Appendix V4-9E

Hope Bay Mine Wind Farm:
Visual, Shadow Flicker and Noise Impact Analysis

TMAC RESOURCES

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EDI Environmental Dynamics Inc.

Hope Bay Mine Wind Farm

Visual, Shadow Flicker and Noise Impact Analysis

13 December 2017

Technical Report

Report Summary

Wood Group has been appointed by EDI Environmental Dynamics Inc. (the Client) to provide visuals, shadow flicker and noise assessment services relating to the proposed Hope Bay Mine wind farm project located in Nunavut, Canada (the Project).

Wood Group understands that the Project is a proposed 25.2 MW wind farm in the pre-construction stage, with the six wind turbine generators (WTGs) expected to be Enercon E-126 EP4. Three potential sites for WTG installation, Doris, Madrid, and Boston, are being considered.

For the purpose of assessing the visual impact of the Project, Wood Group agreed with the Client on eight locations from which the Project might be seen. Previews and viewpoint descriptions are included in this report and full size photomontages have been provided separately.

Shadow flicker is generally not considered to be a significant issue for receptors beyond a distance equal to 10 rotor diameters from the WTGs. Given the distance between the WTGs and the worker accommodation (nearest receptor), any modelled shadow flicker effects are not likely to be experienced in reality. If in the unlikely event that the shadows cast by the WTGs once operational did extend as far as the accommodation, they would be expected to be low intensity and therefore not cause any significant impacts.

The noise impact of the WTGs was modelled using manufacturer's sound power level data. In the absence of any known noise limits for Nunavut, some of the most stringent international limits were applied. The effect of the mine on the background noise was neglected. The results show that the noise criteria will be comfortably met.

Note: SgurrEnergy formally rebranded as Wood Group in early May 2017. The corporate legal entity remains SgurrEnergy Ltd.

Report Details

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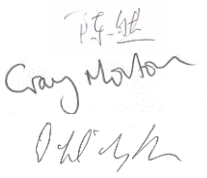
Prepared by:	Ran Chen Craig Morton David McLaughlin	Consultant (Visual) Consultant (Shadow Flicker) Principal Consultant (Noise)	
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Amendment Record

Revision Number	Date	Summary of Amendments	Purpose of Revision
A1	21 August 2017	Compilation of reviewed sections	For internal review
A2	22 August 2017	Minor comments	Internal authorisation
B1	22 August 2017	Minor updates	For issue to Client
B2	13 December 2017	Addition of visual impact and shadow flicker assessments to include the WTGs proposed at Boston and Madrid sites.	For issue to Client

SF/04/023

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Glossary

Abbreviation or Term	Definition
EIS	Environmental Impact Statement
NSR	Noise Sensitive Receptor
UTM	Universal Transverse Mercator
WTG	Wind Turbine Generator

1 Introduction

Wood Group has been appointed by EDI Environmental Dynamics Inc. (the Client) to provide visuals, shadow flicker and noise assessment services relating to the proposed Hope Bay Mine wind farm project located in Nunavut, Canada (the Project).

Wood Group understands that the Project is a proposed 25.2 MW wind farm in the pre-construction stage, with the six wind turbine generators (WTGs) expected to be Enercon E126-EP4, with 127 m rotor diameter,99 m hub height and rated power output of 4.2 MW. The six WTGs, in three pairs, are proposed to be installed near three deposit sites: Doris, Madrid, and Boston. The Project is expected to use both existing and planned mine roads for most construction access, with additional short access roads to each WTG location. The overhead collector network is expected to follow the main north-south road, and the interconnection point will be near the Doris deposit of the Hope Bay Mine, approximately 2.5 km north of the northernmost proposed WTG locations.

Wood Group referenced the following documents in our analysis:

- Memo Cameron Hore, SRK Consulting to John Roberts, PEng, Vice President Environment Client: TMAC Resources Inc., Project No. 1CT022.015, June 27, 2017.
- *ISO 9613-2. (1996). Acoustics - Attenuation of sound during propagation outdoors, Part 2: General method of calculation. ISO.*
- Google Earth file EDI Nunavut visuals.kmz.
- hopebay feis linework 11-10-2017 EDI.kmz.
- Phase 2: Draft environmental impact statement, TMAC Resources Inc, undated.
- Planning for Renewable Energy: A Companion Guide to Planning Policy Statement, United Kingdom Department for Communities and Local Government, 22 September 2004.
- A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise, Institute of Acoustics, May 2013.
- Guidelines for Community Noise, World Health Organization (WHO), 1999.
- Wind Turbine Noise and Health Study, Health Canada, 2014.
- IEC 61400-11 ed3.0, Wind turbines - Part 11: Acoustic noise measurement techniques, IEC, November 2012.
- D0390063-2_#_en_#_Betriebsmodi_E-126_EP4___4200_kW_mit_TES.pdf, Enercon
- Sound Power Level Warranty_Rev006.2_eng-eng.pdf, Enercon, undated.
- W/45/00656/00/00 The Measurement of Low Frequency Noise at Three UK Windfarms. Department of Trade and Industry 2006.
- The Impacts of Wind Power on Terrestrial Mammals: A Synthesis. Jan Olof Helldin, Jens Jung, Wiebke Neumann, Mattias Olsson, Anna Skarin, Fredrik Widemo. Swedish Environmental Protection Agency. Report 6510. August 2012.

2 Visuals

For the purpose of assessing the visual impact of the Project, Wood Group agreed with the Client eight locations from which the Project might present a visual impact. Previews are shown in Figure 2-1 for viewpoints near the Doris site, Figure 2-2 for the two viewpoints near the Madrid site, and Figure 2-3 for the viewpoints near the Boston site, with the viewpoint locations summarised in Table 2-1.

Due to the small size of the previews, the locations of the WTGs are highlighted. Full size photomontages (without highlighting) have been provided separately to the Client.

Figure 2-1: Doris Site Viewpoints, Clockwise from Top Left: VP01, VP02, VP03 and VP04

Figure 2-2: Madrid Site Viewpoints, VP_M1 and VP_M2

Figure 2-3: Boston Site Viewpoints from South, VP_B1 and VP_B2

Table 2-1: Visual Impact Photomontage Viewpoint Descriptions

Nearest Site	Viewpoint	Location Description	Distance from Centre of WTGs in view	View Direction
Doris	VP01	Looking approximately north from road, after rounding corner.	1.5 km	7°
	VP02	Looking approximately south from the mine site, on the west side of the north end of the lake.	3 km	194°
	VP03	Looking approximately southwest across from the east side of the north end of the lake.	3.5 km	212°
	VP04	Looking approximately south-southeast from road, after rounding corner.	1.5 km	159°
Madrid	VP_M1	Looking approximately south west of road.	3.5 km	161°
	VP_M2	Looking approximately north (at Doris site WTGs) from southeastern end of the lake.	6.3 km	356°
Boston	VP_B1	Looking approximately north on southeastern end of the lake.	5.1 km	340°
	VP_B2	Looking approximately northwest.	4.8 km	320°

3 Shadow Flicker Assessment

Shadow flicker is defined as alternating changes in light intensity caused by rotating WTG blades casting moving shadows. These moving shadows can produce a flickering effect when viewed from inside a building through a narrow window opening. Shadow flicker is generally not considered to be a significant issue for receptors beyond a distance equal to 10 rotor diameters from the WTGs. However, shadow flicker issues may be more important in higher latitudes, where the sun is lower in the sky and therefore casts longer shadows that will extend the radius within which potentially significant shadow flicker impact will be experienced.

The proposed WTGs will have a rotor diameter of up to 127 m. Based on the generally accepted 10 rotor diameter guidance, this would result in a potential shadow flicker impact zone with a radius of up to 1.3 km around the WTGs. Given the high latitude of the site, it would be expected that the shadow flicker impact zone may actually extend slightly further. However, the only sensitive residential receptor in the vicinity is the worker accommodation located at the mine, approximately 2.5 km north of the Doris site WTGs, and is even farther from the WTGs near the Madrid site or the Boston site. These distances are far greater than the 10 rotor diameter guidance, and therefore no significant shadow flicker impacts are anticipated. For the Doris Site, there is a road approximately 250 m to the west of the proposed WTG locations. For the Madrid and Boston sites, a new north-south road is planned, and the proposed WTGs are approximately 250 m off the road to be accessed through short access roads. Since these roads are or will be only infrequently used, they are not considered to be significant sensitive receptor locations for shadow flicker impacts.

