PEER REVIEW

2005 AIR QUALITY MONITORING PROGRAM
CALPUFF AIR DISPERSION MODELLING ASSESSMENT
EKATI DIAMOND MINE

Prepared for:

Independent Environmental Monitoring Agency

5004 Franklin Avenue
Yellowknife, NT X1A 2N8

Prepared by:

Bohdan Hrebenyk, M.Sc.
Bryan McEwen, M.Sc.
SENES Consultants Limited
1338 West Broadway, Suite 303
Vancouver, B.C. V6H 1H2

Katherine Enns, RPBio. M.Sc. CCEP, PBiol.
Delphinium Holdings Inc.
602 Tamarack Street
Castlegar, B.C. V1N 2J2

March 2007

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0   INTRODUCTION

SENES Consultants Limited (SENES) was retained by the Independent Environmental Monitoring Agency (IEMA) to conduct a peer review of the 2005 air quality monitoring program and the air dispersion modelling assessment conducted for the EKATI Diamond Mine by Rescan™ Environmental Services Ltd. The reports reviewed are entitled:

- EKATI Diamond Mine 2005 Air Quality Monitoring Program (October 2006)
- EKATI Diamond Mine CALPUFF Dispersion Modelling Assessment (October 2006)

The review focused on the following topics in these reports:

1) a review of the Hi-Vol particulate matter monitoring program;
2) a review of the snow sampling program;
3) a review of the lichen sampling and vegetation distribution surveys;
4) a review of the common air contaminant and greenhouse gas emission inventories;
5) a review of the meteorological data input to the CALMET model;
6) a review of the CALMET and CALPUFF input file switch settings;
7) a review of the CALPUFF model predicted concentrations in relation to relevant ambient air quality objectives and guidelines.

The review of the air quality monitoring program and emissions calculations was conducted by Bohdan (Dan) Hrebenyk of SENES. Mr. Hrebenyk is Manager of the SENES British Columbia office and a Senior Climatologist/Environmental Scientist. He has extensive experience in boundary layer meteorological and air quality monitoring, air pollutant dispersion modelling of emissions from industrial and mining activities, including the design and implementation of meteorological and air quality monitoring and modelling assessments in severe arctic and sub-arctic climates. Mr. Hrebenyk has managed or participated in air quality assessments for a variety of industrial practices. These studies have included the evaluation of particulate matter, gaseous emissions of common air contaminants and toxic chemicals, trace metals and radionuclides from process stacks, bulk material handling operations, wind erosion of stockpiles and exposed mine tailings, and equipment travel on paved and unpaved haul roads. Mr. Hrebenyk has considerable experience in conducting meteorological and air quality monitoring and modelling assessments in severe arctic and sub-arctic climates, and has previously conducted peer reviews of the air quality monitoring and management plans for the EKATI mine, as well as the proposed air dispersion modelling assessment submitted for this mine, in 2004. He has also conducted a peer review of the air quality monitoring program for the DIAVIK Diamond Mine on behalf of the Environmental Monitoring Advisory Board.

The review of the meteorological data and CALMET/CALPUFF input data files was conducted by Bryan McEwen of SENES. Mr. McEwen is a meteorologist and air quality scientist with extensive experience in atmospheric dynamics and meteorological computer modelling. He has conducted numerical meteorological simulations with the Regional Atmospheric Modeling System (RAMS) and the Nonhydrostatic Mesoscale Model (NMM) for use in windflow and air quality assessments. He has also conducted studies using simulated meteorological fields from the MC2 and Eta mesoscale models. Mr. McEwen has assessed and applied meteorological data to several different air quality models currently in use. In particular, he has had a considerable amount of experience with the CALPUFF Modelling System and has recently given a number of presentations on the use of numerical meteorological fields with this dispersion model.

The review of the proposed lichen study was conducted by Ms. Katherine Enns of Delphinium Holdings Inc. Ms. Enns is a plant ecotoxicologist with 27 years experience in defining industrial impacts on soils, vegetation and wildlife. She has extensive practical experience with measured concentrations of heavy metals in soils and vegetation and subsequent effects determination in receptor species and communities. Based on CCME and CSR guidelines, Ms. Enns has developed several field and map-based methods for evaluating the impacts of metal accumulation in soils on forage, wildlife and plants. She completed a biomonitoring baseline and re-measurement of the distribution of heavy metals for Teck Cominco Metals Ltd.. These data were used extensively in their wide area ecological risk assessment. She was an advisor to the Athabasca Oil Sands Wood Buffalo Environmental Group for 6 years, providing advice on use of lichens and other sensitive vegetation for detecting impacts from heavy metals and oxides of sulphur and nitrogen. Ms. Enns has conducted many biomonitoring studies around industrial sites in northern boreal forests, and specializes in heavy metals, sulphur and halide behaviour in soils and uptake by vegetation. She recently completed a four year study on the impact of sour gas well flaring on soils and vegetation of North Eastern B.C. for the Oil and Gas Commission of British Columbia.

2.0   AIR QUALITY MONITORING REVIEW

The review of the air quality monitoring program at the EKATI mine focused on the four components of the program, namely:

- High Volume Air Sampling System (HVAS);
- snow core sampling program;
- lichen sampling program;
- vegetation distribution surveys.

Comments on these four components are discussed below.

2.1   HVAS MONITORING RESULTS

Section 2.2 of the 2005 air quality monitoring report states that TSP sampling data are only available for one sampling location (TSP-2) located at Grizzly Lake, approximately 4.5 km from the main camp and mining pit operations at Koala, North Koala and Panda. A second monitoring station (TSP-1) that was located on the roof of the accommodations building was suspended at the end of 2002 because the sampler was being influenced by the building's ventilation system, and a new location for this sampler had not been determined by 2005. It may be reasonable to ask why it has taken so long to find an alternative location for this monitoring station?

The Rescan report states that data collection at TSP-2 was only conducted sporadically from May to October in 2005. In actual fact, Table 3-2 in the report indicates that only 7 valid samples were collected during the 2005 sampling season from July 5th to September 26th. In fact, there was only one sample collected in July, and 3 samples each in August and September. These samples provide insufficient data to characterize TSP levels in the summer of 2005.

The report states that *samplers are not operated through the winter because electric motors that draw the air through the filter do not function well under extreme winter conditions."* This is the same reason given in EKATI's 2002 report titled High Volume Air Sampler Operation (ENVR-SOP-AIR-01, November 25, 2002). At that time, BHP Billiton suggested that *"the proven difficulty of operating HV equipment in the extreme conditions of cold and blowing snow"* precluded the continuation of the sampling program for the other months of the year. In the review of the latter report, SENES stated that *"while extremely cold temperatures and blowing snow may occur frequently during the winter months, they are not a constant feature of every day. Secondly, I* (i.e., B. Hrebenyk) *have successfully operated high volume air samplers in a sub-arctic environment at temperatures down to –30^{0}C. Therefore, whereas it may not be feasible to conduct high volume TSP sampling on a regular one-in-six day schedule, it should*

still be technically feasible to continue sampling through the cold months of the year when meteorological conditions permit."

It is true that high volume sampler motors will more readily burn out in extremely cold conditions. But, it is also true that these motors are relatively inexpensive to replace, costing on the order of about $200 each. Given the value of the data, this is not an unreasonable cost for the operators to pay, even if they have to go through several motors every year. Furthermore, Environment Canada has operated a high volume dichotomous sampler for $PM_{10}/PM_{2.5}$ sampling in Yellowknife for many years in all seasons, including throughout the 2003, 2004 and 2005 winters. A dichotomous sampler is simply a high volume sampler with a size-selective sampling head to separate the two particulate matter size fractions onto separate filters. If Environment Canada can operate throughout the winter, then there is no reason why BHP Billiton cannot do so either. Moreover, it is not uncommon for mining companies to be required to provide such sampling. For example, SENES is aware that Teck Cominco operated high volume samplers at several locations around the Red Dog mine in Alaska in all seasons for many years. These high volume samplers have now been replaced by the far more expensive TEOM type samplers at the Red Dog mine. Therefore, BHP Billiton's rationale for not being able to operate the high volume samplers at EKATI throughout the year is not supportable.

SENES also takes issue with the stated conclusion in Section 4.0 of the 2005 air monitoring report to the effect that: *"Though road infrastructure increased to accommodate the development of the Fox open pit, emissions of particulate matter (total particulate, PM10 and PM2.5) decreased over the same time period (i.e., 2002 to 2005), suggesting management practices such as road watering and dust suppression have had success."* First of all, the only emissions data provided in this report are those presented in Table 3-1, showing an exponential decrease in particulate matter emissions from 171 tonnes per year in 2002 to just 39 tonnes per year in 2005. However, these emissions are for sources that are reportable under the National Pollutant Release Inventory (NPRI), which specifically excludes fugitive dust emissions. Therefore, this trend in estimated emissions has absolutely nothing to do with dust suppression techniques applied to roads. Furthermore, the average summer season TSP concentrations measured at the Grizzly Lake monitoring site (TSP-2) listed Table 3-2 clearly indicate a steadily increasing trend in TSP concentrations from 1999 to 2004 (as noted above, there were insufficient data in 2005 to compute a valid seasonal average). The increasing trend in average seasonal TSP concentrations is illustrated in Figure 2-1 below, with the decreasing trend in NPRI reported emissions superimposed. Clearly, the increase in measured average TSP concentrations does not support the stated conclusion in the Rescan report that dust suppression practices have had success. In fact, no such evidence is presented in either the monitoring or the modelling report, beyond theoretical assumptions used in estimating fugitive dust emissions.

