EXCELLENCE IN ENVIRONMENTAL CONSULTING SERVICES

August 6, 2009 **XCG File No. 1-664-17-03**

Chief and Council
Mohawks of the Bay of Quinte
13 Old York Road, RR#1
Tyendinaga Mohawk Territory, ON K0K 1X0

Re: Odour Modelling, Richmond Landfill Vicinity

Dear Chief and Council:

1. INTRODUCTION

XCG Consultants Ltd. (XCG) has conducted preliminary and detailed air dispersion modelling to evaluate the potential for odour impacts arising from operations at the Richmond Landfill Site near Napanee, Ontario. This study was completed at the request of the Mohawks of the Bay of Quinte (MBQ), and focused on investigating potential odour impacts from the landfill emissions on the northeast portion of the Tyendinaga Mohawk Territory (TMT). The approach to the air dispersion modelling was based on applicable Ontario Ministry of the Environment (MOE) standards as defined in Ontario Regulation (O. Reg.) 419/05 – Local Air Quality and other supporting MOE guidance. In addition, where appropriate, additional research was completed in order to suitably assess odour emissions resulting from landfill operations.

1.1 Background and Understanding

The Richmond Landfill is approved under Provisional Certificate of Approval (C of A) Number A371203 dated March 30, 1988, with various amendments made to date. The landfill has a licensed tonnage of 125,000 tonnes per year and receives wastes from a combination of municipal/residential, commercial, industrial, institutional, construction, and demolition sources (termed “co-disposal”). The site also accepts hydrocarbon impacted soil for use as cover material. Although the landfill has been in operation since 1954, the waste acceptance rate has varied over the past 55 years. XCG understands that the waste acceptance rate has decreased recently due to reduced designed capacity; however, the landfill is still active and receiving waste.

In this investigation odour dispersion was modelled at a preliminary level using the SCREEN3 air dispersion model. Detailed modelling was conducted using the AERMOD air dispersion model. Appropriate standards described in O. Reg. 419/05 – Local Air Quality and other supporting MOE guidance were used for comparison of modelled point of impingement (POI) concentrations.

XCG Consultants Ltd.
6 Cataraqui Street
Woolen Mill, West Wing,
Suite 105
Kingston, ON
K7K 1Z7
Tel: (613) 542-5888
Fax: (613) 542-0844
kingston@xcg.com

2. DOCUMENTATION REVIEW

Several historic documents were reviewed for information specific to understanding odour characteristics and emissions scenarios at the Richmond Landfill. These included both site-specific reports as well as scientific literature as applicable. The scientific literature review was carried out for landfill odour-specific issues where the site-specific documentation did not provide sufficient information to generate odour-specific data and provide a comprehensive odour emission scenario for the Richmond Landfill and the vicinity.

2.1 Richmond Landfill Site-Specific Reports

The historic site-specific reports reviewed included the following:

- Waste Management of Canada Corporation (WM) document “Richmond Landfill Expansion Environmental Assessment” dated October 2005 (WM EA);
- RWDI Air Inc. report entitled “Richmond Landfill Odour Survey”, dated February 4, 2009;
- WM EA Detailed Background Report to Discussion Paper #5 – Air Quality Background Conditions, dated November 2004 (Final), prepared by SENES Consultants Limited (SENES);
- WM EA Detailed Background Report to Discussion Paper #7 – Air Quality Impact Assessment, dated November 2004 (Initial Draft) and dated September 2005 (Final), prepared by SENES;
- WM 2008 Annual Monitoring Report prepared by Water and Earth Associates (WESA), dated March 2009;
- WM Richmond Sanitary Landfill Site Monitoring Report No. 22, prepared by Genivar Consultants LP (Genivar), dated March 2009;
- Canadian Waste Services Inc. monitoring report prepared by Henderson, Paddon & Associates Limited, dated March 2000; and
- Audit of Canadian Waste Services Richmond Landfill Operation prepared by Terraprobe Limited (Terraprobe), dated May 12, 2000.

Additionally, historic geo-referenced site plans of TMT and the Richmond Landfill as well as aerial survey plans of the landfill from previous work completed by XCG and those available from the reports above were used as the basis for the air dispersion modelling terrain information.

The site-specific documentation reviewed did not have sufficient data in order to adequately estimate odour emissions from all sources at the Richmond Landfill. Odour-specific information was not provided for all landfill operations that might generator odour. For example, the odour generated by active deposition of fresh waste at the working face does not appear to have been adequately accounted for in the previous site-specific air quality modelling studies. Therefore, a concise review of the applicable scientific literature was completed.

2.1.1 Site-Specific Odour Emission Inventory

The following significant odour-related data was compiled, current as of 2008, based on the available site-specific documentation:

- Total accepted landfill waste in 2008: 10,316.29 tonnes;
- Total estimated waste mass: 2.7 million tonnes (up to 2008);
- Total approved landfill area: 16.2 ha (approximately 550 x 300 m);
- Maximum elevation of waste mound (based on 2008 reports): 165.0 metres a.s.l., approximately 40 metres above grade;
- Gas collection vertical gas wells: 47 (depths and efficiencies unknown);
- Leachate/gas collection: 5 clean-outs, 3 manholes listed (12 manholes on drawings);
- Total leachate collected in 2008: 37,942.70 m^3 (approximately 103.95 m^3 per day);
- Total number of waste trucks per day: approximately up to 110 trucks (historically).

This compiled data was used to generate odour emission estimates from landfill gas (LFG) generation and fresh waste placement activities. Based on initial calculations, only odour emission estimates from fresh waste operations were considered significant in this report. It is understood that there are presently air monitoring stations at the property boundary, but details on these locations and their placement rationale are unknown.

A weather station is located to the south of the main office at the Richmond Landfill, but the reliability of data as applicable to representative site conditions is unknown (e.g. anemometer height, proper siting relative to surrounding terrain including the main waste mound, data collection frequency, etc.). Previously, air quality was assessed by WM's consultants using one year of meteorological data from the Kingston airport. This "metdata" was selected due to the station being located "very close" to the Richmond Landfill "from a regional perspective." Additional metdata considerations are provided below related to appropriate data selection for site-specific dispersion analysis.

The leachate holding lagoon located to the north of the main waste site is stated to be only slightly impacted by leachate on a temporary basis (part of WM's leachate management plan) and is considered not odorous according to WM documentation. The lagoon was not used in 2008. It is believed that odorous emissions from this lagoon may have been historically present as a result of leachate management operations. In addition, leachate collection manholes were not assessed quantitatively in terms of their odour emissions in the WM EA documentation. Although they are relatively small sources individually, as these are potentially strong odours and ground level sources, they are less likely to disperse effectively due to relatively stagnant air movement close to the ground surface. In addition, masking of odour from other sources (i.e. landfill gas and freshly placed waste) is difficult to assess or disqualify; additive effects may also occur and produce higher overall odour emissions on a detectable odour basis.

Composting operations are present to the west of the main waste mound at the Richmond Landfill. According to the site-specific documentation, compostable material includes bio-solids and sludge from waste water treatment facilities. Although characteristically different in odorous "tone," the composting operations on-site are another source of odour emissions contributing to the overall odour scenario. The odour emissions were assessed in the WM EA using non-site-specific data. WM's results showed odour impacts to the surrounding area exceeding the MOE odour threshold values. Modelled off-site impacts as high as 3.92 OU/m^3 were identified in the 2005 WM EA document (based on the WM EA report entitled "Detailed Background Report to Discussion Paper #5 – Air Quality Background Conditions." The MOE odour threshold value is 1 OU/m^3 at 0.15% frequency or 3 OU/m^3 at any frequency.

Other potential sources of odour include a pad for temporary soil storage located near the main entrance area, use of hydrocarbon contaminated soil as cover material, and LFG not captured by the gas collection system.

2.2 Scientific Literature and Reference Documentation

A brief review of the available scientific literature related to landfill odour was completed. XCG focused on gathering and reviewing odour emission and flux data specific to significant odour sources at landfills. Despite WM EA documentation regarding odour source inventories at the landfill, only composting and LFG sources of odour were historically assessed.

The literature reviewed (Bibliography attached) indicated that odour from fresh waste operations is the most significant source of odour emissions from landfills, with odour emissions and flux data typically orders of magnitude greater than those calculated from LFG generation. The odour emission rate of LFG for the Richmond Landfill site was conservatively calculated by XCG based on compiled odour-specific data from WM documentation (see above) to be on the order of 10^2 odour units per second (OU/s), with an odour flux rate on the order of 10^{-4} $OU/s/m^2$ (accounting for assumed 70% LFG collection efficiency). By comparison, the equivalent odour emission rate based on odour flux conversions for fresh waste operations is on the order of 10^3 to 10^4 OU/s (or between 10^{-1} to 10^1 $OU/s/m^2$). For example, one study indicated that typical fresh waste tipping operations generated a geometric mean of 67,000 OU/s (Nicolas, J. *et al*., 2008), based on actual field measurements. This value was used in the odour dispersion modelling performed and reported below. It should be noted that odour from fresh waste acceptance at the Richmond Landfill was not assessed to any degree in the WM EA documents reviewed. According to Nicolas, J. *et al*. (2008), there is only low correlation between odour emission rate and truck frequency, and that odour is mainly generated from fresh waste handling operations.

