but that there are several areas where the assessment could be improved. The recommended modifications to the assessment are summarized below.

### **Sources and Emission Rates**

The emission inventory provides a relatively comprehensive summary of average emission rates (based on annual average production rates) from point and area sources at the mill. The inventory is well-organized and SENES was able to reproduce the estimated emissions from the information provided by JW.

The inventory is suitable for a dispersion modelling assessment designed to support a health risk assessment for chronic exposure scenarios to Substances of Potential Concern (SoPCs), but is not suitable for estimating peak SoPC concentrations for acute effects over 24-hours or less, or for comparison with ambient air quality objectives over averaging times of 24 hours or less. Although daily variability in production rates is discussed, that variability has not been incorporated into the emission modelling analysis. The assessment would benefit from the following:

- directly incorporating variability in NCASI-derived emission factors into the inventory;
- developing peak 1-hour and 24-hour average emission rate scenarios for key compounds (SO<sub>2</sub>, NO<sub>2</sub>, HCl, PM<sub>10</sub> and PM<sub>2.5</sub>) to address worst-case daily emission rates based on variability in daily production rates;
- a more detailed discussion of operations that contribute to fugitive emissions and the inclusion of all fugitive emissions in the modelling analysis;
- estimates of emissions, or at least a discussion of those emissions, from marine vessel, truck and rail traffic servicing the mill that contribute to overall facility emissions;
- further validation of the emission rates through comparisons between ambient monitoring data and predicted impacts for specific compounds such as H<sub>2</sub>S, SO<sub>2</sub> and particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>).

### **Meteorological Input Data**

The meteorological data available to JW for this assessment was not ideal. SENES agrees with and supports the conceptual approach used by JW in combining mesoscale meteorological model data (MC2) with surface observations as input to the CALMET model. Unfortunately, surface observation data at Crofton were not available for the same time period as the MC2 data. Comparisons between surface observations at Duncan and modelled meteorological data one level above the surface indicate that the MC2-derived air flow near the surface was not capturing essential features of the air flow at that location, and by extension, raising questions about the accuracy of the predicted winds at Crofton. Comparisons between surface observations at Crofton for different time periods, using different types of wind sensors, also indicate significant differences for periods before and after the change in instrumentation, as well as between surface observations and modelled winds used in the JW air quality dispersion modelling analysis. These comparisons raise questions about which data set best represents the wind flow at Crofton, and the magnitude of any differences in predicted air quality impacts stemming from uncertainty about the meteorological data used. SENES cannot conclude that the meteorological data used for the analysis is representative of actual wind speed and direction in the vicinity of the mill. Note that this would affect near field predicted concentrations (<10 km), but not far field predicted impacts (>10 km), and would have a greater effect on maximum predicted short term concentrations (<24 hours) than on annual averages that are used to evaluate chronic health risks.

To address this uncertainty in the meteorological data, SENES suggests two possible alternatives:

1. The preferred alternative would be to obtain a new MC2 data set that coincides with representative surface observation data at Crofton. The only caveat to this suggestion is whether the data derived from the current sonic anemometer at the mill provides representative data, due to concerns about instrument exposure and possible interference from noise at the mill.
2. The second alternative would be to re-model the emissions using only surface observation data from another period (without the MC2 data), and to choose whichever of the two analyses produces the higher predicted concentration as a conservative measure of potential air quality impacts from the mill.

Other concerns with the meteorological data stem from previous SENES experience in using the MC2 data and are related to vertical temperature profiles and their effect on determining atmospheric stability in the CALMET model. Based on past experience, the use of MC2 vertical

temperature profiles can increase the estimated frequency of very stable conditions, thereby decreasing the frequency of other stability categories in the meteorological data set. Since maximum ground level pollutant concentrations are more likely to be predicted for the less stable categories, the increased frequency in stable conditions in the data used by JW may affect conclusions about the maximum predicted concentrations of some pollutants for short term averaging times (e.g., <24 hours), and the potential frequency (if any) with which pollutants may exceed the ambient air quality objectives.

The meteorological modelling analysis would also benefit from the use of a higher resolution vegetation dataset which would allow distinction between types of vegetation cover.

The discussion of the meteorological modelling analysis would also benefit from more rigorous editing of misleading and/or superfluous sections of the report.

### **Air Quality Modelling**

The CALPUFF modelling configuration used by JW for the assessment was appropriate. The primary concerns with the air quality assessment are related to the following:

- uncertainty about variability in peak emission rates for some sources that may affect conclusions about the potential for mill emissions to meet or exceed ambient air quality objectives for pollutants with short term averaging periods (1-24 hours);
- the comparison of predicted incremental air quality impacts to ambient air quality objectives due to mill emissions alone, in the absence of estimated contributions from other sources to background air quality;
- limiting the evaluation of potential adverse impacts on vegetation to effects of SO<sub>2</sub> emissions only for acute exposures (1-3 hours) without considering long term average impacts, as well as the lack of evaluation for potential adverse impacts from NO<sub>x</sub> and ammonia emissions.

Due to the uncertainties related to: 1) variability in emission rates and omission of some fugitive emission sources from the dispersion modelling, 2) the lack of representative surface meteorological data at Crofton, and 3) uncertainty about the contributions from other emission sources to background concentrations, no definitive conclusions can be made about whether the air quality concentrations in the Crofton area are within applicable ambient air quality objectives, or the frequency with which those objectives may be exceeded. There is greater confidence in the predicted far field impacts (>10 km) than in the predicted near field impacts (<10 km), and

more confidence in the long term impacts (annual averages) than for peak short term concentrations (1-24 hours).

### **Human Health Risk Assessment**

The risk assessment completed by JW follows generally accepted practices and assumptions. In general, the assumptions have been provided and documented.

There are some areas that should be addressed to ensure that the risk assessment is defensible:

- much of the discussion relating to air quality modeling and measurement should be condensed and referenced to the details in the Air Quality modelling report;
- the Toxicity Reference Values should be revisited to determine whether the OMOE AAQC values are the most appropriate values to be used in the assessment;
- the TRV values in the main body need to be consistent with the values provided in Appendix B;
- the assessment needs to acknowledge when AAQC values were derived using the OMOE empirical factors;
- a standardized approach should be used in Section 6 to assess the four SoPCs; and,
- clarifications to the uncertainties associated with the TRVs should be made in Section 7;
- a discussion should be added on the significance of the health effects related to particulate matter, similar to the discussion on PAH.

On a minor note, there are some typographical errors in the document. We are sure that these will be corrected when the final document is finished. A few examples are that the title of Problem Formulation is spelled incorrectly; in Section 6 the tables need to be renumbered and there are some superscripts that are missing for  $\mu\text{g}/\text{m}^3$ .