Figure 2.1
Trend in Measured Average Summer Season TSP Concentrations at Grizzly Lake
And Report Particulate Matter Emissions to the NPRI
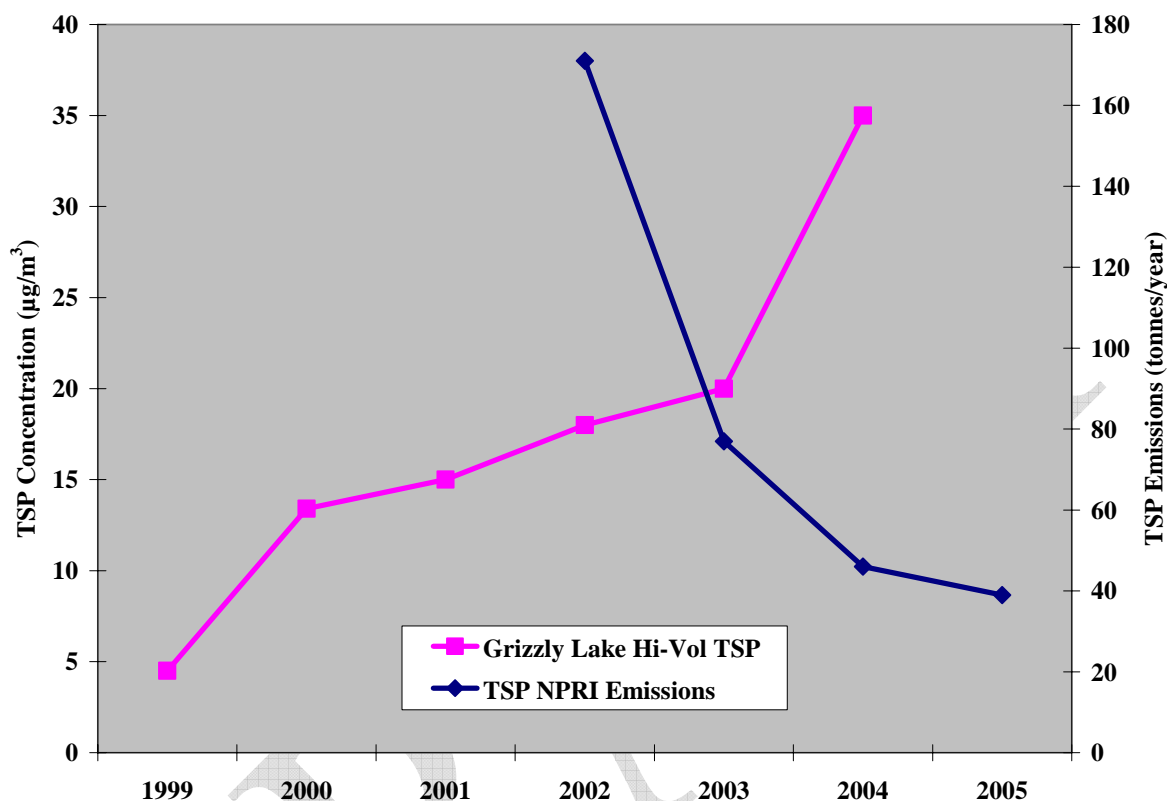
It should also be noted that Rescan's conclusion that the HVAS results from 1999 to 2005 at TSP-2 were consistently below the benchmark Canada Ambient Air Quality Objective of 60 µg/m^3 is meaningless because the samples were not collected over the entire year. It is therefore inappropriate to compare the average values over a few months of the year to an annual average objective.

2.2 SNOW CORE SAMPLING

Section 2.3 of the Rescan air quality monitoring report states that 61 snow core samples were collected between April 14th and April 30th, 2005. Figure 2-1 of the report shows the locations of these sampling sites. The first notable aspect of the snow core sampling program is the rather odd distribution of the background sampling locations. Nine sampling sites (AQ-33,AQ-34, AQ-36, AQ-37, AQ-38, AQ-39, AQ-40, AQ-41, and AQ-42) are grouped to the north of the Central EKATI mining area, and no explanation is provided in the Rescan report for the rationale used in choosing these sampling locations. Another 10 snow core sampling sites (AQ-32, AQ-35, AQ-

43, AQ-48, AQ-49, AQ-50, AQ-51, AQ-54, AQ-55 and AQ-C4) are indicated as being background snow, lichen and vegetation monitoring sites. Six of the latter sites are also grouped in the area north of the Central EKATI mining area. Therefore, a total of 15 background sampling sites are located north of the mining activity while only three are located to the west-northwest and only one is located to the southwest of the Central EKATI mining area. This is obviously neither a random nor grid-based distribution of sampling locations and warrants some explanation for why these locations were chosen to represent background sampling sites. None is provided in the Rescan report.

The results of the snow core sampling program are briefly discussed in Section 3.3 of the Rescan report. The report states that, for many parameters, the 2005 sampling results were within the historical range of average values, and that many values for 2005 were below those reported from sampling programs in 1998-2001. However, close inspection of the data presented in Table 3-3 and in Appendix 2 of the Rescan report raises some concerns about these sampling results. Specifically, these concerns are as follows:

- With respect to sulphate, both the average and median values listed in Table 3-3 are meaningless because 47 of the 59 samples were below detection limits. Rescan simply took one-half the detection limit as the value for these samples in calculating the average and median values. This was inappropriate from a statistical perspective, and should simply have been reported as a range from below detection limits to the maximum observed. However, the fact that so many of the samples were below the analytical detection limit is a concern because the samples should have been able to at least pick up the background sulphate levels in the area. The fact that 80% of the samples were below the detection limit suggests that either the sulphate levels in the area are very low, or that sulphate was lost from the snow core samples. The latter is likely the case if there was any period of melt prior to the sample being collected. Sulphate is relatively stable in a snow pack so long as melt does not occur, but sulphate can be lost from the snow pack after a period of melt. The high number of non-detect samples raises concerns about whether the samples provide a true measure of sulphate deposition in this area over the winter period.

- Background sampling sites AQ-34 and AQ-35 are located very close together (i.e., within about 1 km), yet the snow pack chemistry of these two sites with respect to nitrogen deposition (i.e., as nitrate and ammonia) is very different. For example, the ammonia level for AQ-34 was reported as being below the detection limit of 0.005 mg/L while that of AQ-35 was listed as 0.016 mg/L (see Appendix 2 of the Rescan report). Similarly, the nitrate level at AQ-34 was listed below the detection limit of 0.005 mg/L, compared with 0.0462 mg/L at AQ-35. For two 'background' sites located so close together, the

differences between the reported ammonia and nitrate levels appear to be too large. Either one of these sites is very sheltered, or there has been contamination of the other sample before laboratory analysis. It should also be noted that a number of recently published research papers have reported on the instability of nitrogen species in snow packs. Amoroso et al. (2006)[1] reported on the photochemical transformation of the nitrate ion to form nitrous acid (HONO) in the interstitial air in polar snow packs, and the release of HONO to the atmosphere in springtime. Rapid air-snow surface transfer processes of nitrogen species have also been reported for Alert, Nunavut, by Albert et al. (2002).[2] Other examples of similar reported reactions and releases of nitrogen from snow packs are also available. Given that the snow core samples at EKATI were collected in the second half of April, it is possible, even likely, that some of the nitrate and ammonia had been released from the snow pack before the samples were collected. Therefore, the lack of any trend in decreasing nitrate or ammonia concentrations in snow core samples is likely not an indication that these species were "advected out of the region" as Rescan concluded in its report. It may simply be that the samples collected were not suitable for determining the impact of the NO_x and ammonia emissions from mining activity because of the loss of nitrogen from the snow pack before the samples were collected. It would be useful to know whether there are any differences in the exposure of the two sampling sites at AQ-34 and AQ-35 to see whether that may have contributed to the differences in reported nitrate and ammonia concentrations.

- The sample at AQ-11, close to the mining activity at the Misery pit, had the highest parameter values for nitrate (although a background sample at AQ-51 was only slightly lower), aluminium, antimony, arsenic, barium, calcium, total chromium, total cobalt, total copper, total iron, total lead, total magnesium, total manganese, total nickel, total phosphate, total potassium, total silicon, total uranium, total vanadium and total zinc. Clearly, the AQ-11 site is impacted by the mining activity. With respect to total suspended solids (TSS) in the snow core samples, the highest value of 143 mg/L was also from the snow core sample collected at AQ-11. However, the second highest TSS value of 88.8 mg/L was reported for the 'background' at AQ-41 north of the EKATI mining area. Furthermore, the highest turbidity level of 265 NTU was also reported for the 'background' AQ-41 sample, as was the highest TKN value of 1 mg/L. No explanation

---

[1] Amoroso, A, Beine, H.J, Sparapani, R., Nardino, M. and I. Allegrini (2006). *Observation of Coinciding Arctic Boundary Layer Ozone Depletion and Snow Surface Emissions of Nitrous Acid.* Atmospheric Environment (40): 1949-1956.

[2] Albert, M.R., Grannas, A.M., Bottenheim, J, Shepson, P.B., and F.E. Perron (2002). *Processes and Properties of Snow-Air Transfer in the High Arctic with Application to Interstitial Ozone at Alert, Canada.* Atmospheric Environment (36): 2779-2787.

was provided by Rescan for these high TSS, TKN and turbidity levels at a supposed 'background' site.

The concerns raised above speak to the design and implementation of the snow core sampling program. It is recommended that the entire program be reviewed and revised to ensure that data useful to the assessment of the EKATI mine's impacts are indeed being collected.

2.3 BIOMONITORING PROGRAM

This review addresses several aspects of the biomonitoring system (i.e., lichen and vegetation distribution) that has been developed, and the documentation to describe it.