Although it is acknowledged that WM applies daily cover to the fresh waste in order to control odour emissions, there is potential for significant areas of exposed waste to be present over the surface of the active working face each day before daily cover has been applied. XCG's modelling is based on estimates of the daily exposed area of fresh waste at the working face.

3. APPLICABLE CRITERIA

Several sources of information were gathered and reviewed to determine appropriate emission data, applicable standards, and procedures related to assessing odour-related impacts. These sources are documented below.

3.1 MOE Proposed Approach for the Implementation of Odour-Based Standards and Guidelines

According to the MOE Proposed Approach for the Implementation of Odour-Based Standards and Guidelines, an odour impact occurs when there is a simultaneous occurrence of the following:

- Discharge of a contaminant from a facility;
- A human receptor; and
- The correct meteorology to direct the emissions from the facility to the receptor.

Consequently, an odour impact may not occur under all meteorological conditions. Thus, a sampling program consisting of limited grab samples is not deemed adequate to assessing potential odour impacts (as was the case in the WM EA documentation). Furthermore, sampling field investigations including representative sampling data is considered part of Tier 2 Procedures described in the MOE Interim Guide to Estimate and Assess Landfill Air Impacts (see below). Representative sampling data may be difficult to obtain due to the complex nature of odour discharges from landfill sites. The limited sampling completed historically (in terms of both time and location sampling) suggests a high degree of uncertainty for the overall odour emissions scenario.

An appropriate regional meteorological data set must be chosen to represent a geographical region in order to reflect parameters that would affect dispersion modelling. The Richmond Landfill is located within the MOE Eastern Region (Ottawa, Peterborough, Belleville) and the applicable regional meteorological datasets have been used from the MOE website (see details below). As noted previously, the WM EA documentation indicated that only a limited meteorological data set (one “representative” year’s worth of data from the Kingston airport) was used for dispersion modelling.

The guidance regarding odour-based standards details a 10-minute odour-based limit of 1 OU/m^3 at the receptor location and a frequency limit of 0.15% (or approximately 13 exceedances per year). It should be noted that the historic WM EA documentation considered odour impacts exceeding a 0.60% frequency as the non-compliance scenario.

3.2 MOE Interim Guide to Estimate and Assess Landfill Air Impacts

The MOE Interim Guide to Estimate and Assess Landfill Air Impacts (Interim Guide), dated October 1992, provides guidance on estimating emission rates related to landfill emissions to the atmosphere. The three-staged recommended procedures (Tier 1, 2, and 3) describe progressively detailed information in order to estimate landfill gas generation and associated odours.

The first stage, Tier 1, is a first-order kinetic model using the site history to estimate landfill gas generation and non-methane organic compound (NMOC) emissions. Tier 2 describes requirements for statistically representative field investigations in order to replace the NMOC constant calculated in Tier 1. Tier 3 Procedures involve detailed site-specific data to replace the NMOC constant and the landfill gas generation rate constant.

The Tier 2 Procedures describe a minimum of five preliminary samples to determine what number of samples will ensure a statistically representative data set. The historic background reports (WM EA "Detailed Background Report to Discussion Paper #5 – Air Quality Background Conditions" November 2004, WM EA "Detailed Background Report to Discussion Paper #7 – Air Quality Impact Assessment, Initial Draft (November 2004) and Final (September 2005)) document that a total of five grab samples were collected for odour-related analyses, including one quality control blank sample, which was not deemed to be representative due to possible cross-contamination.

Furthermore, the samples collected were not evenly distributed across the landfill, as recommended by the Tier 2 Procedures. Additionally, emission rates were not explicitly provided for any of the contaminants or were stated without reference to supporting calculations. Site-specific data may be used to replace the "upper range" default values for odour concentration estimates. However, due to inappropriate or statistically insignificant sampling procedures (i.e. the sampling results from the Tier 2 procedures must indicate statistical significance of at least 90% confidence and specify the 20% confidence interval, neither of which were stated to be achieved with the limited WM sampling program), the site-specific historic data has not been used in the calculations for odour emission estimates. WM EA documentation states in Appendix H: Uncertainty Analysis of the "Detailed Background Report to Discussion Paper #5 – Air Quality Background Conditions" (November 2004) that a "medium degree of confidence with a conservative bias" was assessed for odour flux, but the statistical specifics were not stated.

Tier 3 Procedures also provide guidance in estimating odour impacts. In preliminary odour emission calculations, it was determined by XCG that odour emissions as a direct result of LFG were significantly less than the odour from fresh waste operations described previously. XCG's dispersion modelling was based on odour emissions from fresh waste operations only; other sources of odour were not included in this odour assessment in order to consider a conservative odour impact scenario.

3.3 USEPA AP42 Emission Factors

The US Environmental Protection Agency provides AP42 emission factor documentation in order to estimate landfill air emissions. The Landfill Air Emission Estimation model equation provided is also referenced in the MOE Interim Guide to Estimate and Assess Landfill Air Impacts. There are minor variances in accepted equation factors and coefficients, as well as representative NMOC constituents (e.g. hexane versus vinyl chloride) and number of speciated LFG components. Because XCG's modelling was based only on odour from fresh waste operations, as explained above, these NMOC components, which are associated with LFG emissions and not fresh waste, were not taken into account at this time.

4. Historic Odour Emission Dispersion Modelling

As mentioned previously, historic WM EA background documentation included information regarding odour emission dispersion modelling. Upon review of the available information, several deficiencies were noted and are described below.

Samples collected for odour analyses were essentially "grab" samples. The number of samples collected failed to account for potential odour impacts (see definition of simultaneous occurrence above) as a result of time, location, and correct meteorology. In addition, research indicates that even the sampling equipment itself (the sampling bags) can contribute to masking or enhancing perceived odours (Juarez-Galen, J.M., I., 2008).

XCG reviewed the February 2009 RWDI report, which documented an odour survey conducted from December 8 to 31, 2008. The report indicates that meteorological conditions were recorded each day, but this information is not provided in the report. Therefore, it is not possible to assess whether the weather conditions during the survey would at any time have been approaching worst-case conditions in terms of odour impacts from the landfill. More extensive odour monitoring, with well documented meteorological information, conducted through all seasons of the year, is needed to more accurately characterize the odour impacts of the site.

The meteorological data used in the historic dispersion modelling is not considered comprehensive. Only one year of data (1991) from the Kingston Airport was used and determined to be representative. The MOE-provided data is compiled from five years of hourly weather station data. The average wind speed was noted to be 4.5 m/s. For comparison, the MOE-approved weather station data for use at the Richmond Landfill location (Ottawa) is 3.33 m/s, or approximately 25% less, with more easterly and northeasterly wind vector components. The Kingston Airport location is located very close to the Lake Ontario shoreline and is subject to shoreline meteorological effects. Even the WM EA (October 2005) document indicates (Section 5.4, page 5-14) that the Bay of Quinte (and thus, the Richmond Landfill site) is “isolated from the main lake” and unlikely to be affected by “wind induced mixing.” Therefore, the chosen meteorological data is not considered representative for the subject site. Historic wind roses and explanatory documentation are attached (Attachment A) for regional locations for comparison, including up to 30 year compiled hourly data. Note that the Kingston wind rose indicates higher wind classes more likely to provide higher dispersion of emissions from the landfill.

The dispersion model chosen in the WM EA was ISC3. The US EPA has stated that ISC3 is being phased out in favour of AERMOD, which should be used effective December 9, 2005 for most scenarios. A number of technical differences indicate that the “next-generation” AERMOD model provides more realistic and representative results.

As noted previously, odour impacts exceeding the 1 OU/m^3 limit at a frequency of 0.15% is now considered the appropriate guideline.

5. DISPERSION MODELLING

Air dispersion modelling was conducted in accordance to the MOE “Air Dispersion Modelling Guideline For Ontario” dated March 2009. This document provides guidance for air dispersion requirements set out in O. Reg. 419/05. Both screening level (SCREEN3) and detailed (AERMOD) dispersion models were used. Both models are approved by the MOE as provided by the US EPA. Approved graphical user interfaces/software for the models were used (Screen View 3.0.0 and AERMOD View 6.1.0).

5.1 SCREEN3 Screening Level Dispersion Modelling

Screening level dispersion was conducted using the geometric mean rate of odour emission for a fresh waste operation source (67,000 OU/s as reported by Nicolas, J. *et al.*, 2008). Based on the understanding that the working face of the landfill would be the most likely source of fresh waste odour emissions, an "area" source was provided as input for the model. It was conservatively assumed that the working face was approximately 100 m by 25 m, with a conservative release height of 40 metres above grade. The areal odour emission rate for the working face was calculated to be 26.8 OU/s/m^2 based on the assumed area and odour emission rate referenced above. This odour emission rate was assuming a single pollutant contributing to the overall odour emission scenario (see Section 5.2.6 for additional discussion concerning multiple pollutants) and thus no unit factor conversions were changed for the SCREEN3 dispersion modelling.

Although the SCREEN3 model produces a 1-hour averaging period data which needs to be converted to a 10-minute averaging period, it was observed that even the raw data indicated significant potential impacts at distance of up to five kilometres of the source. The maximum concentration of 4.8 OU/m^3 is observed at 500 m from the source. At five kilometres, the 1-hour averaging period indicated an odour concentration of approximately 1 OU/m^3. For reference, the northeast region of the TMT is approximately four kilometres from the Richmond Landfill.

