1 Introduction
There has been a significant increase in the installation of wind farms in Ontario. Wind farms will be a major energy supplier in Ontario due to the strong green-energy initiative of the provincial government. Noise impact of the wind turbines on nearby receptors has been a contentious issue. The current assessment procedures limit the methods to simple application of ISO-9613-Part 2. Detailed applications of terrain and weather information are beyond the scope of ISO-9613-part 2 procedures. Two improvements to the simple procedures are used to evaluate the receptor locations noise levels from a 5-turbine wind farm in southern Ontario. Comparisons between the three methods are presented in this paper.

2 Background
Simple procedures have been conventionally applied to evaluate the wind farm noise levels at nearby residential receptors [1, 2]. Many of the constraints assumed by the simple procedures are easily not complied with when such procedures are applied to wind farms. One constraint is the height of the wind turbine hub, usually in excess of 50 metres. Many of the receptors are located beyond the allowable distance of the simple procedures.

As part of the major research study of a 5-turbine wind farm in West Lincoln, Ontario, investigations were carried out to evaluate the noise levels at receptors from the wind farm. The results of the investigations are described below.

3 Noise Propagation Models

3.1 Cadna_A model
Cadna_A (Computer Aided Noise Abatement) is a leading software for calculation, presentation, assessment and prediction of environmental noise [3]. The procedures of ISO9613-Part II are applied in the evaluation. All the desired sources and receiver locations, the sound power level of the source are defined by the user. The weather data is defined in terms of the humidity, temperature, wind speed, wind direction, and temperature gradient, etc.

3.2 NORD 2000
The platform is designed for predicting noise level generated from a stationary source, infinite straight road or rail track sources [4]. The model is based on geometric ray theory and diffraction. The calculations are carried out in one-third octave bands. The sound power level of the source for various frequencies is defined along with the height of the source. Terrain profile is defined by the distance from the source, height, and ground type and roughness. Also, if there any scattering zone in the terrain, it can be categorized as forest area or housing area. The weather data is defined in terms of wind speed, wind direction, wind speed, turbulence strength, standard deviation of wind speed, temperature, temperature gradient, standard deviation of temperature gradient and turbulence strength (temperature).

3.3 Parabolic equation solver
The INPM noise model was developed by JASCO Applied Sciences, originally for use by the Canadian Department of National Defence as an environmental impact assessment and forecasting tool [5]. The INPM propagation modelling algorithm involves numerical computation of the parabolic form of the acoustic wave equation in vertical planes, thus providing a full description of the sound pressure in the air column along a radial from the source. The model takes fully into consideration the physical properties of the propagation media resulting in the complex structure of sound distribution.

INPM accounts for the acoustic influence of vertical profiles of atmospheric parameters (temperature, pressure, humidity) and is able to account for the influence of atmospheric turbulence. The model inputs the ground elevation and terrain type or cover (from which acoustic ground impedance is computed) from geo-referenced files to account for the local influence of these parameters on sound waves as they interact with the terrain. Sound propagation in each frequency band is computed independently and the results are summed to provide broadband estimates. Planar maps of noise footprints are obtained from multiple runs of the model along a fan of propagation radials from a source, a process that can be further expanded to multiple sources; the sound intensity is estimated at a standard receiver height (ear level) above ground.

4 The Wind Farm
The wind farm under investigation is located in the Town of West Lincoln, near Hamilton, Ontario. The layout in West Lincoln is shown in Figure 1. The wind farm and the five turbines became operational in May of this year. The distances from each turbine to each of the four receivers are shown in Table 1. SENES Consultants of Markham, Ontario evaluated the detailed weather data for three days for the month of June. Wind speed profiles evaluated by Senes Consultants at the four receiver locations are shown in Figure 2 for 8.30 at night.
5 Results and discussion

The main finding of the simulation is that results of CADNA_A and NORD2000 are seen to agree within engineering accuracy. However, INPM results are at least 10 dB higher. Unattended long-term monitoring was conducted at the four receptor locations after the turbines became operational in May of 2014. Preliminary results show that wind farm produced levels at the receptor that varied between 35 and 40 dBA. Measurements are still undergoing. In addition to long term measurements, spot measurements of noise levels as well as weather will be conducted.

Each of the prediction procedure are currently being refined. It will be difficult to determine the correct method of predicting results at the time of writing this paper.

6 Conclusion

The receptor sound levels at four residential locations were evaluated using three prediction models from a small wind farm of five wind turbines. The results show that two of the three methods predict lower noise levels.

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