The monitoring program has been recently revised by Rescan to compensate for, or replace some aspects of, the original program and as such is likely an improvement on the previous monitoring program. However, there are several features of the program, and the documentation that should be further improved to make the program workable over the long term.

In the comments below, the authors of the EKATI air quality monitoring report are referred to as Rescan (for Rescan Environmental Services Ltd). In summary, the general comments are discussed 2.3.1. Comments on specific sections of the report are discussed in Section 2.3.2.

2.3.1 General Comments

The use of a lichen as an indicator of metal, sulphur and nitrogen uptake is an excellent method of monitoring emissions, and Rescan has improved on the previous work by focusing on replicates of a single species *Flavocetraria cucullata* in 27 plots. (Rescan is using an out-dated name for this species). They state that *Flavocetraria cucullata* is a locally abundant and common species, which is an important consideration for long-term comparisons of changes in metals and oxide concentrations over time. This species, and this group in general, also has a reasonably large amount of relevant published data on concentrations in relation to apportioned sources that should have been used for comparison.

Some examples of comparisons can be found in Rhoades (1999)[3] and Bargagli and Nimis (2002)[4]; where an average value for Aluminium in arctic grown F. *cuculatta* is 633 ppm; in the Rescan report, Aluminium concentration in lichen tissue ranges from under 1000 ppm down to

---

[3] Rhoades, F.M. 1999. A *review of lichen and Bryophyte elemental content literature with reference to Pacific Northwest species*. For United States Dept. of Agriculture, Forest Service Mt. Baker-Snoqualmie National Forest.

between 100 and 400 ppm at distances from 10 to 50 km from dust sources. Aluminium concentrations in average lichen tissues near mines will range from 1300 to 1900 ppm; therefore, EKATI is relatively low on the scale of impacts from dust at this stage of development, as is to be expected, but this fact is missed by Rescan. An examination of the concentrations plotted in the appendix (in comparison to literature; below) show that some key elements *are* elevated in EKATI lichens, due to dust, not surprisingly, but Rescan has not noted this, which leads us to suppose that they may not know what to look for in the concentration data. As mentioned above, the Aluminium concentrations footprint of the EKATI mine is very small, but there is usually a small number of typical metals that become elevated around a source like EKATI, that shows up in the concentration and dustfall data. Therefore, more information is available in the data and the literature than has been presented by Rescan. (See below for a brief discussion of what the key indicator elements are at this site, in comparison to the literature).

Rescan is correct in their decision that the previous use of lumped species of lichens introduces too much unpredictable variation and non-reproducibility to the sample data. It is well known that different species have different facility for absorption or retention of metals and oxides. However, it is still useful to compare the previous study's lumped lichen species chemistry with values in the literature for generic purposes, as a reference for pre-industrial levels. Lichens do have a saturation point for absorption of high concentrations of metals, although EKATI lichens have a way to go before they reach saturation. The previous lichen data can be used as a benchmark. Were archived samples kept? If they were kept, then some separation into individual species is possible.

Water sampling using snowmelt to reflect acid pulse effects from nitrite and sulfite are used in this program. It is recommended that better effects monitoring of species response to changes in snowmelt chemistry, more thorough background monitoring and the examination of pH data be used.

The EKATI "Background" samples are presumed to represent clean-air conditions, and impacted samples are presumed by Rescan to be impacted by emitted substances, but the decision to call something background is not rationalized. In fact, when the graphs in the Appendix are examined, very few transects beyond 20 km exist and these are most likely the underrepresented background plots.

Usually, background status is considered in relation to monitor data. The relationship between lichen uptake of individual metals, S and N and actual air emissions monitoring (dustfall, etc.) is

---

[4] Bargagli, R and P.L. Nimis. 2002. *Guidelines for the use of epiphytic lichens for biomonitoring of atmospheric deposition of trace elements*. In: Nimis, Luigi, Christoph Scheidegger and Patricia Wolseley; eds. "Monitoring with lichens – Monitoring Lichens." Kluwer Academic Publishers. London. Page 295 - 299.

not examined or explained by Rescan. This is due to the fact that the dustfall monitoring data is very sparse, represents only 7 sample periods of the given sampling year of 2005 and is apparently restricted to only one location. Most biomonitoring studies rely on considerably higher numbers of sample points in relation to monitor data, and Rescan should recommend more monitoring than used to date.

The constellation of the sample locations is clustered around the sources, and although the number of sample locations for which Rescan has actual tissue and dust data together is relatively small, it is still a large enough number of sites to get useful bioindication data (i.e., N = 27). However, in order to examine geospatial statistical trends, such as kriging, the plots should ideally be in a grid pattern with random, or at least systematically random, samples within each grid. Right now, there are some plots that seem to align with the wind rose, which is a good start, but samples are missing away from the directions of prevailing winds. Rescan uses different sized dots to show high, medium, and low concentrations, but these are not as powerful or convincing as kriging. The fact that there are a lot of large dots (both for water and lichens) and a few small ones is an indication that the sampling has inherent bias. The spatial arrangement of high concentration dots in water and lichens (Figures 3-2, 3-6) do not really show where the higher concentrations start to drop with distance, for example. (Again: the graphs of lichen concentrations over distance show that few plots actually represent the lower concentrations). With the present sample site constellation, it is likely that a very small number of transects or sample sites will be comparable to a larger number of source-impacted plots over the long term (from Figure 2-1). This is not to suggest that existing transects should be decommissioned; rather, that a further 5 transects (at least) be added to the southwest and 5 transects be added to the northeast at least 40 km away from all present or potential sources. New transects are not expensive to establish once the field work is underway, and the ICP analysis of the lichen tissue should not exceed $110 per sample.

For relating the lichen data to the dustfall data, it would be better to co-locate some dustfall and lichen sampling sites at much greater distances from sources than shown in Figure 2-1. There is some indication from the S data that sulphur dioxide and the semi-volatile metal species are likely ranging far outside the largest cluster of biomonitoring plots that have been established for the study. Sulphur dioxide alone travels much further than the 18 km discussed in the document, even at 10 degrees C, before it precipitates out as sulphate. Total sulphur and sulphate sulphur should both be used.

In fact, there is no demonstration that source behaviour is really well understood in the Rescan report. The report refers to the CALPUFF modelling but does not show a predicted area of impact versus 'background' or un-impinged area.

The vegetation species list has many southern species, no crustose lichens and no liverworts (which is not possible) and it looks as though some species may have been missed. Also, the names that have been used are out of date and, in at least one case, misspelled. This is an indication that a lichenologist or cryptogam specialist with a substantial background in boreal to arctic field ecology has not done the work. There are many excellent lichen and moss specialists available to do this work. It is not something that an average botanist can do, therefore a specialist **is** necessary.

The presentation of the vegetation species data is poor and requires better resolution. Vegetation responds to dust deposition, acidification and exposure to chronic levels of sulphur dioxide in rather subtle ways, related to individual species response. Also, other sources of pathology and the ordinary dynamics of ecology on these sites has to be considered. The Rescan report does not describe the ecology of the sites; perhaps the physiography, soils, species compositions, existing pathogens, microclimate effects, etc. are available but have not been reported? Although this may seem like unnecessary ecological detail, it becomes very useful when sorting out effects of EKATI from all other sources of pathology in this environment, and will be very important over the long term. Also, the use of cover classes of vegetation type is very coarse, too inexact and will not show precise changes over time. For this reason, a complete and accurate species list for marked sites and use of repeated photometry is critical, as shifts in species dominance, the disappearance or decline of somewhat obscure low cover species and the growth of tolerant species will be the main indication of effects, along with changes in lichen thalline chemistry. By using very generic assessments not only is the potential for statistical power lost, but the potential for missing significant effects increases (*beta* error).

The whole idea is to relate all of these data together in a way that shows interactions and changes over time. This has not really been done, and should have been. The methods section is long, but it does not state how samples were treated, whether or not they were washed, was the ICP method ICP MS? Was the SALMethod (BC MELP 2001)[5] used, and if so were standards analyzed? If so, where is the data? Reporting of concentrations should be in ppm as a standard form.

The use of European derived WHO standards as a comparison to EKATI is possibly inappropriate, especially in the case of NH_3 (Cape et al. 2006)[6] in a relatively pristine high Arctic

---

[5] B.C. Ministry of Environment, Lands and Parks. 2001. *Strong Acid Leachable Metals (SALM) in soil Version 1.* February 2001

[6] Cape, J.N., L.J. Sheppard, I.D. Leith and M.A. Sutton. 2006. *Is there a need to redefine the critical levels for ammonia?* UNECE Ammonia Workshop (4-6 December 2006, Edinburgh, Scotland). Background document for Workshop Group I). 19 pages.

environment. Similar criticisms have been made about European critical load standards for northern boreal forests concerning both Scots pine and lichens (Manninen et al. 1996).[7]

2.3.2 Specific Comments

The following are comments on specific sections of the Rescan report.

Executive summary: The data may show that there is no trend with distance from the mining operations, but this does not mean that sulphate, ammonia or NO_x are "advected" out of the region! (advection is defined as heat transfer by horizontal flow of air. Rescan probably means dispersed, here). Virtually all source apportionment studies show that depositional gradients occur where concentrations decline with distance from sources, especially in flat or undulating terrain. Topographical interference can alter depositional gradients but that is probably not significant in the EKATI environment. What this trend more likely means is that the tails of the distribution of the contaminants have not been adequately sampled, and sampling needs to be better distributed over a wider area in such a way that a decline in concentrations is evident. The gradient may be very slight, but it is there, it just has not been sampled adequately.