If required, Wood Group can undertake indicative modelling of the potential shadow flicker impacts at the worker accommodation, assuming no limit to the extent of shadow flicker effects. This modelling, based on a worst-case scenario, will provide an indication of the duration of shadow flicker effects potentially experienced at the accommodation, assuming that the shadows cast by the WTGs could extend all the way to the mine. Adopting this conservative approach, the results of the indicative worst-case modelling would be benchmarked against international guidance such as the World Health Organization’s Environmental, Health, and Safety Guidelines for Wind Energy (2015).

Given the large distances between the WTGs and the worker accommodation, any modelled shadow flicker effects are not likely to be experienced in reality. If in the unlikely event that the shadows cast by the WTGs once operational did extend as far as the accommodation, they would be expected to be low intensity and therefore not cause any significant impacts.

3.1 Wind Farm Impacts on Caribou

The Project site is located within a caribou habitat. To the best knowledge of Wood Group, there are no Nunavut government policies constraining wind farm development specifically in the vicinity of caribou herds.

From our literature review, and knowledge of wind farm projects in reindeer habitats in Scandinavia, there is no clear evidence of shadow flicker impact on caribou grazing patterns. The main risks identified in most studies are: displacement or injury by collision during construction, and increased hunting, due to new access infrastructure, during operation.

Potential collision risks could be mitigated through fencing off the construction areas and warning delivery drivers/construction workers about the possible presence of caribou. The risks associated with the construction phase are temporary for the duration of construction works only. Wood was informed that other mitigation measures for project activities concerning wildlife-human interactions will be provided separately.

During operation, new wind farm access roads will improve access for recreation and hunting activities in areas that were previously remote and inaccessible, which may increase human impacts on wildlife in the area. The new roads also potentially make easier access for predators to reach caribou herds. However, in this instance, the WTGs are proposed within approximately 250 m of the existing or planned major road and so the associated access tracks are not considered likely to significantly increase access to areas previously devoid of human influence. In addition, the remoteness of the project inherently limits recreational and commercial hunting activities. By contrast, the habitat changes caused by access roads are not necessarily a problem for larger mammal species such as caribou. New edge zones and roadsides could rather benefit many wildlife species. Edges create new browsing areas; roads can facilitate animal movement in the landscape or help animals escaping parasitic insects.

As there is already human influence in the area due to the mining activity, the impact of WTG construction and operation on caribou may be expected to be less significant than in more remote areas with no pre-existing human activity. Given the limited scientific data available regarding wind farm impacts on caribou populations, Wood Group recommends monitoring of the impacts on caribou during the construction and operational phases of the wind farm, including cumulative impacts with the mine’s construction activities.

4 Noise Assessment

4.1 Introduction

The noise impact of the proposed Doris site development was calculated considering a single candidate WTG type, the Enercon E-126 EP4 with a rated power output of 4.2 MW. From the preliminary design memo[1], the hub height is taken to be 99 m. Standard atmospheric conditions were assumed in the ISO 9613-2[2] noise propagation model.

4.1.1 Wind Farm Layout

The WTG coordinates of the two WTGs at Doris site were supplied by the Client[3] and are provided below in Table 4-1. They are also shown in Figure 4-1.

Table 4-1: Doris Site WTG Locations

WTG No	Latitude	Longitude	Easting [m]	Northing [m]
1	68°06'47.95"N	106°36'30.89"W	433089	7556370
2	68°06'20.37"N	106°36'30.26"W	433074	7555516

4.1.2 Noise Sensitive Receptors

The nearest noise sensitive receptor (NSR) is the accommodation camp for the mine. From the EIS for the mine[4], that is taken to be as presented in Table 4-2 and as indicated in Figure 4-1.

[1] Memo Cameron Hore, SRK Consulting to John Roberts, PEng, Vice President Environment Client: TMAC Resources Inc., Project No. 1CT022.015, June 27, 2017

From: Cameron Hore

[2] *ISO 9613-2. (1996). Acoustics - Attenuation of sound during propagation outdoors, Part 2: General method of calculation. ISO*

[3] Google Earth file EDI Nunavut visuals.kmz

[4] Phase 2: Draft environmental impact statement, TMAC Resources Inc, undated

Table 4-2: NSR Location (UTM)