The averaging time can be converted to a 10-minute averaging period by specifying the appropriate conversion factor according to MOE guidance (1.65 using historical power exponent decay factor of n=0.28). Therefore, the converted 10-minute averaging period results would be approximately 65% greater. The SCREEN3 dispersion modelling indicates potential exceedances of the 10-minute 1 OU/m^3 POI limit described in the MOE odour guidelines. See Attachment B for a visual representation of the screening level dispersion modelling results as well as the raw output from the model.

As the screening level dispersion modelling results indicated significant modelled odour impacts, refining of the modelling using AERMOD was performed.

5.2 AERMOD Dispersion Modelling

For the AERMOD air dispersion model, several inputs are necessary in order for the modelling exercise to be successfully completed. The explicit inputs have been described below for reference. The most current version of AERMOD-View (version 6.1.0) was used for the completion of all AERMOD modelling runs.

5.2.1 Meteorological Conditions

Historical meteorological data ("metdata") was obtained and reviewed from several sites in southern Ontario. The metdata was obtained from the Environment Canada Atmospheric Hazards website for Ontario. Historical metdata for Ottawa, Kingston, Trenton, and Peterborough in the form of annual and seasonal wind roses have been attached (Attachment A). Wind rose documentation provided by Environment Canada has also been attached (Attachment A). The wind data spans from 1971-2000, with up to hourly 24-hour records.

Noticeable spatial and temporal effects are evident for all wind roses. For example, the seasonal Kingston wind roses differ greatly in wind direction and frequency. More specifically, south, southwest, west, and northeast components are very frequent and include higher wind speeds in the fall, but other seasons have relatively infrequent, lower speed, and variable wind vectors. Seasonal variations in wind aspects affect dispersion models due to other associated meteorological factors such as the mixing zone height due to convection effects.

As mentioned previously, it should be noted that the Kingston wind rose is based on data collected from the Kingston airport. While this meteorological station is located within 40 kilometres of the landfill site to the west, the station itself is located less than one kilometre from the shore of Lake Ontario. Significant shoreline effects are known to affect predominant wind direction, speed, and frequency; as a result, the historic dispersion models using Kingston metdata are not considered representative of the modelling area in question.

The Richmond Landfill site is located approximately eight kilometres from the Bay of Quinte. However, Prince Edward County to the south is a large landmass that essentially “buffers” the landfill site from significant offshore winds. Effectively, the landfill site is approximately 40-50 kilometres inland from the prevailing southwest winds, and approximately 30-35 kilometres inland from the southeast shoreline.

Metdata was obtained from MOE online metdata resources. An analysis of the approved regional metdata was performed in order to select appropriate metdata for the air dispersion modelling in the vicinity of the Richmond Landfill. The Richmond Landfill and TMT is within the MOE Eastern Region (Ottawa, Peterborough, Belleville). The selected regional metdata (Ottawa Surface, Maniwaki Upper Air) were prepared with AERMET, the AERMOD meteorological pre-processor, to ensure that the metdata inputs were in the correct AERMOD format. The entire metdata file (approximately 5 years of data) was compiled for the model input to ensure that all recorded meteorological conditions would be accounted for in the model. The compiled metdata wind rose has been included in Attachment A.

Note that very light wind conditions (i.e. wind speeds of less than 1.0 m/s) may not be accurately recorded by standard wind instruments due to minimum sensitivity thresholds. Consequently, metdata may not fully describe all calm conditions (when dispersion would be at a minimum). This limitation may underestimate dispersion effects if there is inadequate or incomplete metdata under calm conditions. An examination of the raw metdata reveals that several records are incomplete; these incomplete records are discarded in the dispersion modelling input.

5.2.2 Area of Modelling Coverage

The area of modelling coverage prepared for the AERMOD model was set to consist of the model extents as well as several kilometres beyond. The additional area of modelling coverage is to ensure unbiased localised meteorological effects in the AERMOD model. The area of modelling coverage was prepared in AERMAP, the AERMOD terrain pre-processor, to ensure that the inputs were in the correct format for the AERMOD model.

To visually determine the dispersion modelling output, a relatively coarse receptor grid was set up with 1,000 metre spacing overlaying the TMT. The MOE specified tiered or radial receptor grid was not used in the model set up since the modelling area was not centred around the Richmond Landfill site. Additional discrete receptors were placed along the border of the TMT for added information specific to the MBQ.

5.2.3 Terrain Data

Ontario Digital Elevation Modelling (DEM) mapping was used to provide terrain data for the AERMOD model. The DEM mapping was obtained from the MOE DEM web site and Tile 124, UTM Zone 18 was used for the model. The DEM was available in 7.5' 30 m resolution. The terrain data was imported into AERMAP and elevations were assigned to the modelled area according to AERMAP defaults. The land use for the modelled area was assigned the default crop/cultivated land values for albedo (reflectance), Bowen ratio (surface moisture), and surface roughness.

The elevation of the TMT is located several metres below the base elevation of the Richmond Landfill. In addition, areas farther north of the landfill are elevated several more meters. The elevated areas may cause under-predictions of modelled concentrations toward the TMT with respect to terrain-following emissions such as odour. The model has been run with both "elevated" and "flat" terrain options to investigate possible terrain effects in the dispersion model.

5.2.4 Averaging Periods

A 1-hour averaging period was used with the AERMOD model. The averaging time was converted to a 10-minute averaging period by specifying the appropriate conversion factor according to MOE guidance (1.65 using historical power exponent decay factor of n=0.28). The converted model results were compared to the 10-minute 1 OU/m^3 POI limit described in the MOE odour guidelines.

5.2.5 AERMOD Results

The significantly more complex nature of the AERMOD model conducted provided more refined dispersion results. The geometric mean rate of odour emission for a fresh waste operation source (67,000 OU/s as reported by Nicolas, J. *et al*., 2008) and working face dimensions (similar to the screening level dispersion model's dimensions) were used as inputs. The resulting 10-minute averaging period odour concentration ranged from approximately 12 OU/m^3 at the northeastern-most region of the TMT to approximately 2 OU/m^3 at the southwestern-most region of the TMT. The model indicates that under certain meteorological conditions the entire TMT may be significantly impacted by odour emissions, over the MOE odour guideline limits, as a result of fresh waste operations at the Richmond Landfill. A frequency analysis of the potential impacts has not been completed at this time. See Attachment C for a visual representation of the AERMOD dispersion modelling conducted.

5.2.6 AERMOD Odour Modelling Considerations

As there are several sources of odour from the landfill, landfill operations, and within the working face of the fresh waste area itself (i.e. there are multiple waste types contributing to the overall odour emissions), it is understood that multiple odour-producing pollutants must be considered. These multiple pollutants may mask and/or enhance the overall detected odour scenario from the landfill, and the relationship between emitted pollutant concentration(s) and odour are not well defined.

When multiple pollutants contribute to the overall odour emission scenario, Lakes Environmental, creator of the AERMOD-View software package, provides specific guidance on how to address this scenario. Several parameters in the AERMOD source pathway are required to be changed to provide meaningful output. The unit factor for the source pathway emission rate is to be changed from 1,000,000 to one (1), the emission units label from grams/sec to OU/sec, and the concentration unit label from microgram/m^3 to OU/m^3. The Lakes Environmental odour modelling support document has been attached for reference (Attachment D).

6. Conclusions and Limitations

6.1 Conclusions

Based on the air dispersion modelling activities completed, there is potential for odour impacts to receptor locations on the TMT during fresh waste handling operations at the Richmond Landfill, under certain meteorological conditions. It should be noted that other odour sources at the landfill site were not modelled and may contribute to additional potential odour impacts. Based on the modelling results and XCG's research, it is anticipated that the potential odour impacts in the area of the landfill site would be reduced substantially if the landfill were fully capped and closed, and no further operations leading to fresh waste exposure were carried on at the site.

6.2 Limitations

The air dispersion modelling exercises conducted were based on numerous assumptions due to the limited site-specific information available. Furthermore, information on the site was limited to historic reports and documentation. Based on recent site observations of the Richmond Landfill vicinity and a limited literature review, site-specific source data was developed. These data may vary from actual site conditions and the resultant dispersion models produced may produce results that differ from actual observations. Other variables (such as more detailed temporal data accounting for seasonality) may also affect the dispersion models produced and all possible modelling scenarios have not been fully investigated. Modelling was conducted using the latest available versions of the software specified; future versions issued by the US EPA may result in changes to the modelling results produced. Other dispersion models may give varying results.

The scope of this report is limited to the matters expressly covered. This report was prepared for the sole benefit of the Mohawks of the Bay of Quinte, and may not be relied upon by any other person or entity without the written authorization of XCG Consultants Ltd. Any use or reuse of this document (or the findings, conclusions, or recommendations represented herein) by parties other than the Mohawks of the Bay of Quinte is at the sole risk of those parties.

6.3 Closing

If you have any questions regarding the above, please do not hesitate to contact the undersigned.

Yours very truly,

XCG CONSULTANTS LTD.

David Chang, B.Sc.
Project Specialist

Attachments:

Bibliography

Attachment A: Comparison wind rose plots and documentation

Attachment B: SCREEN3 Screening Level Dispersion Modelling Output

Attachment C: AERMOD Dispersion Modelling Output

Attachment D: Lakes Environmental Odour Modelling Support Document

Bibliography

Nicolas, J., Romain, A.C., Delva, J., Collart, C., Lebrun, V. 2008. Odour annoyance assessment around landfill sites: methods and results. NOSE2008: International Conference on Environmental Odour Monitoring and Control. AIDIC: Rome, Italy.