Introduction: Why is the 2005 sample interval the only sample period that is being reported on? With no baseline, EKATI is reduced to making comparisons over time to a previously impacted sample. The characteristics of emissions are only identified and not quantified in any way except very generally at the end of the report. This is highly unusual. The date of the start of emissions, whether they are dust from construction, or exhaust, etc. is necessary, and it is not clearly provided. A description of the bedrock chemistry as a source of dust should be included. Section 1.2 provides a time frame, but the starting date is not given. It would have been preferable to see a more focused description of the characteristics of the contaminants of concern, sources, quantities, duration of exposures, patterns in deposition. What CALPUFF information was used to change the 2005 sampling? This should be described (and referenced).

Figure 1-1 cross referenced with Figure 2-1: It is evident that samples appear to have been placed in areas next to existing roads but it is not possible to tell from this report, because the details of sampling are not recorded. Sample sites should be located at least 100 meters from roads; otherwise, you quickly have a road effects study (alone) and not a study of the overall impact of the mine site and all its working sources including roads. Samples placed too close to unpaved, gravel roads can over-represent the impact of the mine (i.e., result in much higher values than the overall effect of the mining operation). From looking at the data, this appears to have happened to the samples. As Rescan does not have a pre-industrial baseline sample, this is

---

[7] Manninen, S., S. Huttunen, P. Rautio, and P. Peramaki. 1996. *Assessing the critical level of SO_2 for Scots pine in situ*. Environmental Pollution. 93(1):27-38

a serious problem; they will end up with rather unrepresentatively high concentrations over the long term. It may be that samples *were* located >100m from roads, but it is not clear from this document.

Page 2-1: the CALPUFF isopleths are assumed to be correct, but the ground level meteorology data was not very complete, so it is possible these isopleths are not accurate. It is always better to follow standard biomonitoring practice and use a grid sample with randomly placed samples that avoid direct point source contamination (i.e., roads, disturbed sites, buildings, etc).

Page 2-2: It is good that flexibility is being built into this biomonitoring program, with the provision for more plots. It is recommended that some more distant plots be established, as the current constellation is too close to operations, and a much smaller number of plots (transects) are located at greater distances from sources.

Page 2-2: There is only one TSP sampler which operated sporadically through 2005? That is insufficient. At least 2 or 3 and possibly more TSP samplers should be used to show the dispersal characteristics at various distances along the direction of prevailing winds. (Rescan correctly notes that placing samplers on buildings is introducing bias into the previous sample.) Passive samplers could also be used, also, at a cost savings.

Table 2-1: Total S should be reported if ICP analysis was used. For some reason, the S is being reported as a sulphate which has to be determined with colorimetry[8]. Therefore, one suspects that the laboratory has reported S from ICP; otherwise, they have reported sulphate, but they would have had follow a completely separate process for sulphates. This is not made clear, and there is a difference, so Rescan should find out from the laboratory exactly what analysis they did, report it correctly and state what their findings are.

Section 2.4.1: Counts of species or cover type? See comments above regarding the need for full and correct species lists for each transect. By the time you start to see changes in cover types, serious damage from exposure to pollutants has occurred. As mentioned above, there are several specialists available in the Pacific Northwest with expertise in the identification and measurement of the complete arctic flora. This is really necessary if you are going to do a

---

[8] Sulphate sulphur (in lichens or other tissues) is determined using a method adapted from Johnson, C.M. and Nishita, H. (1952). *Microestimation of Sulfur in Plant Materials, Soils, and Irrigation Waters*. Analytical Chemistry. Vol 24 No 4. P736-742. A single gram aliquot of tissue is boiled in dilute 0.1 N HCI for ten minutes, then a 2 ml aliquot is removed to a flask. Concentrated hydriotic, formic, and hypophosphoric acids are then added. This solution is bubbled through with nitrogen gas diffusion, followed by the trapping of sulphur nitrates with a sodium hydroxide catalyst. A bismuth nitrate yellow indicator is used to reveal a colour change, which is then read by spectrophotometer. If ICP is used only the total sulphur signature is read off the mass spectrometer along with all the other elements.

reasonable job. It is possible to use school children to collect and process lichens for chemical analysis; this has been done in several national programs including EMAN in Canada, and Monitoring Programs in Great Britain, but for species shifts in response to depositional gradients, acidification, etc., a cryptogamic epiphyte specialist is necessary.

Page 2-6 last paragraph: Do not use aluminium stakes near your lichen collection sites, for obvious reasons. A long plastic tent peg works well. Or, long stainless steel nails, but these are expensive.

Page 2-7: You would not expect observed differences in "vegetation composition" (Rescan means vegetation species composition) to be directly attributable to air quality unless the sulphur dioxide and NO_x emissions, metals deposition or acid deposition are high enough or occur over a long enough duration to cause effects. Such effects will likely occur, but they will be subtle, relatively contained near the mine site and easily tracked over time. The idea of this whole monitoring program is to ensure that you have a record of any declines in sensitive species cover or increases in tolerant species cover occurs over time so you can define the area of impact, however small it may be. At present, the biomonitoring program has not obtained sufficiently detailed or exact information, and EKATI should consider adding specific expertise to the field team.

Section 2.5: While it may not have been the objective of the Rescan report to review the literature on air pollution monitoring using lichens, most of the citations in this short section are sourced in two papers, and the interpretation of them is somewhat thin. Lichens are suitable biomonitors for the reasons listed by Rescan (the actual citation is more appropriately attributed to Blett et al. as the language comes directly from Blett et al.), but more importantly because of their precise and accurate response to varying concentrations of metals in the environment. They act like very exact, but cheap passive monitors, showing a precise change in metal concentration in direct proportion to exposure, whether it is dry or wet deposition. Also, there is a great deal written about their ability to absorb air pollutants that reflect ambient air concentrations or rainfall-borne concentrations, including their ability to show a decline in concentrations over distance and time. Blett et al. (2003) is not really applicable to the study area because it only provides a review of problems associated with using lichens in U.S. forested ecosystems. Also, although precipitation is a major source of metals in pristine areas (attributed to Puckett), in fact they should not be as interested in precipitate-source metals here but rather depositional metals from dust. More applicable published references are available and should have been used.

Page 2-8: If you store lichens in plastic and freeze them, then thaw and dry them for ICP-MS analysis, you will lose at least some of the mercury[9], arsenic, cadmium, ammonia, potassium, etc. in this process. This is especially true if they were wet when collected. If you collect them, clean them, cool-air dry and store them in paper bags, then analyze them, you lose less of the elemental content. Also, it is not indicated in the Rescan report whether samples are washed or not, but if they were they would also have lost some elemental content.

Page 2-9: If the analysis had included total sulphur by LECO furnace, it would have also been possible to calculate the Si:So ratio, which is useful for indicating changes in S depositional gradients over distance.

Page 2-9: In general, the data analysis section is good and shows that an understanding of statistics for showing trends in data. However, the pooling of samples within datasets (background and near mine infrastructure) indicates that Rescan has assumed they know what is a background sample and what is an impacted sample. This has biased the analysis to reflect a preconceived concept of what background is and what is impacted, rather than using the data to indicate which plots are actually having some levels of measurable exposures to contaminants. Also, Rescan does not refer to background levels from the literature, or from previous analysis. These data probably show lower concentrations of metals in lichen tissue previous to the 2005 sample, and in any case they can be compared to literature values as well.

Table 3-1: The units are tonnes, but does Rescan mean tonnes per year? If this is an annual measurement, then the concentrations produced as small, and should be simply measured with an adequate biomonitoring program and should show very little impacts over the long term. However, the system being used has some potential problems that could be easily resolved with some additional work in the field.

Table 3-2: Given the variation in the TSP in this table, the small size (only 7 measurements in 2005) does not inspire confidence in the statements that emissions have been reduced.

Page 3-6: The vegetation analysis is based on cover types only, and although this may be useful for understanding the general ecology of the mine site, it will not be exact enough for showing effects of dust deposition, response to emissions, snow melt or rainfall chemistry over the long term.

Table 4-2: The concentrations are not elevated for heavy metals but some typical dust-borne elements appear to be characteristically high for a small source such as EKATI. This is not

---

[9] It is not specified, but mercury is usually analyzed with a cold vapour method, and not with ICP, as reported here.

surprising and it shows the effects of dust in the environment. Iron, Nickel, Magnesium and Manganese are much higher than the usual NWT Arctic background levels for lichens, and this is most likely not from exhaust but from crustal materials (earth dust). Also, this looks like ICP analysis, (it's not stated, though) so should this be reported as total sulphur? The sulphate (or S?) values are actually very low for an arctic location, but one cannot tell what the analysis consisted of. It is suggested that this be revised. Titanium and zinc also show some fluctuation which may be due to dust.

Appended Figures 4-1 These are the most interesting and useful figures in the report. They show the trends in 2005, and these are likely to change over time. They show that the number of background plots representing nil to low impacts are usually greater than 20 km from the current mine sites, and that a much larger number of samples represented the impacted areas adjacent to the mine or other developments. What are they doing in the Appendix?

3.0 CALPUFF DISPERSION MODELLING ASSESSMENT REVIEW

The EKATI dispersion modelling assessment report provides a thorough description of the CALPUFF dispersion modelling system (which includes both the CALMET meteorological model and the CALPUFF dispersion model) and the rationale for making some of the more important choices for model configuration (these choices relate to selection of individual algorithms or parameterizations, commonly referred to as 'switches' in the model). Much of the modelling discussion is quite helpful for an external reviewer to assess the approach selected.

The modelling simulation described in the EKATI report required a greater level of skill from the modeller than would normally be the case for dispersion modelling assessments in more populated areas. This is due to the use of a sophisticated model without the complete data sources usually available for its configuration (meteorological data sources primarily). Therefore, the approach used for the CALMET meteorological model in particular needed to be clearly explained and this was done. Many of the steps required to configure CALMET were non-trivial and were skilfully accomplished by the Rescan modeller.