NSR	Easting [m]	Northing [m]
Doris workers' camp (active)	432965	7559019

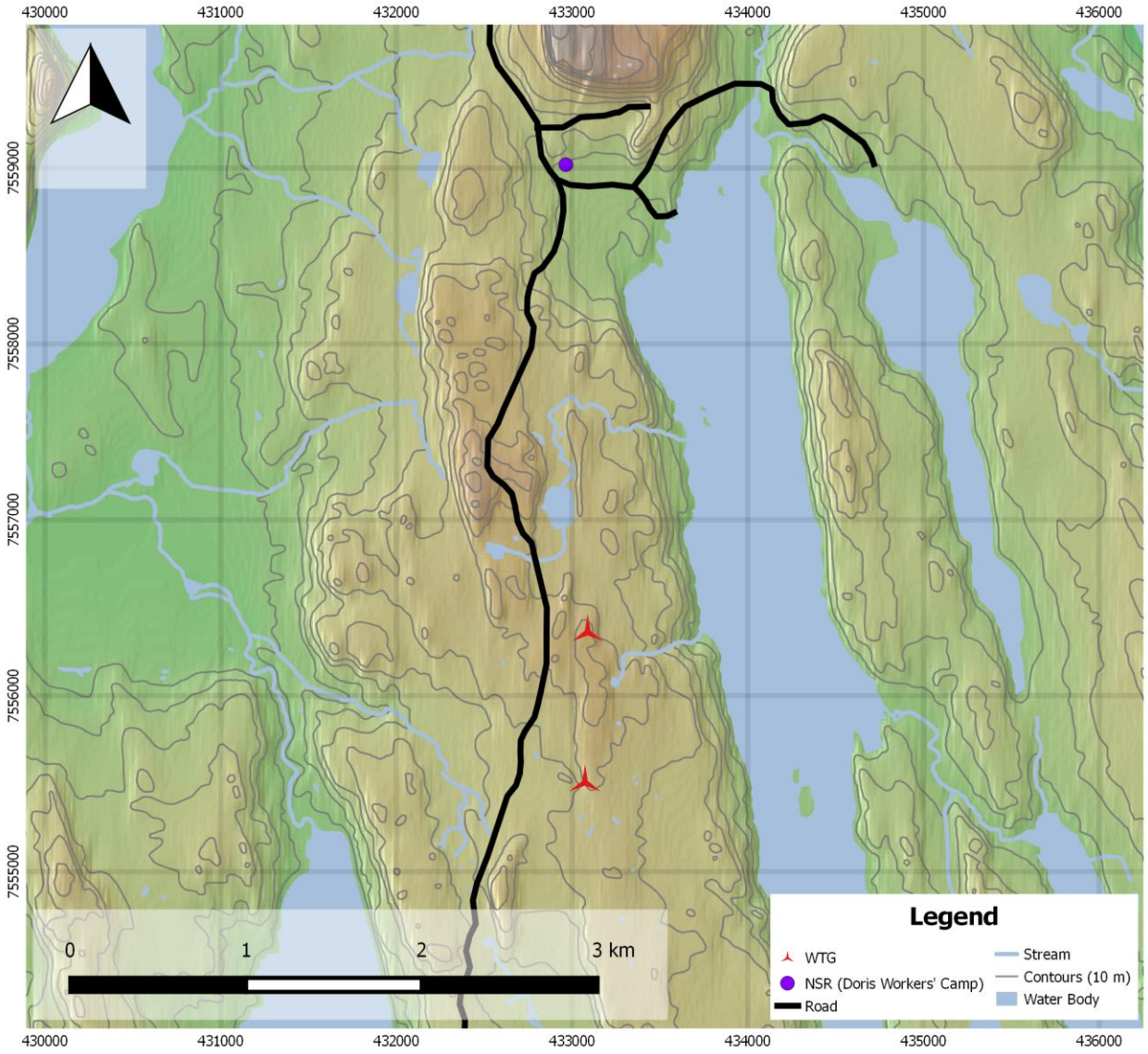

Figure 4-1: Map of Doris Site WTGs and NSRs

4.2 Noise Modelling

4.2.1 Noise Propagation Model

The sound propagation over distance, including the effect of atmospheric absorption, was calculated using the WindPRO model based on ISO 9613-2[2]. The values used were as follows:

- Atmospheric absorption (the attenuation of sound due to absorption of sound energy by the air) appropriate for a temperature of 10°C and 70% humidity were used, as described in ISO 9613-2.
- Ground absorption (the attenuation of sound due to absorption of sound energy by the ground), A_{gr}=0.5, as recommended by the UK Institute of Acoustics' good practice guide[5].
- A receiver height of 4 m.