Juarez-Galen, J.M., Martinez, J.V., Amo, A., Valor, L. 2008. Background odour from sampling bags: Influence in the analysis of the odour concentration. NOSE2008: International Conference on Environmental Odour Monitoring and Control. AIDIC: Rome, Italy.

Termonia, A., Termonia, M. 1999. Characterisation and on-site monitoring of odorous organic compounds in the environment of a landfill site. *Intern. J. Anal. Chem.,* 73(1): 43-57.

Sarkar, U., Hobbs, S.E. 2003. Landfill odour: assessment of emissions by the flux footprint method. *Environmental Modelling & Software,* 18(2):155-163.

Selena Sironi, Laura Capelli, Paolo Céntola, Renato Del Rosso and Massimiliano Il Grande. 2005. Odour emission factors for assessment and prediction of Italian MSW landfills odour impact. *Atmospheric Environment*, 39(29):5387-5394.

Roebuck, D., Stretch, D., Strachan, L. Investigating odour sources and odour emission rates from landfills through direct communication with residents. NOSE2008: International Conference on Environmental Odour Monitoring and Control. AIDIC: Rome, Italy.

ATTACHMENT A

COMPARISON WIND ROSE PLOTS AND DOCUMENTATION

Hazards Topics
Help
View Prepared Maps
Create Maps from Database
Collected Documents
Utilities/ Customization
Download
Links
Contacts
Search
Feedback
Ontario Hazards Home
AIRG Websites

WIND ROSES

A wind rose is often used to summarize the characteristics of wind (wind climatology) found at a measurement location. It can display wind speed, direction and frequency information for any selected period of time and station for which wind measurements have been taken. The annual and seasonal wind roses presented on this website are based on observed wind data from the 30-year period, 1971-2000. For some stations, the data is only available for a shorter period of record than 1971-2000 (e.g. 1986-2000 for Toronto Buttonville Municipal Airport). The annual wind roses represent wind measurements taken over the available period, while seasonal wind roses depict data only from the respective seasons: Winter (December-February), Spring (March – May), Summer (June – August), and Fall (September – November).

Hourly measurements of average wind speed and direction, used in the generation of the wind roses, are measured at airport locations in Ontario and have been extracted from Environment Canada's National Climate Data Archive. The instrumented wind measurements are made by anemometers, which are typically at 10 m height above the ground surface at level, open sites, free from surrounding obstacles to the wind flow such as trees or buildings (although some exceptions from this standard may occur). In most cases, the hourly wind observations are taken 24 hours per day. However, there are some locations where the observing program is limited to a shorter period than 24 hours (e.g. 15 hours, primarily during the day, at Hamilton Airport).

The wind rose can be thought of as a compass, with north pointing upwards on a wind rose graphic. Each of the extending arms on the wind rose represents one of the 16 wind directions the wind is blowing FROM. Hence a wind from the north would be represented by an arm pointing towards the top of the wind rose. The full 360 degree range of direction is divided equally into the 16 compass points, meaning each of the compass points (e.g. N, NNE, NE, ENE, E, etc.) represents a 22.5 degree range. Consequently, a wind direction classified from the north (N) would represent winds recorded between 348.75 and 11.25 degrees, as measured from TRUE north.

Concentric circles drawn from the centre of the wind rose represent the percent frequency of wind occurrences from each direction (see example below). The longer the arm for a specific direction, the more frequent the wind is from that direction. Note that summing the frequencies for all directional arms may not necessarily add to 100%, since "calm" periods (or periods with wind speeds under 1 knot) are not included. The difference between 100% and the sum of all the arm frequencies would represent the frequency of calms. The frequency of calm winds varies widely between stations.

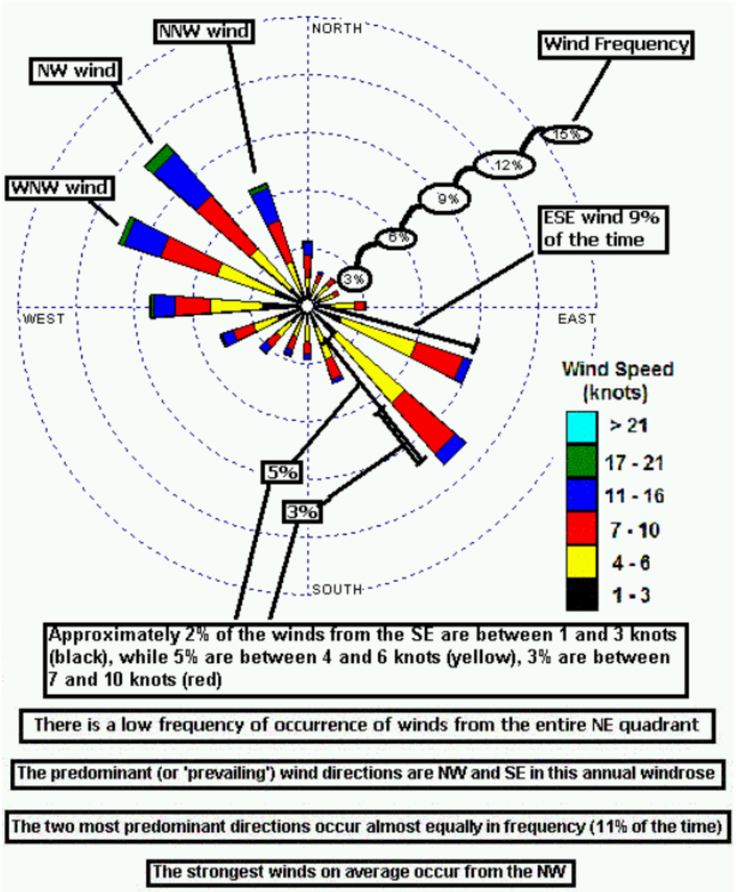
Also shown on the wind rose is an indication of the frequency of wind speeds within six specific speed categories, with wind speeds measured in knots. The six wind speed categories in knots are shown below, with their equivalent speeds in kilometers per hour and meters per second also provided:

Speed Category	Wind Speed (knots)	Wind Speed (km/h)	Wind Speed (m/s)
1 (black)	1 to < 4	1.8 to < 7.2	0.5 to < 2.0
2 (yellow)	4 to < 7	7.2 to < 12.6	2.0 to < 3.5
3 (red)	7 to < 11	12.6 to < 19.8	3.5 to < 5.5
4 (blue)	11 to < 17	19.8 to < 30.6	5.5 to < 8.5
5 (green)	17 to < 21	30.6 to < 40.6	8.5 to < 11.3
6 (light blue)	21 and over	40.6 and over	11.3 and over

As noted above, wind speeds under the lowest threshold (1 knot) are classified as "calm" and not included in the six categories.

The different colours of each section of the arm represent the wind speed frequency found within each speed category. For example, a longer 'red' section of the arm would indicate a more frequently occurring wind speed between 7 and 11 knots. The concentric circles can assist in interpreting the frequencies within each wind speed category. In the sample wind rose below, the concentric circles represent frequencies at 3%, 6%, 9%, 12% and 15% intervals for each wind speed category and direction. It should be noted that the percentage frequency values of the concentric circles can differ between wind roses. The frequencies are scaled to best fit the observed wind data frequencies.

A sample of an ANNUAL wind rose and some interpreted information is shown below. The interpretations are outlined in the boxes. In this example, the wind information is based on data from the observational period 1971-2000.