The report itself and the attached CALMET and CALPUFF input file printouts were reviewed. SENES has three significant concerns related to model configuration that should be highlighted, namely:

1) *Validation of the CALMET fields.* Significant differences were noted in the dominant prevailing wind directions from the local surface observation stations and the simulated prognostic model (MM5) fields provided to Rescan by Environment Canada (see Figure 3.1-3 in the EKATI report). The effect that this issue may have had in the resulting CALMET wind fields (which used both observed and prognostic wind inputs) was not investigated at all by Rescan. Other model validation procedures for parameters such as model mixing heights were also not done. Due to the complexity of dealing with incomplete and conflicting meteorological datasets, CALMET model validation should have been conducted and discussed in the report.

2) *Resolution of CALPUFF Modelling.* CALPUFF was used to estimate air concentrations at consistent 1km grid spacing in east/west and north/south directions. This resolution is not adequate to capture the maximum theoretical concentrations within several kilometres of the emission sources. A number of discrete receptor locations could have been chosen and used in the model such that better comparisons could be made between model concentrations and either sampling measurements or ambient guidelines/standards. However, the EKATI report states that the main intent of the assessment was to estimate *regional* deposition of fugitive dust and acid species. Therefore, use of a coarse network

of receptors may, or may not, be considered problematic, depending on the objectives of the modelling analysis.

3) ***Source Emission Rates.*** Emission rates used for the modelling analysis were not consistent with NPRI reported emission rates, or were calculated using inappropriate methods, raising concerns about the accuracy of the entire modelling analysis.

These and other issues of somewhat lesser importance are described in detail in the following sections of the review.

3.1   CALMET METEOROLOGICAL MODEL

CALMET was properly configured with terrain and landuse information, which were verified by example plots presented in the report. The model requires a full set of surface meteorological observations from at least one station. This presented a problem, since the only surface station that collects all of the parameters required by CALMET in the region operates during daytime hours only. A second on-site station collects wind and temperature data. The missing cloud cover, ceiling (and other) data points were interpolated between late afternoon and subsequent morning measurements. This approach was described in the report (page 2-8), and was a reasonable methodology to apply given the circumstances. The result of applying this interpolation was never actually assessed in the output fields. This should have occurred.

The CALMET model was configured to use numerical weather prediction (NWP) meteorological fields to account for the lack of upper air data near the modelling domain. This was an appropriate decision, and one made with the cooperation of Environment Canada (EC), who supplied the NWP fields. These fields were generated by use of the National Center for Atmospheric Research (NCAR) / Penn State Mesoscale Model Version 5, more commonly referred to as MM5. The report indicates that MM5 was 'run' for 2002 by EC (page 2-5). Some additional information on this MM5 simulation would have been helpful for the reader, in particular because there were significant differences noted between the MM5 surface winds and observations at the Koala meteorological station.

The CALMET switches chosen represent the usual or 'default' choices in most cases. Significant exceptions (as extracted from the EKATI report Appendix B input file) were:

IKINE = 1   Kinematics effects turned on (default is off).
IOBR = 1   O'Brien vertical velocity adjustment turned on (default is off).

These defaults were established several years ago (by the model architects, in collaboration with U.S. authorities[10] and have been discussed in more than one Canadian modelling guidelines report. The B.C. Modelling Guidelines, which the EKATI report cites as justification for using CALPUFF for the assessment, clearly states that these two switches should be turned off. If used, the modeller is to provide justification. There was no justification given in the report. Due to the reasonably flat terrain surrounding EKATI, it is unlikely that the IKINE switch would have much effect. However, due to significant differences between the observed and MM5 wind fields, the O'Brien adjustment may have had an influence on predicted concentrations, but the degree of any such influence cannot be determined without re-modelling with the O'Brien adjustment turned off.

A crucial decision to the ultimate meteorological simulation was to select an approach to combine the modified surface observation dataset and the NWP dataset. In particular, choice of a blending procedure for wind data in CALMET can have a large effect on the resulting 3-dimensional wind field simulated. There is no clearly established protocol to follow for this step, and expert judgment is required. The following summary describes the approach followed to establish the final wind field in the EKATI simulation (as described in the EKATI report pages 2-10 – 2-12, and Appendix B CALMET input file):

- Observed surface winds were given dominant influence in the first atmospheric layer (i.e., surface) only, with reduced influence as distance from the meteorological station location increased. At 20km, equal weighting was given to surface observed winds and MM5 winds (the report erroneously states this distance was 15km).

- MM5 surface winds had equal weighting to observed surface winds at a distance from station of 20 km. MM5 wind fields alone were used to establish winds in all layers above the surface.

It has been SENES' experience that the differences noted in the EKATI report between the MM5 and observed wind directions are too high to be considered 'normal' differences between prognostic, grid cell averaged winds and point-specific wind observations at a meteorological station. SENES has conducted several comparisons of observed winds with MM5 winds and have found the comparisons to be quite good in most cases. The few exceptions are not surprising; these have occurred in regions with significant terrain influence (i.e., narrow valley or proximity to large hill or mountain).

---

[10] In particular, an early report from the Interagency Workgroup on Air Quality Modeling (IWAQM) advised to keep these two CALMET switches off for long range transport modeling in December 1998. This report can be found at http://www.epa.gov/scram001/7thconf/calpuff/phase2.pdf

Due to the lack of large terrain features surrounding EKATI, the comparison of annual MM5 and observed wind direction should be reasonably good (at least in terms of annual wind speed and direction frequency distributions). The fact that this was not the case implies there is a problem in either the MM5 or the observation station winds. Since there is a good match between annual average Koala station and EKATI Tower wind direction, the clear implication is that there is a problem with the MM5 winds, either due to the simulation itself, or a conversion process to either produce wind estimates for direct comparison to observations or for input to CALMET[11]. It is not clear how Rescan (or EC) extracted the MM5 winds for the comparison described in the EKATI report (Figure 3.1-3).

Rescan discovered and adequately described the issue of disagreement between surface station and MM5 winds. However, this discovery should have prompted one of two possible actions:

1) Investigation of the MM5 winds. Why do the prognostic winds disagree with surface observations in the area surrounding EKATI?
2) Use of a revised meteorological modelling methodology such that the mismatch of observed and prognostic winds would not have a strong potential for adversely affecting the modelling outcomes.

SENES appreciates that an investigation of the MM5 simulation would be difficult and time consuming. Therefore, the second action described above would have been prudent. In SENES' opinion, CALMET should have been configured such that MM5 winds would have no influence near the surface. This would involve extrapolating the surface winds aloft. A case could be made for any of the three options (IEXTR = 2, 3 or 4) available in CALMET.

Rescan ultimately made a different choice for merging the observed and prognostic meteorological datasets. Regardless of whether or not their choice was reasonable, there clearly was the need for a number of tests to be conducted on the output CALMET fields. Suggested comparisons have been published in various modelling guideline documents, including the B.C. Modelling Guidelines. These comparisons relate to output CALMET fields (as opposed to tests involving the inputs). SENES suggests the following comparisons would have been of considerable value to a reviewer:

- Annual surface wind rose diagrams for CALMET winds at one or more locations. Compare to station data. Purpose: ensure that the model properly ingested the input observations.

---

[11] SENES does not know if validation exercises were conducted for the original MM5 simulation under the management of Environment Canada.

- Examine several surface vector wind field plots at different times. Purpose: ensure that there are no problematic discontinuities (i.e., 'bullseyes' or 'doughnuts' in the wind fields).
- Plot the average mixing heights by hour of day. Examine reasonableness. Alternatively, check distribution of PG classes (even though these were not directly used in the modelling). Purpose: check merger of datasets and interpolation of observation data – are the simulated dispersion parameters as expected?
- Additional wind rose diagrams for CALMET winds at two or more elevations above the same location. Purpose: establish the difference between surface layer winds and those aloft.

3.2   CALPUFF DISPERSION MODEL

The CALPUFF switches chosen for the EKATI simulation were found to be reasonable and consistent with use of this model for similar purposes elsewhere. A potential exception to this statement is the resolution chosen for the output concentration estimates.

The horizontal grid resolution used in CALMET was 1km by 1km. This is typically considered too coarse to represent wind flow near the surface if significant terrain influences are present. Due to the reasonably flat topography, use of 1km resolution in the meteorological simulation was reasonable. The grid resolution in CALPUFF must relate to that used in CALMET. Air concentrations can be estimated using the same resolution or any integer division of the CALMET resolution. In effect, a different resolution could have been chosen for the grid of output CALPUFF concentrations, such as 250m by 250m. For example, the dispersion modelling guidelines for British Columbia suggest using finer grid resolution close to the source, with increasing grid size with increasing distance from the source. In order to ensure that maximum predicted concentrations are appropriately identified in a modelling analysis, the B.C. guidelines suggest the following configuration as a starting point:

- 20 m receptor spacing along the plant boundary;
- 50 m spacing within 500 m of source;
- 250 m spacing within 2 km of source;
- 500 m spacing within 5 km of source;
- 1000 m spacing beyond 5 km of source.

The final grid configuration may require several modeling runs to establish the most appropriate grid size to be used. In cases such as the EKATI assessment, where the computer time required to complete the simulations at high resolution can be considerable, the use of a high resolution grid near the emission sources and a coarse resolution grid further away (i.e., a nested grid

approach) should have been considered. By ignoring the use of finer grid resolution close the emission sources, EKATI modelling analysis rendered it impossible to determine maximum pollutant concentrations and deposition rates.