4.2.2 Limits for WTG Noise

There are no known noise limits for wind farms in Nunavut. As a worst case, the limits used in the United Kingdom have been adopted. These are among the strictest in the world, and are well below the night-time (between 22:00 and 06:00) limit of 50 dB(A) and daytime (between 06:00 and 22:00) limit of 55 dB(A) set for outdoor living areas in the World Health Organization guidelines for community noise[6].

The limit is set to be an L_{A90} level (the level exceeded 90% of the time) of background noise + 5 dB or 35 dB(A), whichever is greater. The L_{A90} level is assumed to be the L_{AEq} level minus 2 dB. The background noise level is taken from the mine EIS[4]. Normal practice would be to have separate daytime and night-time limits but, given the absence of anthropogenic activity when the background noise was measured, the difference between the two is likely to be small.

It is not known at what height the wind speed has been measured, so it was assumed to be near ground level at 1.5 m. This has been scaled to a height of 10 m in accordance with IEC 61400-11[7].

A second order polynomial has been fitted through the data, as shown in Figure 4-2.

[5] *A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise, Institute of Acoustics, May 2013*

[6] *Guidelines for Community Noise, World Health Organization (WHO), 1999.*

[7] IEC 61400-11 ed3.0, Wind turbines - Part 11: Acoustic noise measurement techniques, IEC, November 2012

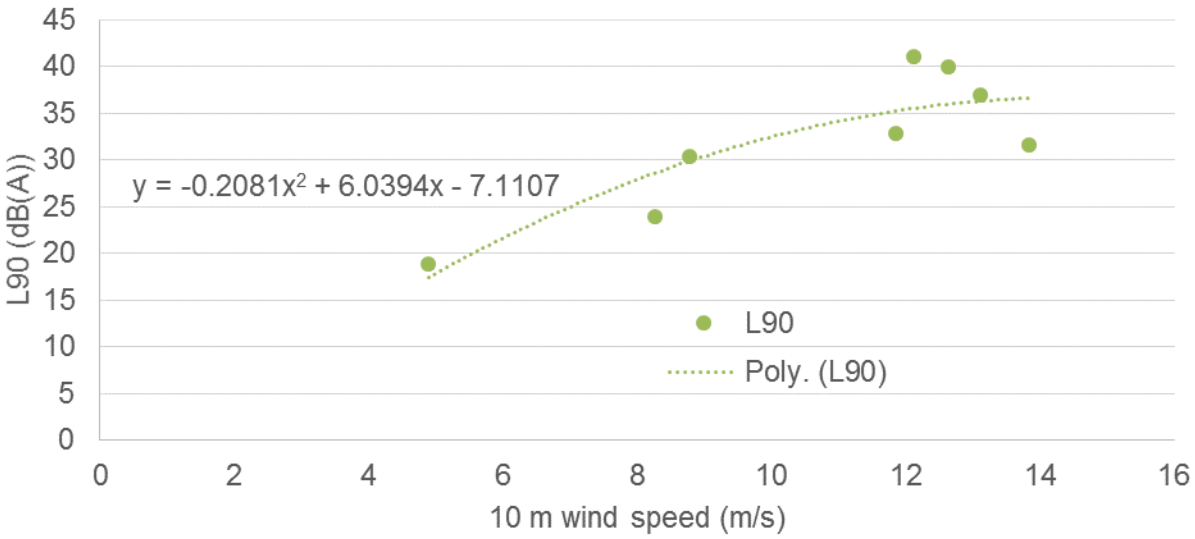

Figure 4-2: Background Noise against Wind Speed

4.2.3 WTG Noise Data

The sound power emission level against wind speed has been taken from WTG documentation supplied by Enercon[8]. This is for a device with trailing edge serrations, which may reduce the sound power level by about 2 dB. The sound power emission levels as a function of wind speed at 10 m, for a 99 m hub height[1] are shown in Table 4-3.

Table 4-3: Sound Power Emission Level of Enercon E-126 E4 99 m Hub Height

10 m wind speed [m/s]	Sound Power Emission Level [dB(A)]
5	100.4
6	102.8
7	104.1
8	104.6
9 +	105.0

[8] D0390063-2_#_en_#_Betriebsmodi_E-126_EP4___4200_kW_mit_TES.pdf, Enercon

In the noise propagation model, an additional 1 dB is added to each of the values in Table 4-3 to account for uncertainty in the sound power levels, in accordance with a typical Enercon warranty document[9].