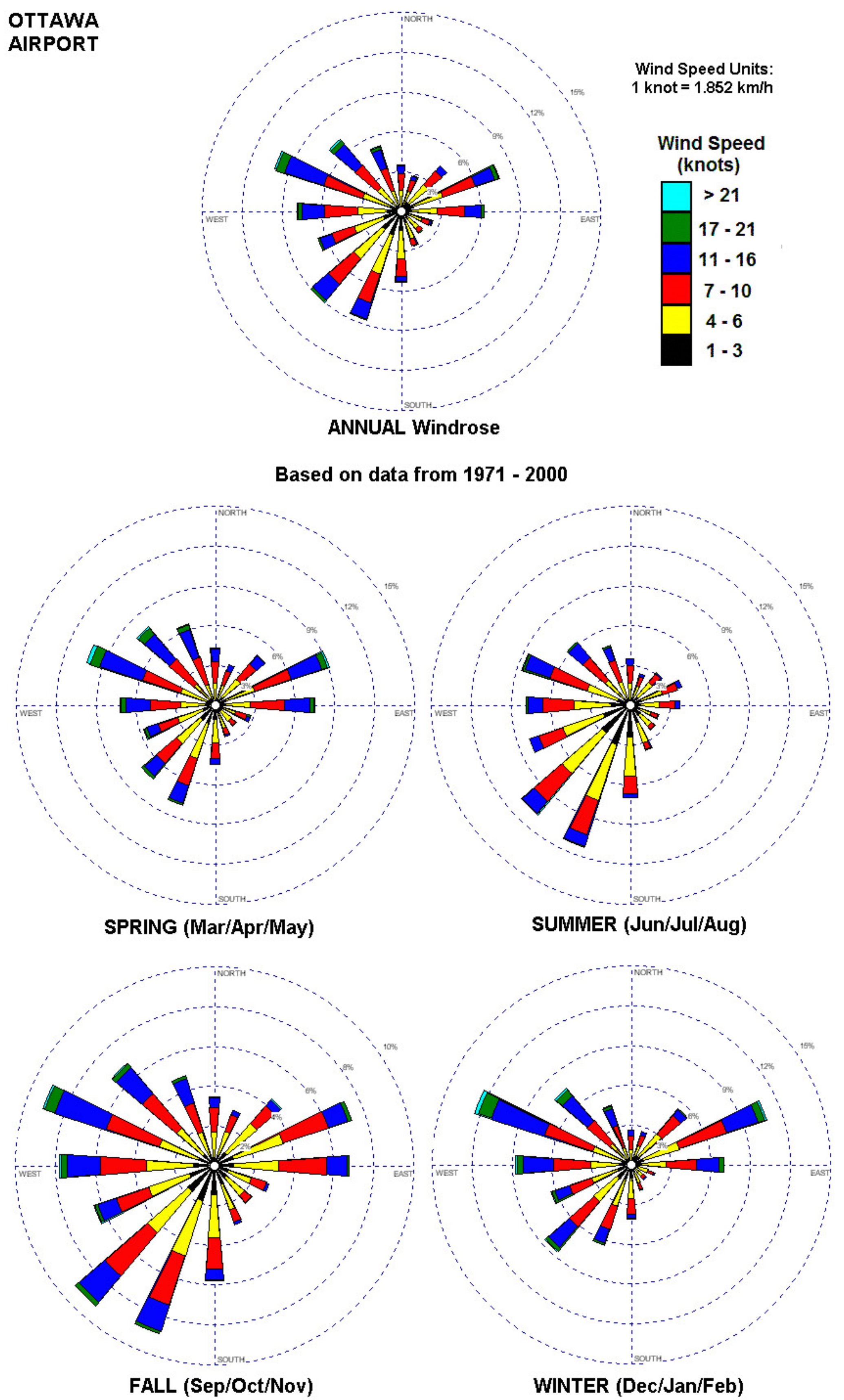
DOCUMENTATION PREPARED BY:

Meteorological Service of Canada-Ontario Region, August 2004.

PRINT THIS PAGE | CLOSE THIS WINDOW

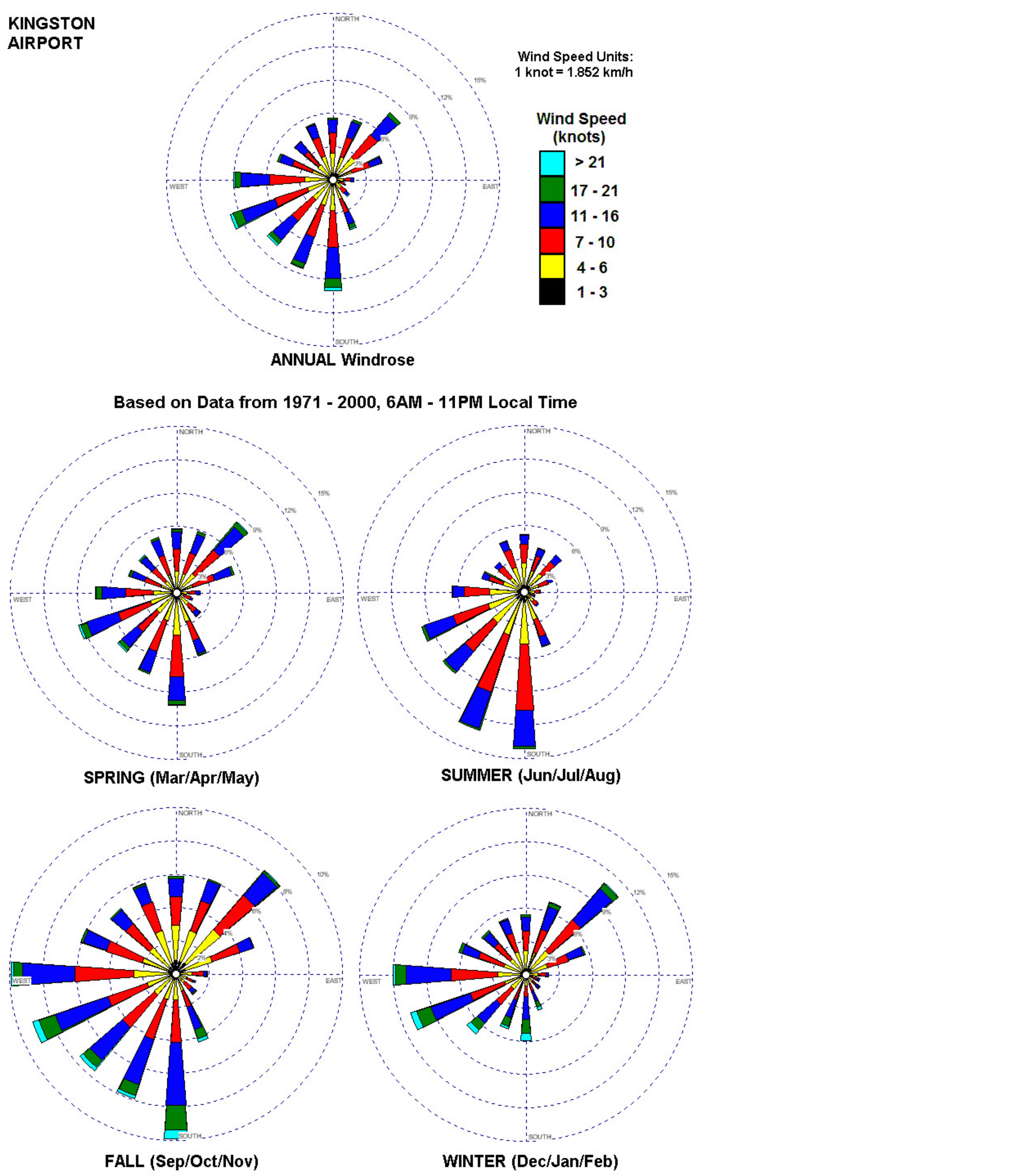
Annual and Seasonal Wind Roses for Ontario Airport Locations (1971-2000) (summarizing hourly wind speed, direction and frequency at each site)

Source: Meteorological Service of Canada - Ontario Region, 2001. Internal. Graphics Provided Courtesy of Erik Buhler of the Ontario Storm Prediction Centre, Toronto.



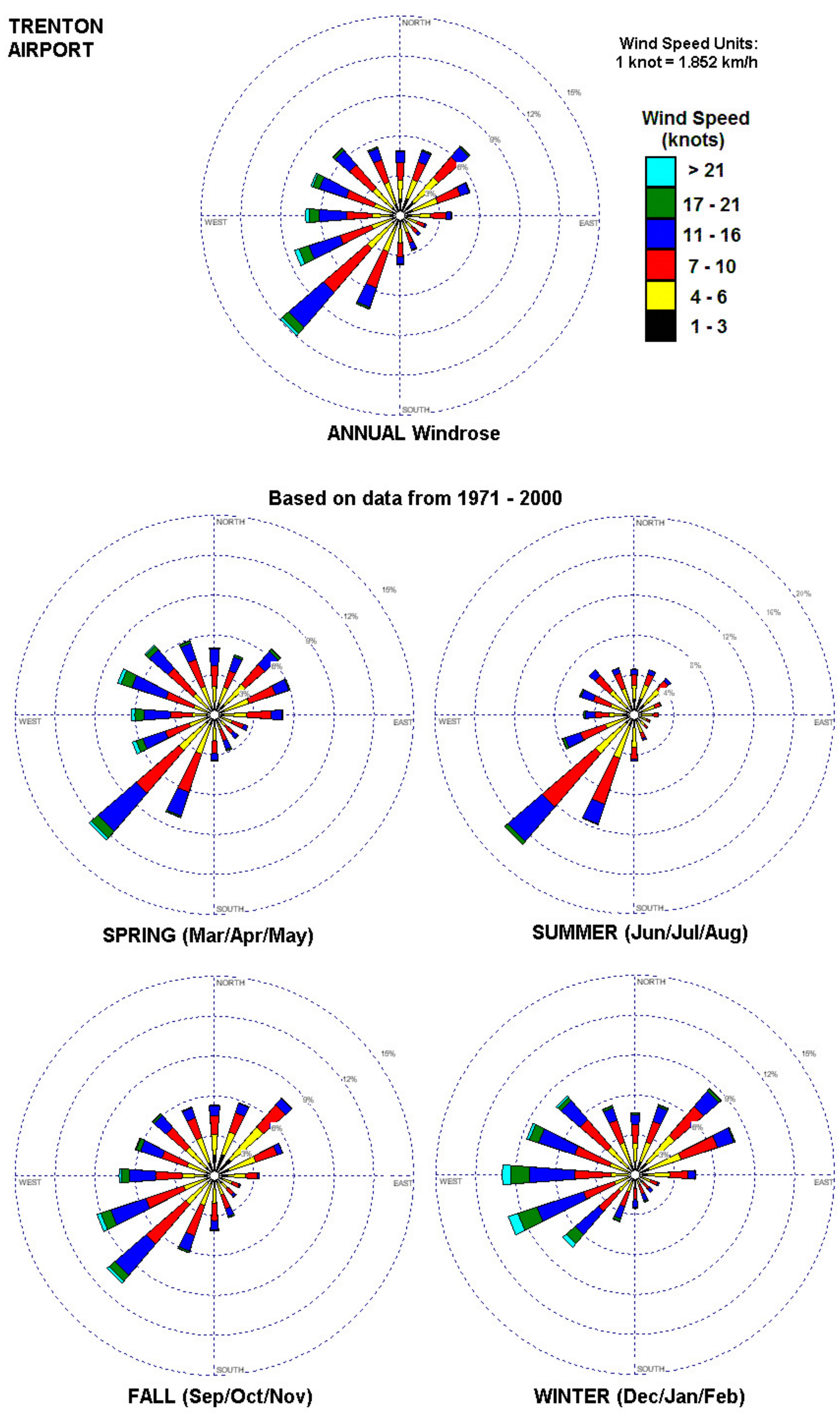
Annual and Seasonal Wind Roses for Ontario Airport Locations (1971-2000) (summarizing hourly wind speed, direction and frequency at each site)

Source: Meteorological Service of Canada - Ontario Region, 2001. Internal. Graphics Provided Courtesy of Erik Buhler of the Ontario Storm Prediction Centre, Toronto.