In addition to the sole reliance on gridded output concentration estimates, a number of discrete receptors could, and should, have been established and used to gain point-specific concentration estimates at locations of interest. In particular, discrete receptor points should have been used to predict the TSP concentration at the high volume TSP monitoring station near Grizzly Lake, as well as at the various snow core sampling sites for direct comparison of predicted to observed deposition rates.

3.3   EMISSION SOURCES

A general comment on the presentation of emission rates for the EKATI mine is that the air dispersion modelling report should have used a more systematic and coherent approach to presenting the basis for the emission estimates. Information needed to understand how the emissions were estimated was not presented in a formal manner in the body of the report, but was instead presented in Appendix E as responses to reviewer comments from the Government of the Northwest Territories (GNWT) and Environment Canada. This is contrary to commonly accepted practice in regulatory air quality assessments in that all of the information needed to check emission calculations is presented in the report.

Based on the review of the emission inventory, concerns are raised about the following issues:

1) Emission rates reported in the dispersion modelling assessment do not always match emission rates reported to the National Pollutant Release Inventory (NPRI). Although the emission rates for point sources were supposed to be representative of 2003 emissions, the emission rates used for SO_2, TSP, PM_{10} and $PM_{2.5}$ are much lower than the 2003 emission rates reported to NPRI. In addition, with respect to maximum predicted 1-hour and 24-hour average concentrations, the emission rates used for the modelling do not appear to reflect the maximum hourly emissions, but are simply taken as the total annual emission rate divided by the number of hours in the year. This would tend to underestimate maximum predicted 1-hour and 24-hour averages because it does not take into account the downtime for maintenance that is common to all emission sources.

2) Exhaust emission rates from haul trucks and heavy duty mining equipment were improperly based on emission factors for stationary engines and equipment manufacturers rather than on generally accepted emission factors that are readily available from the MOBILE6.2C model for heavy duty on-road vehicles, and from the

NONROAD model for equipment such as excavators, backhoes, wheeled loaders, bulldozers, hydraulic shovels, and rotary drills.

3) SENES concurs with the concerns expressed by Environment Canada and the GNWT about the use of the precipitation correction factor in the calculation of fugitive dust emissions from haul roads.

4) Blasting emissions do not appear to have been considered in the assessment.

5) Emission factors for greenhouse gases (GHG) have not been properly referenced and the factors for methane (CH_4) and nitric oxide (N_2O) may be in error by up to an order of magnitude.

6) Use of the 1998 emission inventory for the Diavik Mine may underestimate particulate matter emissions from that set of sources.

3.3.1 Inconsistencies in Emission Inventory

The single largest concern related to the air dispersion modelling analysis is the inconsistencies in the emission rates used for that analysis. Specifically, the inconsistencies refer to the total annual emission rates reported in Table 3-1 of the 2005 Air Quality Monitoring Program report, and those used in the CALPUFF modelling analysis as listed in a table entitled Model Emissions Sources in Appendix C of the modelling report. For convenience, these data are reproduced below in Tables 3.1 through 3.4.

Table 3.1
Summary of Annual Air and GHG Emissions (2002 to 2005)
(From Table 3-1 – 2005 Air Quality Monitoring Program)

Pollutant	Estimated Emissions (tonnes/year)			
	2002	2003	2004	2005
CO	522	259	170	154
NO_x (expressed as NO_2)	2044	2985	3625	2673
TSP	171	77	46	39
PM_{10}	171	76	45	37
$PM_{2.5}$	n/a	76	45	33
SO_2	56	161	148	157
VOC	n/a	200	185	192
GHG	175,484	214,431	227,315	259,702

Table 3.2

Modelled Emission Sources - Point Sources

(from Appendix C – CALPUFF Air Dispersion Modelling Assessment)

Source	Source ID		Estimated Emissions (g/s)				
			NO$_x$	SO$_2$	TSP	PM$_{10}$	PM$_{2.5}$
EKATI Diesel Power Plant	EDPP	Winter	57.04	1.64	1.152	0.948	0.84096
Misery Diesel Power Plant	MDPP		1.898	0.104	0.06	0.0494	0.044
EKATI Glycol Boilers	EGB		0.158	0.107	0.016	0.0079	0.002
EKATI Incinerator	EINC		0.086	0.056	0.04	0.0168	0.0116
Misery Incinerator	MINC		0.0215	0.014	0.01	0.00419	0.0029
EKATI Diesel Power Plant	EDPP	Summer	57.04	1.64	1.152	0.948	0.84096
Misery Diesel Power Plant	MDPP		0.834	0.046	0.026	0.022	0.019
EKATI Glycol Boilers	EGB		0	0	0	0	0
EKATI Incinerator	EINC		0.086	0.056	0.04	0.017	0.012
Misery Incinerator	MINC		0.022	0.014	0.01	0.004	0.003
Total Annual Emissions (tonnes/year)			**1854.3**	**58.9**	**39.8**	**32.0**	**28.2**
Total Annual Emissions (tonnes/year) (NO$_x$ as NO$_2$)			**2843.0**				

Table 3.3: Modelled Emission Sources – Line Sources
(from Appendix C – CALPUFF Air Dispersion Modelling Assessment)
(modelled as area sources)

Source	ID	Area		NO$_x$	SO$_2$	TSP		PM$_{10}$		PM$_{2.5}$	
		m^2		g/s	g/s	g/m^2-s	g/s	g/m^2-s	g/s	g/m^2-s	g/s
Koala Waste	L1	16000	Winter	0	0	1.04E-04	1.664	3.23E-05	0.517	4.95E-06	0.079
Koala Ore	L2	16000		0	0	2.40E-06	0.038	7.43E-07	0.012	1.14E-07	0.002
Koala North Waste	L3	16000		0	0	2.43E-06	0.039	7.50E-07	0.012	1.15E-07	0.002
Fox Waste	L4	16000		0	0	4.65E-04	7.440	1.44E-04	2.304	2.21E-05	0.354
Panda Waste	L5	16000		0	0	4.39E-06	0.070	1.36E-06	0.022	2.08E-07	0.003
Misery Waste	L6	8000		0	0	1.02E-05	0.082	3.16E-06	0.025	4.85E-07	0.004
Beartooth Waste	L7	16000		0	0	1.18E-05	0.189	3.66E-06	0.059	5.63E-07	0.009
Ekati Airport	L8	15200		0	0	1.34E-06	0.020	4.80E-07	0.007	7.36E-08	0.001
Subtotal							9.54		2.96		0.45
Koala Waste	L1	16000	Summer	0	0	1.04E-03	16.640	3.23E-04	5.168	4.95E-05	0.792
Koala Ore	L2	16000		0	0	2.40E-05	0.384	7.43E-06	0.119	1.14E-06	0.018
Koala North Waste	L3	16000		0	0	2.43E-05	0.389	7.50E-06	0.120	1.15E-06	0.018
Fox Waste	L4	16000		0	0	4.65E-03	74.400	1.44E-03	23.040	2.21E-04	3.536
Panda Waste	L5	16000		0	0	4.39E-05	0.702	1.36E-05	0.218	2.08E-06	0.033
Misery Waste	L6	8000		0	0	1.02E-04	0.816	3.16E-05	0.253	4.85E-06	0.039
Beartooth Waste	L7	16000		0	0	1.18E-04	1.888	3.66E-05	0.586	5.63E-06	0.090
Ekati Airport	L8	15200		0	0	1.34E-05	0.204	4.80E-06	0.073	7.36E-07	0.011
Subtotal				0	0		104.97		32.53		4.99
Total Annual Emissions		t/y		**0**	**0**		**1097.8**		**340.3**		**52.2**

Table 3.4: Modelled Emission Sources - Area Sources
(from Appendix C – CALPUFF Air Dispersion Modelling Assessment)

Source	ID		Area	NO$_x$		SO$_2$		TSP		PM$_{10}$		PM$_{2.5}$	
			m^2	g/m^2-s	g/s	g/m^2-s	g/s	g/m^2-s	g/s	g/m^2-s	g/s	g/m^2-s	g/s
Panda Pit	A2		400006	6.17E-06	2.47	4.53E-06	1.81	1.26E-06	0.504	1.04E-06	0.416	8.67E-07	0.347
Beartooth Pit	A3		1806	2.46E-04	0.444	1.85E-04	0.334	5.55E-05	0.100	4.56E-05	0.0824	3.81E-05	0.0688
Fox Pit	A4	All Seasons	320889	2.55E-05	8.18	1.31E-05	4.20	3.36E-06	1.08	2.77E-06	0.889	2.31E-05	0.741
Misery Pit	A5		134579	8.13E-05	10.9	6.51E-05	8.76	1.84E-05	2.48	1.52E-05	2.05	1.27E-05	1.71
Main Camp	A6		423327	3.65E-06	1.55	3.00E-06	1.27	8.69E-07	0.368	7.17E-07	0.304	5.98E-07	0.253
Koala Pit	A7		423241	2.23E-05	9.44	1.51E-05	6.39	4.22E-06	1.79	3.48E-06	1.47	2.90E-06	1.23
Koala North	A8		423241	3.82E-07	0.162	3.13E-07	0.132	8.52E-08	0.0361	7.03E-08	0.0298	5.86E-08	0.0248
Subtotal		g/s			33.18		22.9		6.35		5.24		4.37
Total Annual Emissions		t/y			**1046.4**		**722.3**		**200.2**		**165.2**		**137.9**
Total Annual Emissions (NO$_x$ as NO$_2$)		t/y			**1604.3**								

Section 2.3.2.2 of the dispersion modelling report states that the emission data used for the modelling analysis for EKATI was based on the 2003 emissions inventory. Table 3.1 above indicates that NO_x emissions (expressed as NO_2) for sources reported to the NPRI registry amounted to 2,985 tonnes in 2003. These would include all of the point sources. Table 3.2 above indicates that total NO_x emissions (expressed as NO_2) modelled from these sources amounted to 2,843 tonnes, in reasonable agreement with the NPRI estimate. However, the SO_2 emissions in 2003 as reported to NPRI were 161 tonnes (Table 3.1), while the modelled emissions amounted to only 58.9 tonnes (Table 3.2), only 36.6% of the NPRI estimate.