As no frequency spectral data were available, the noise model in the WindPRO software package has assumed a generic frequency distribution.

4.3 Results

The predicted WTG noise is the level of noise experienced at the NSRs due to the operation of the WTGs. If the predicted WTG noise exceeds the limit then the noise emissions from the site would be considered to be causing a significant impact. It should be noted that this is an extremely conservative assumption as the background noise will be significantly elevated by the mine itself. The predicted noise limit exceedances (the predicted noise level minus the noise limit level) are presented in Table 4-4.

Table 4-4: Predicted Excess Over-Noise Limits for the Doris Site Development

10 m wind speed [m/s]	Noise limit [L_{A90}, dB]	WTG noise [L_{A90}, dB]	Excess over limit [dB]
4	35	14.5	-20.5
5	35	16.9	-18.1
6	35	19.3	-15.7
7	35	20.6	-14.4
8	35	21.1	-13.9
9	35.4	21.5	-13.9
10	37.5	21.5	-16.0
11	39.1	21.5	-17.6
12	40.4	21.5	-18.9

A noise contour map at 8 m/s wind speed is shown in Figure 4-3.

[9] Sound Power Level Warranty_Rev006.2_eng-eng.pdf, Enercon, undated

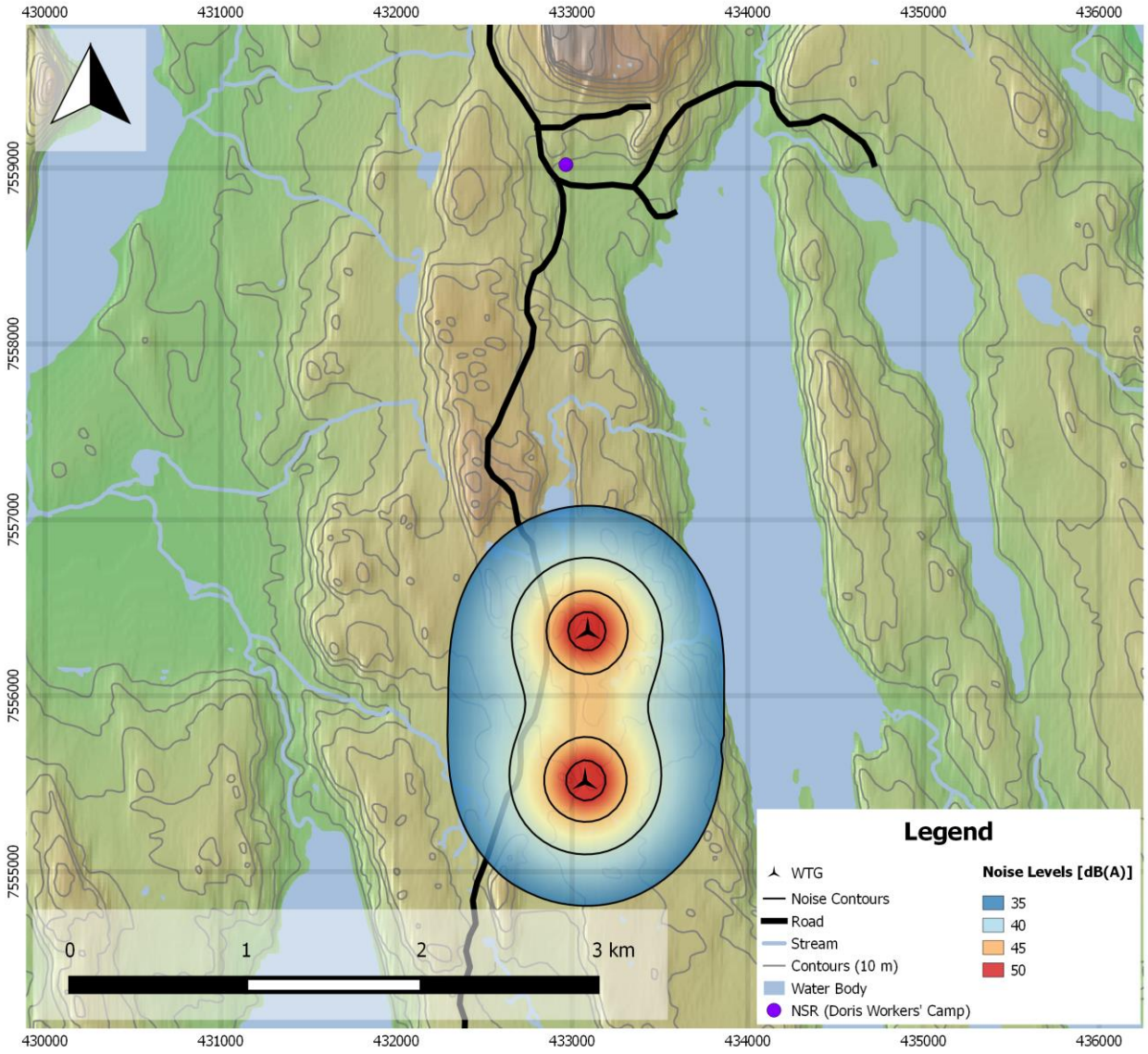

Figure 4-3: Noise Map of Wind Turbines and NSR for the Doris Site Development

4.4 Discussion

It can be seen from the results of Table 4-4 that the predicted WTG noise (including an additional 1 dB for uncertainty) to be emitted from the Doris site does not exceed either the daytime or night-time noise limits at any NSR. For a WTG with an 80 m hub height, the wind speed would be 2.5% lower, resulting in a negligible decrease in noise.

Note that Wood Group has not analysed the cumulative acoustic impacts due to the operation of WTGs at the Madrid and the Boston sites. However, given that these two sites are south of the Doris site and thus even farther from the existing worker's camp, the noise emitted from the WTGs of these sites is expected to be negligible at the NSR location.

4.5 Other Noise-related Issues

4.5.1 Infra-sound

Infra-sound is defined as noise occurring at frequencies below that at which sound is normally audible, i.e. at less than 20 Hz, due to the significantly reduced sensitivity of the ear at such frequencies. In this frequency range, for sound to be perceptible, it has to be at very high amplitude and it is generally considered that when such sounds are perceptible then they can cause considerable annoyance to humans and wildlife.