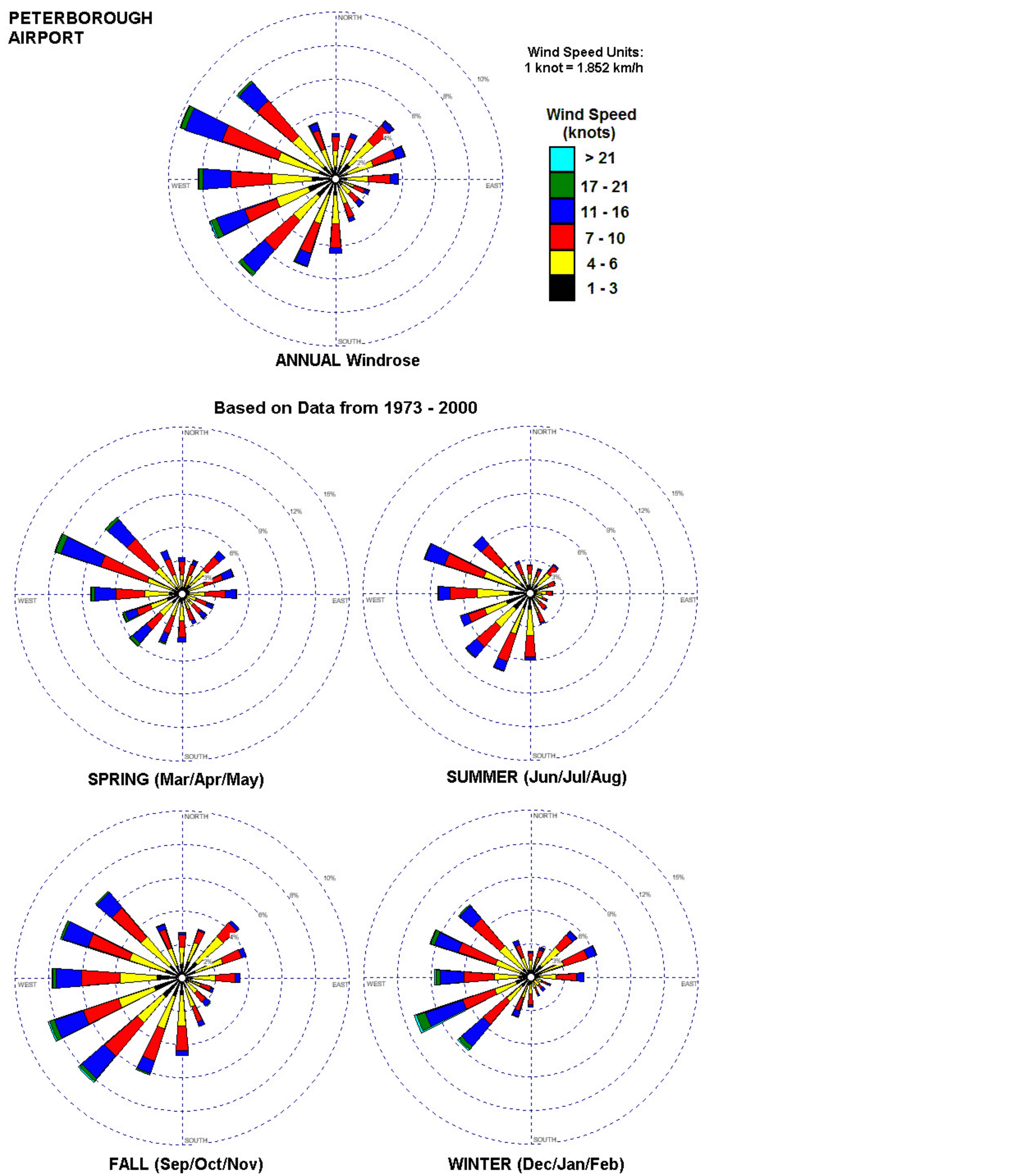
Annual and Seasonal Wind Roses for Ontario Airport Locations (1971-2000) (summarizing hourly wind speed, direction and frequency at each site)

Source: Meteorological Service of Canada - Ontario Region, 2001. Internal. Graphics Provided Courtesy of Erik Buhler of the Ontario Storm Prediction Centre, Toronto.



Annual and Seasonal Wind Roses for Ontario Airport Locations (1971-2000) (summarizing hourly wind speed, direction and frequency at each site)

Source: Meteorological Service of Canada - Ontario Region, 2001. Internal. Graphics Provided Courtesy of Erik Buhler of the Ontario Storm Prediction Centre, Toronto.

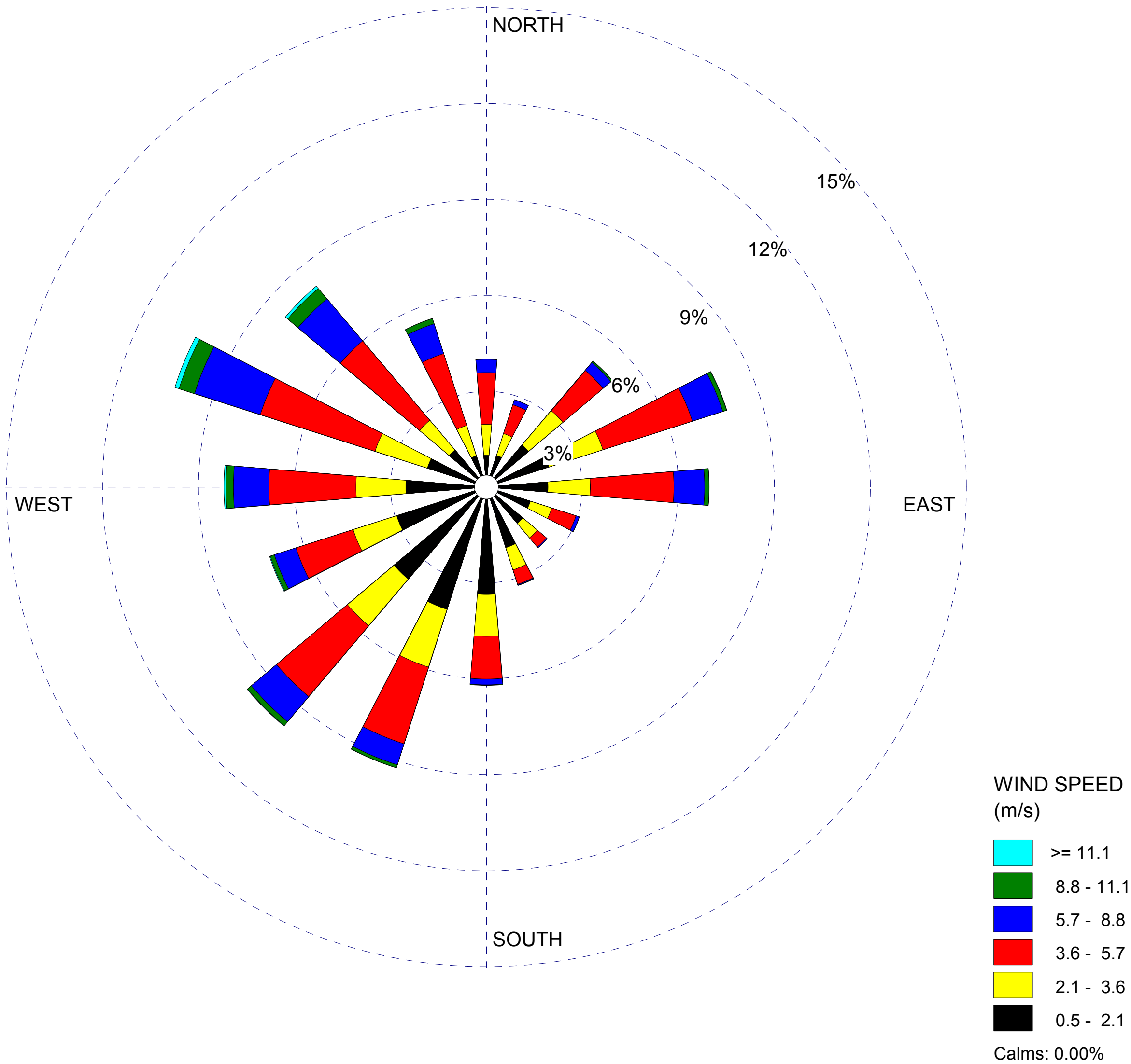


WIND ROSE PLOT:

MOE Eastern Region (Ottawa, Peterborough, Belleville) Annual Windrose
Station #61060 - Ottawa, ON

DISPLAY:

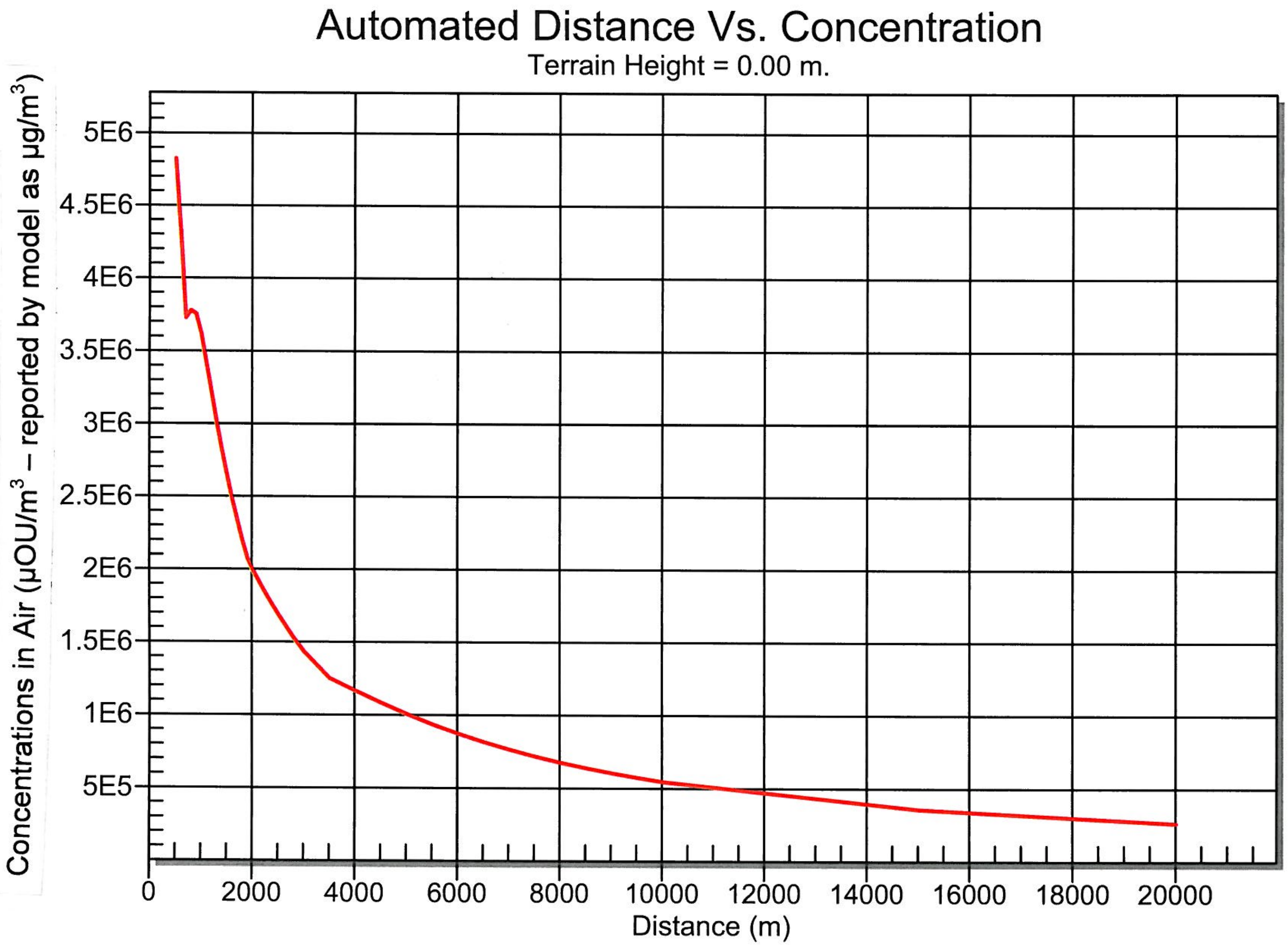
Wind Speed
Direction (blowing from)



COMMENTS: 1996-2000 Hourly Data Availability: 99.06%	DATA PERIOD: **1996-2002** **Jan 1 - Dec 31** **00:00 - 23:00**	COMPANY NAME: **XCG Consultants Ltd.**	
		MODELER: **DYC**	
	CALM WINDS: **0.00%**	TOTAL COUNT: **54347 hrs.**	
	AVG. WIND SPEED: **3.33 m/s**	DATE: **4/24/2009**	PROJECT NO.: **1-664-17-03**

ATTACHMENT B

SCREEN3 SCREENING LEVEL DISPERSION MODELLING OUTPUT



Screen View by Lakes Environmental Software

C:\Documents and Settings\davidc\Desktop\Richmond\Richmond.scr

08/05/09

16:29:10
*** SCREEN3 MODEL RUN ***
*** VERSION DATED 96043 ***

C:\Documents and Settings\davidc\Desktop\Richmond\Richmond.scr

SIMPLE TERRAIN INPUTS:

SOURCE TYPE	=	AREA
EMISSION RATE (G/(S-M**2))	=	26.8000
SOURCE HEIGHT (M)	=	40.0000
LENGTH OF LARGER SIDE (M)	=	100.0000
LENGTH OF SMALLER SIDE (M)	=	25.0000
RECEPTOR HEIGHT (M)	=	1.0000
URBAN/RURAL OPTION	=	RURAL

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

MODEL ESTIMATES DIRECTION TO MAX CONCENTRATION

BUOY. FLUX = 0.000 M**4/S**3; MOM. FLUX = 0.000 M**4/S**2.

*** FULL METEOROLOGY ***

****
*** SCREEN AUTOMATED DISTANCES ***
****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	MAX DIR (DEG)
500.	0.4825E+07	3	1.0	1.1	320.0	40.00	0.
600.	0.4314E+07	3	1.0	1.1	320.0	40.00	0.
700.	0.3728E+07	3	1.0	1.1	320.0	40.00	1.
800.	0.3777E+07	4	1.0	1.2	320.0	40.00	0.
900.	0.3753E+07	4	1.0	1.2	320.0	40.00	0.
1000.	0.3618E+07	4	1.0	1.2	320.0	40.00	0.
1100.	0.3419E+07	4	1.0	1.2	320.0	40.00	0.
1200.	0.3213E+07	4	1.0	1.2	320.0	40.00	0.
1300.	0.3014E+07	4	1.0	1.2	320.0	40.00	0.
1400.	0.2826E+07	4	1.0	1.2	320.0	40.00	0.
1500.	0.2651E+07	4	1.0	1.2	320.0	40.00	0.
1600.	0.2489E+07	4	1.0	1.2	320.0	40.00	0.
1700.	0.2340E+07	4	1.0	1.2	320.0	40.00	0.
1800.	0.2202E+07	4	1.0	1.2	320.0	40.00	0.
1900.	0.2076E+07	4	1.0	1.2	320.0	40.00	0.
2000.	0.1999E+07	5	1.0	1.6	10000.0	40.00	0.
2100.	0.1934E+07	5	1.0	1.6	10000.0	40.00	1.
2200.	0.1870E+07	5	1.0	1.6	10000.0	40.00	1.
2300.	0.1808E+07	5	1.0	1.6	10000.0	40.00	1.
2400.	0.1748E+07	5	1.0	1.6	10000.0	40.00	1.
2500.	0.1690E+07	5	1.0	1.6	10000.0	40.00	0.
2600.	0.1635E+07	5	1.0	1.6	10000.0	40.00	0.
2700.	0.1581E+07	5	1.0	1.6	10000.0	40.00	0.