Similarly, the TSP emissions modelled from point sources were estimated at 39.8 tonnes (Table 3.2), in reasonable agreement with the value of 39 tonnes reported to NPRI for 2005. However, for 2003, the TSP emissions were 77 tonnes, almost double the value used in the modelling. If the emission inventory was meant to represent 2003, as stated in the modelling report, then the TSP emissions from these sources were significantly underestimated.

Similarly, both the PM_{10} and $PM_{2.5}$ emission estimates used in the modelling analysis were approximately 5 tonnes lower than was reported to NPRI for 2005 (i.e., 37 tonnes PM_{10} reported to NPRI versus 32 tonnes used for the modelling analysis, and 33 tonnes $PM_{2.5}$ reported to NPRI versus 28.2 tonnes used for the modelling analysis). However, for 2003, the reported PM_{10} and $PM_{2.5}$ emissions were each 76 tonnes. Therefore, the modelling analysis underrepresented the 2003 emissions by a factor of 2.4 for the PM_{10} and a factor of 2.7 for the $PM_{2.5}$ emissions from point sources.

For line sources (Table 3.3 above), only the fugitive dust emissions from haul trucks were modelled along the haul roads, while exhaust emissions for NO_x, SO_2, and particulate matter were all included in the area source emissions listed in Table 3.4 above. The reason for this is that Rescan used incorrect emission factors for stationary engines (see discussion in Section 3.3.2 below) to represent exhaust emissions from haul trucks. As such, they did not compute exhaust emissions per vehicle kilometre travelled, and could not incorporate these emissions into the line source emission category. This is an important weakness in the modelling analysis because it concentrates all of the vehicle exhaust emissions in the mine pits, and lowers predicted impacts along the haul roads. Spatially, this is incorrect.

3.3.2   Heavy Duty Equipment Exhaust Emissions

In response to comments by Environment Canada and the GNWT, Appendix E (page 7) in the air dispersion modelling assessment report states that particulate matter emission rates for haul trucks and loaders with engines greater than 600 hp were calculated using AP-42 emission factors (expressed in lb/MMBtu of fuel burned) for large stationary sources, and that the

emission rates for smaller engines were based on emission factors for gasoline and diesel industrial engines in AP-42 Section 3.4. These emission factors are completely inappropriate for this type of equipment. Section 13.2.2 of the US EPA AP-42[12] on emissions from unpaved roads clearly states that "*particulate emissions from vehicle exhaust, brake wear, and tire wear are now estimated separately using EPA's MOBILE6.2*" (in Canada, Environment Canada's MOBILE6.2C model). Furthermore, it is not made clear from the Rescan report whether the exhaust emission rates for other pollutants such as NO_x and SO_2 from haul trucks were also estimated in the same manner, or on some other emission factors. For example, Table 14-8 suggests that the haul truck and other heavy equipment emissions in the open pits were estimated using unit emission factors expressed in grams per second. It is assumed that these emission factors were provided by equipment manufacturers. For haul trucks, these emissions should have been estimated using the MOBILE6.2C model.

The greatest concern for this approach to estimating emissions from heavy duty equipment is that it assumes that emissions from a diesel engine are identical whether that engine is a stationary engine or one that is used to power a moving piece of equipment. The difference is that a mobile engine must overcome the vehicle's inertia and the resistance of the surface on which the vehicle travels. Idling emission rates for heavy duty diesel trucks must also be taken into account. Appropriate emission factors for heavy duty diesel truck travel are available from the MOBILE6.2C model, and idling emission factors are also available from recent studies. These factors should have been used instead of the factors for stationary diesel engines. Similarly, generally accepted emission factors for heavy duty off-road equipment is available from the NONROAD model, and should also have been used to estimate emissions from equipment such as loaders, bulldozers, etc. Without re-doing the emission inventory using the proper factors, it is not possible to state with confidence how the revised emission rates would affect the results if the dispersion modelling assessment.

3.3.3   Fugitive Dust from Unpaved Haul Roads

In their comments on the emission inventory, Environment Canada and the GNWT expressed their concern about the use of a correction factor for precipitation in the calculation of fugitive dust emissions from vehicle travel on haul roads. The correction factor ([365-p]/365, where 'p' the total number of days with measurable precipitation in a year) is applied when calculating the average annual particulate matter emission rate from such activity. The agencies' concern was that the application of this factor "*would tend to smooth and reduce shorter term emission rates, hourly or daily.*" In Appendix E of the dispersion modelling assessment, Rescan responded that

---

[12] U.S. Environmental Protection Agency (EPA) 2006. *Compilation of Air Pollutant Emission Factors. Volume I. Point and Area Sources, Fifth Edition (AP-42).* Office of Air Quality Planning and Standards, Research Triangle Park, NC.

it was not possible to do a more detailed calculation of fugitive dust emissions for time periods shorter than one year (i.e., daily emissions) without having detailed information about silt and moisture content on the road surfaces, as well as detailed traffic activity. Furthermore, Rescan stated that the precipitation correction factor was needed in order to calculate the efficiency of dust suppression using chemical stabilizers.

SENES agrees with and supports the concerns expressed by Environment Canada and the GNWT on this matter. Although Rescan's description of the process used to calculate emissions would benefit from a clearer description in the report, SENES understands that the methodology used to calculate fugitive emissions from the haul road was as follows:

1) Annual average PM emissions were calculated using the equation:

$$E \text{ (kg/VKT)} = k \ (s/12)^{0.8} \ (W/2.7)^{0.4} \ (M_{dry}/0.2)^{-0.3} \ (365\text{-}p)/365$$

Where

E   is the emission rate in kilograms per vehicle kilometer traveled (kg/VKT)
s   is the surface material silt content (%)
W   is the mean vehicle weight in tons
M_{dry} is represents the surface moisture under dry, worst-case conditions because the equation assumes that emissions are at the dry uncontrolled road emissions for days without rain and are negligible for days with measurable precipitation. In the absence of appropriate site-specific information, the default value for M_{dry} of 0.2% is recommended.
p   is the total number of days with measurable precipitation, assumed to be 118 by Rescan for 2003 at the EKATI mine.

2) A control efficiency of 80% was applied to reduce emissions based on the use of chemical stabilizers.

3) Emissions were averaged over the entire year, and subsequently arbitrarily set to 10% of summertime (June to September) emissions for the eight winter months (October through April).

The problem with this approach is that the precipitation correction factor incorporates days with wintertime precipitation as well as summertime precipitation to calculate a total annual average emission rate for fugitive dust (i.e., 118 days), then averages out the emissions in tonnes per day as if the days with measurable precipitation were evenly distributed throughout the year when there is no evidence presented to support that assumption. This would tend to under estimate maximum daily fugitive dust emission rates, although it may be suitable for determining average

annual TSP, PM_{10} and $PM_{2.5}$ concentrations and deposition rates. To obtain maximum daily concentrations of these pollutants, the maximum daily emission rate should have been calculated using the above equation without the precipitation correction factor (i.e., assuming a day without precipitation for dry road conditions).

3.3.4   Blasting Emissions

SENES notes that there is no evidence in the Rescan report that blasting operations were factored into the emission calculations. In the review of the air quality reports for the EKATI mine in April 2003, blasting activity was a major concern for the mine. Table 14-8 in Appendix E lists emission rates for a blasthole stem machine, but no emissions from actual blasting activity. Is the absence of blasting emission rates from the Rescan air dispersion modelling assessment due to a lack of such activity at this time, or is this an omission that should be rectified?

3.3.5   Greenhouse Gas Emission Factors

The emission factors used by Rescan for the estimation of GHG emission rates were obtained from the following reports:

- *An Action Plan for Reducing Greenhouse Gas Emissions, September 2006 Annual Report*. Prepared by Winston Fillatre, BHP Billiton Diamond Mines Inc., Yellowknife, NWT.
- *An Action Plan for Reducing Greenhouse Gas Emissions, 2005 Annual Report*. Prepared by Winston Fillatre, BHP Billiton Diamond Mines Inc., Yellowknife, NWT.

Both reports used the same set of equations to calculate GHG emissions, namely:

CO_2 (tonnes) = litres of diesel * 0.00273 tonnes/ litre
CH_4 (tonnes CO_2e) = litres of diesel * 0.00000016 tonnes/litre*conversion factor of 21
N_2O (tonnes CO_2e) = litres of diesel * 0.0000004 tonnes/litre * conversion factor of 310

CO_2 (tonnes) = litres of Jet A1 * 0.00255 tonnes/ litre
CH_4 (tonnes CO_2e) = litres of Jet A1 * 0.00000008 tonnes/litre * conversion factor of 21
N_2O (tonnes CO_2e) = litres of Jet A1 * 0.00000025 tonnes/litre * conversion factor of 310

CO_2 (tonnes) = litres of used oil * 0.00309 tonnes/ litre
CH_4 (tonnes CO_2e) = litres of used oil * 0.000000034 tonnes/ litre * conversion factor of 21.
N_2O (tonnes) CO_2e) = litres of used oil* 0.000000064 tonnes/litre * conversion factor of 310

SENES can confirm that the emission factors for CO_2 emissions are reasonable, based on guidance provided by both Environment Canada and the EPA. However, the same cannot be

said for the methane and nitric oxide emission factors. In particular, for used oil, the CH_4 factor for used oil is about an order of magnitude too small, while that for N_2O is about an order of magnitude too large (when compared to EPA references). This does not necessarily represent an 'error', since there is not the same level of understanding of CH_4 and N_2O emission rates with that of CO_2. . The difficulty is that BHP Billiton does not provide references for the origin of these emission factors in the two reports cited above. SENES cannot verify the applicability of these factors without knowing the source from which they were derived.