WTGs have been cited as significant producers of infra-sound. This has, however, been due to the high levels of such noise, as well as an audible, low frequency, thumping noise, occurring on older 'downwind' WTGs of which many were installed in the USA prior to the large-scale take up of wind power production worldwide. Downwind WTGs are configured with the blades downwind of the tower such that the blades pass through the wake left in the wind stream by the tower resulting in a regular audible thump, with infra-sonic components, each time a blade passes the tower. All modern WTGs, including the units proposed for the Project, are of the upwind design, with the blades upwind of the tower, such that this effect is eliminated.

A study for the UK Department of Trade and Industry[10] concluded that 'Infrasound noise emissions from WTGs are significantly below the recognised threshold of perception for acoustic energy within this frequency range. Even assuming that the most sensitive members of the population have a hearing threshold which is 12 dB lower than the median hearing threshold, measured infrasound levels are well below this criterion'. It goes on to state that, based on information from the World Health Organisation, that 'there is no reliable evidence that infrasound below the hearing threshold produce physiological or psychological effects' it may be concluded that 'infrasound associated with modern WTGs is not a source which may be injurious to the health of a wind farm neighbour'. Therefore, it is concluded that this effect is negligible.

[10] W/45/00656/00/00 The Measurement of Low Frequency Noise at Three UK Windfarms. Department of Trade and Industry 2006

4.5.2 Low Frequency Noise

Noise from modern WTGs is essentially broadband in that it contains similar amounts of noise energy in all frequency bands from low to high frequency. As distance from a wind farm site increases, the noise level decreases as a result of the spreading out of the sound energy but also due to air absorption which increases with increasing frequency. This means that although the energy across the whole frequency range is reduced, higher frequencies are reduced more than lower frequencies with the effect that as distance from the site increases, the ratio of low to high frequencies also increases. This effect may be observed with road traffic noise or natural sources such as the sea where higher frequency components are diminished relative to lower frequency components at long distances. At such distances, however, overall noise levels from WTGs are so low that this effect is not significant.

4.6 Cumulative Noise Impact

There are no other known wind farms in the area, so cumulative wind farm noise is not an issue.

4.7 Conclusions

The noise impact of the Doris site WTGs was modelled using manufacturer's sound power level data. In the absence of any known noise limits for Nunavut, some of the most stringent international limits were applied. The effect of the mine on the background noise was neglected.

The results show that these noise criteria will be comfortably met with the modelled WTGs and based on measured background noise levels.