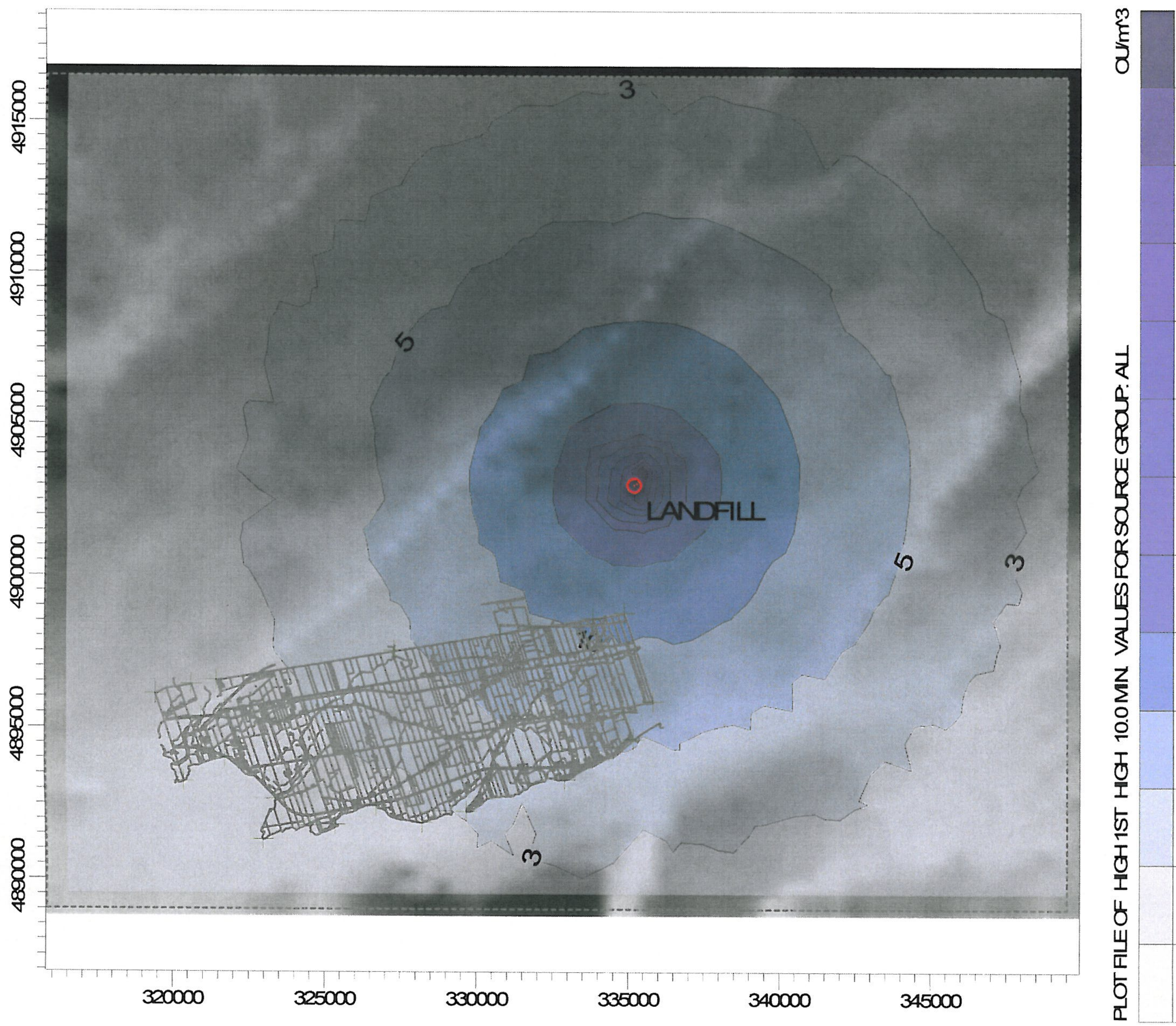
```
  2800.  0.1530E+07    5      1.0    1.6 10000.0   40.00       0.
  2900.  0.1481E+07    5      1.0    1.6 10000.0   40.00       0.
  3000.  0.1434E+07    5      1.0    1.6 10000.0   40.00       1.
  3500.  0.1250E+07    6      1.0    2.1 10000.0   40.00       0.
  4000.  0.1165E+07    6      1.0    2.1 10000.0   40.00       0.
  4500.  0.1082E+07    6      1.0    2.1 10000.0   40.00       0.
  5000.  0.1006E+07    6      1.0    2.1 10000.0   40.00       0.
  5500.  0.9358E+06    6      1.0    2.1 10000.0   40.00       0.
  6000.  0.8725E+06    6      1.0    2.1 10000.0   40.00       0.
  6500.  0.8155E+06    6      1.0    2.1 10000.0   40.00       0.
  7000.  0.7640E+06    6      1.0    2.1 10000.0   40.00       0.
  7500.  0.7177E+06    6      1.0    2.1 10000.0   40.00       0.
  8000.  0.6760E+06    6      1.0    2.1 10000.0   40.00       0.
  8500.  0.6383E+06    6      1.0    2.1 10000.0   40.00       0.
  9000.  0.6041E+06    6      1.0    2.1 10000.0   40.00       0.
  9500.  0.5730E+06    6      1.0    2.1 10000.0   40.00       0.
 10000.  0.5446E+06    6      1.0    2.1 10000.0   40.00       0.
 15000.  0.3570E+06    6      1.0    2.1 10000.0   40.00       0.
 20000.  0.2637E+06    6      1.0    2.1 10000.0   40.00       0.

MAXIMUM 1-HR CONCENTRATION AT OR BEYOND   500. M:
   500.  0.4825E+07    3      1.0    1.1   320.0   40.00       0.

     ***************************************
     *** SUMMARY OF SCREEN MODEL RESULTS ***
     ***************************************

 CALCULATION        MAX CONC    DIST TO   TERRAIN
  PROCEDURE        (UG/M**3)    MAX (M)    HT (M)
--------------    -----------   -------   -------
SIMPLE TERRAIN     0.4825E+07      500.        0.


***************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
***************************************************
```

ATTACHMENT C

AERMOD DISPERSION MODELLING OUTPUT

PROJECT TITLE:

Richmond Landfill Odour Modelling
Working Face Fresh Waste Area Source



COMMENTS:

Meteorological Data: MOE Eastern Region (Ottawa, Peterborough, Belleville)
Flat terrain option.
10-minute averaging period.

SOURCES:

1

RECEPTORS:

975

OUTPUT TYPE:

Concentration

MAX:

199.46229 OU/m^3

COMPANY NAME:

XCG Consultants Ltd.

MODELER:

DYC

DATE:

5/4/2009

SCALE: 1:209,168

0 5 km

XCG

PROJECT NO.:

1-664-17-03

AERMOD View - Lakes Environmental Software

C:\Documents and Settings\davidc\My Documents\Lakes\AERMOD View\Ottawa Region\final large\large.isc

ATTACHMENT D

LAKES ENVIRONMENTAL ODOUR MODELLING SUPPORT DOCUMENT

Odor Modeling

Description: The mechanisms of odor dispersion in the atmosphere are the same as the dispersion of other pollutants. When modeling odor concentrations using the U.S. EPA AERMOD or ISCST3 models, there are a few considerations to be made.

Solution:

Determining Odor Emissions Rates

1) Single Odor-Producing Pollutant:

• *Odor Emission Rate* [g/s]: specify the pollutant emission rate in g/s as you would specify if doing a normal air dispersion modeling study.

• *Model Output Concentration* [µg/m3]: the model predicted concentration will be given in mass per volume (µg/m3). Compare this concentration with the pollutant specific odor threshold which is generally given in parts per million (ppm) and/or ug/m3.

2) Multiple Odor-Producing Pollutants:

When multiple pollutants are emitted, masking and enhancing effects may occur, in this case the relationship between concentration and odor is not well defined and odor must be characterized in terms of an odor detection threshold value (OTV).

• *Odor Detection Threshold Value* [OTV]: Using a panel of testers, the OTV is the value at which 50% of the panelists can just detect the odor. Odor complaint levels are usually 2 to 3 times higher than the odor threshold levels.

• *Odor Concentration* [OU/m3]: Odor concentration is expressed in terms of odour dilution ratio or odor units (OU) per cubic meter of air (OU/m3), where the odor is no longer perceptible by 50% of the panelists.

Example: If an odorous air sample of the exhaust stream was diluted with 1000 volumes of odor-free air to reach the OTV, then the odor concentration of the sample would be given as 1000 OU/m3.

• *Odor Emission Rate* [OU/s]: The odor emission rate of the source can then be calculated as follows:

$$E = V \times DTT$$

E = Odor emission rate (OU/s)
V = Volumetric flow rate of the emission source (m3/s)
DTT = Odor concentration in OU/m3 (which is the number of dilutions to odour threshold)

• *Model Output Concentration* [OU/m3]: The model predicted odor concentration will be given in terms of OU/m3. These values should than be compared with the odor threshold of 1 OU/m3 (odor detection threshold).

AERMOD View Users: You can specify the emission unit label of OU/s and the concentration unit label of OU/m3 in the Source Pathway under Emission Output Unit.

Setting Correct Units in AERMOD and ISCST3

For a single pollutant, the emission rate can be given in grams per second [g/s] and the output concentration in micrograms per cubic meter [µg/m3]. These are the default values for AERMOD and ISCST3, and hence no changes are needed.

For *multiple pollutants*, the emission rate is given in terms of odor units per second [OU/s] and the output concentration is given as odor units per cubic meter [OU/m3]. This requires several parameters in AERMOD and ISCST3 to be changed. These parameters can be found in the source pathway, and should be changed as follows:

Parameter	Default Value	User-Defined Value
Unit Factor	1000000	1
Emission Unit Label	GRAMS/SEC	OU/SEC
Concentration Unit Label	MICROGRAMS/M**3	OU/M**3

This may be written in the source pathway as:

CONCUNIT 1 OU/SEC OU/M**3

AERMOD View Users: These changes can be made directly in the Source Pathway under Emission Output Unit.

Calculating Short-Term Odor Concentrations

Because the nose can detect odors very quickly, an averaging period less than 1-hour is more appropriate (e.g., 3-min or 10-min). Therefore, you will need to convert the 1-hour AERMOD and ISCST3 concentration results into the appropriate shorter average period using the formula below:

$$C_{new} = C_{1\text{-hour}} (T_{1\text{-hour}}/T_{new})^{q}$$

Where:

Cnew = Concentration for the shorter time period
C1-hour = 1-hour concentration
Tnew = Shorter average period in seconds
T1-hour = 3600 (for 1-hour average period)
q = decay factor (values for q vary, please contact your regulator for guidance)
Note: This conversion is available in the *Concentration Converter* under the Tools menu.

Lakes Environmental

support@weblakes.com - www.weblakes.com