3.3.6   1998 Diavik Diamond Mine Emission Rates

On page 2-13, Section 2.3.2.2 of the dispersion modelling report, Rescan states that: *"Emissions data for Diavik were adapted from the 1998 Environmental Effects Report prepared by Cirrus Consultants (Cirrus, 1998). The inventory was based on the best available data."*

A review of the dustfall monitoring program for the Diavik Diamond Mine by SENES completed in October 2005 for the Environmental Monitoring Advisory Board (EMAB) revealed that observed dustfall levels in the period 2003-2005 were about an order of magnitude higher than had been estimated in the 1998 Environmental Effects Report by Cirrus Consultants. This information was presented in a report to EMAB and submitted by EMAB to the public hearings on Diavik Diamond Mines' Application to renew Water Licence N7L2-1645 (re-numbered to MV2005L2-0009) which were held in November 2006. Diavik Diamond Mines did not question or reject the contention made by SENES that dustfall monitoring data indicated that actual dustfall levels were as much as 10 times higher than was predicted in their 1998 Environmental Effects Report. Therefore, it is relevant to question whether the emission inventory in the latter report accurately estimated emissions from the Diavik mining operations, and whether the further use of that emission inventory in the Rescan modelling analysis was reasonably representative of that mine. If the emission inventory for the Diavik mine is a factor of 10 too low (i.e., based on observed dustfall rates), then the cumulative effects of the two operations as presented in the Rescan dispersion modelling analysis may also be too low.

3.4   CHEMICAL TRANSFORMATION SCHEMES

Section 2.3.3.2 of the dispersion modelling report states that the "five species MESOPUFF II scheme was used for the modelling of chemical transformations." This relates to the conversion of SO_2 to SO_4 and NO_x to NO_3.   Rescan may, or may not, be aware that although CALPUFF is suitable for modelling SO_4 and NO_3 formation and deposition over long range transport distances (e.g., 50-500 km), significant (20-30%) underestimation of SO_4 deposition rates have been reported over these distances for the old MESOPUFF II chemical transformation scheme in CALPUFF. Comments made by attendees to the 7th conference on air quality modelling in June

2000 noted that the chemical transformation algorithms in CALPUFF were out of date (i.e., the model underpredicts sulphate formation), and that the aqueous phase chemistry algorithms that were subsequently installed in the model code were too new and untested to be trusted for applications involving air quality related values (AQRV). While these limitations are acknowledged by the U.S. Environmental Protection Agency, the latter agency has concluded that these limitations do not preclude the agency from recommending the use of CALPUFF for long range transport assessments of PSD increment consumption in Class I areas.

Although the CALPUFF model has also been used (inappropriately, in SENES's opinion) for modelling secondary particulate matter (PM) as sulphate and nitrate in the near field (<10 km) on one B.C. assessment, SENES is not aware of any validation studies on the accuracy of the CALPUFF model's ability to simulate sulphate and nitrate deposition at near field distances. Consequently, SENES has recommended in the past[13] that the PM formation algorithm in CALPUFF not be used for near-field applications. Instead, the PM emissions should be modelled as the total emission of filterable and condensable PM.

3.5   MISCELLANEOUS ERRORS

With the exception of the 200 µg/m^3 and 250 µg/m^3 contours, Figure 3.2-13 showing the maximum predicted 1-hour average NO_2 concentration is identical to that presented in Figure 3.2-14 for the maximum predicted 24-hour average NO_2 concentrations. Isopleth maps of maximum 1-hour and 24-hour average concentrations are usually quite different, differing by as much as a factor of three in any given location. It is not technically possible for the isopleths to be identical, and it is assumed that the same modelling output file was used to generate both figures (i.e., the wrong isopleths were plotted for one of the two figures).

3.6   MODELLING VALIDATION

Section 3.2.4.3 of the Rescan dispersion modelling report states that the modelling results *"are in reasonable agreement with actual conditions"* because the average and maximum observed TSP concentrations for the summer of 2003 at Grizzly Lake were 20 µg/m^3 and 61.8 µg/m^3 (24-hour average), compared with the average summer and maximum summer predicted TSP concentrations of approximately 18 µg/m^3 and 45 µg/m^3 for that location. However, since the model did not use discrete receptors at specific points (e.g., the TSP-2 HVAS sampling location), the values for model predicted concentrations can only be estimated from visual inspection of the figures presented in the modelling report. The predicted values of 18 µg/m^3 and 45 µg/m^3 at Grizzly Lake are, at best, a guess based on inspection of Figures 3.2-17 and 3.2-18. It should be

---

[13] SENES Consultants Limited 2003. *Guidelines for Air Quality Dispersion Models: Critical Review & Recommendations.* Prepared for the B.C. Ministry of the Environment, Victoria, B.C.

noted that the latter two figures are not in fact summer time average and maximum concentrations but based on modelling of year round emissions. Moreover, these two figures are affected by the substantial smoothing of the contours due to the use of a coarse (1 km) grid spacing, and there are the concerns about potential underestimation of the emissions noted in Section 3.3 above. For all of these reasons, any claims about how well the modelling analysis compares to observed TSP levels should be considered suspect until the modelling is re-run following correction of the deficiencies noted in this review.

4.0   Conclusions and Recommendations

Having completed the peer review of the air quality monitoring and dispersion modelling assessment reports prepared by Rescan, it is concluded that there are some fundamental flaws in the reports which need to be corrected before the impact of the air emissions from the EKATI mine on the local environment can be determined.   The flaws noted in this review are summarized as follows:

1) *HVAS monitoring:*
   a. The justifications given for limiting the sampling program to just the summer months are not credible as other mining companies and government agencies have demonstrated an ability to conduct monitoring throughout the year in similar environments;
   b. The conclusion in the monitoring report that management practices such as road watering and dust suppression have had success in reducing emissions has not be substantiated;
   c. Seasonal average TSP levels have been steadily rising over the period 1999-2004, and there was insufficient data for 2005 to determine a meaningful average TSP concentration;
   d. Comparison of seasonal average concentrations collected over a few months to annual average ambient air quality objectives is inappropriate;

2) *Snow core sampling:*
   a. The distribution of 'background' snow core sampling sites is not random and there is a need to provide a rationale for the current distribution of background sampling sites;
   b. There are concerns about the validity of the snow core sampling methods being used due to:
      i. The large number of non-detect values for sulphate concentrations in snow core samples since these samples should have been able to, at least, capture the background sulphate levels;
      ii. Wide disparity in nitrate an ammonia concentrations in snow core samples from 'background' sampling sites located in close proximity;
      iii. Unexplained high TKN, TSS and turbidity levels at one 'background' sampling site;

3) *Biomonitoring program:*
   a. Revisions to the original biomonitoring program have resulted in positive improvements, but additional improvements are deemed necessary;

    i. Sulphur dioxide concentrations are likely not high enough to cause chronic exposure symptoms, but there may be a loss of some sensitive species in the highest deposition/exposure areas over the long run, and the current biomonitoring system is not set up to recognize this;

    ii. The methods used for elemental analysis, and sulphur determination need to be reviewed and the document revised to reflect what actually happened with the samples;

    iii. The program needs to use full and accurate up to date species lists at the transects;

    iv. Some permanent photographic plots on the transects need to be established;

    v. The number of transects at distances from the mine sites (i.e., these should be greater than 20 km from sources) should be increased;

    vi. The number of dust measurements should be increased, and the use of passive SO_2 and NO_x monitors at various distances from the mine site, co-located with the vegetation transects where feasible, should be added to the program;

4) *Dispersion modelling assessment:*

    a. There should have been more validation work on the meteorological data used for the modelling, given the large discrepancies between the observed surface wind fields and those derived from the MM5 data;

    b. Receptor grid resolution in the CALPUFF model was too coarse to determine maximum predicted concentrations within several kilometres of the sources, or to make meaningful comparisons between predicted concentrations and ambient air quality objectives;

    c. There are major concerns about the source emission rates used for the analysis, namely:

        i. Emission rates used in the dispersion modelling assessment, which were intended to represent 2003 emissions, do not match reported NPRI emission rates for that year, and maximum short-term emission rates were not used for major point sources;

        ii. Emissions from haul trucks and other heavy mining equipment were improperly calculated;

        iii. Maximum short-term emission rates for fugitive dust were not considered in the analysis;

        iv. Blasting emissions were not included in the analysis;

     v.   GHG emission factors were not properly referenced and the factors for methane and nitric oxide may be in error by up to an order of magnitude;

    vi.   Use of the 1998 emission rates for Diavik may underestimate particulate matter emissions from these sources, thus underestimating cumulative impacts for the two mines;

  d. The chemical transformation scheme used to model conversion of SO_2 to sulphate and NO_x to nitrate is known to underestimate conversion rates over far field distances and has never been validated for near field distances (<10 km);

  e. Comparisons between predicted and observed TSP concentrations as evidence of reasonable agreement between predicted and actual particulate matter levels is not convincing due to the problems noted above with the meteorological data, use of a coarse receptor grid and problems with the emissions estimates used for the modelling analysis.

The problems noted with respect to the emission rates used for the dispersion modelling analysis alone are sufficient cause to doubt the accuracy of the analysis and to recommend that the entire analysis be re-done.