Appendix E

Sound Analysis Report

Badger Wind, LLC
February 2022

BADGER WIND FARM

Sound Assessment

Badger Wind, LLC

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Task and objective:
This report presents the results of a sound analysis conducted by DNV on behalf of Badger Wind, LLC.

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C	16 February 2022	Substation update	J. Puggioni	A. Nercessian	G. Constantin

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EXECUTIVE SUMMARY

DNV Energy USA Inc. ("DNV") has conducted a sound assessment for the Badger Wind Farm (the "Project") located in Logan County and McIntosh County, North Dakota. The Project consists of 79 wind turbine generators (WTGs) and two step-up transformers within the substation. There are no neighboring wind farms or solar farms near the Project. Only 74 of the 79 turbines are planned to be constructed.

45 sound receptors, representing inhabited residences or community buildings, within one mile of a WTG or substation transformer have been included in this report.

The sound pressure level (SPL) at each receptor for the aggregate of all WTGs and transformers was calculated based on the ISO 9613-2 method.

The calculated results include a +2 dB adjustment to the published wind turbine sound power level (PWL).

The loudest cumulative SPL is 47.5 dBA at receptor 258, which is in close proximity to the substation transformers, and at participant receptor 263.

Calculations were performed at the receptor location and at a distance of 100 feet from the respective noise sensitive building in the loudest direction as per North Dakota Administrative Code Section 69-06-08-01. Badger Wind has obtained or is in the process of obtaining waivers from the owners of receptors modeled above the 45 dBA sound limit.

1 INTRODUCTION

Badger Wind, LLC ("Badger" or the "Customer") requested that DNV Energy USA Inc. ("DNV") perform a noise analysis for the Badger Wind Farm (the "Project") located in Logan County and McIntosh County, North Dakota.

The Project layout considered for the noise analysis includes 79 GE3.4-140 wind turbine generators (WTGs) with a hub height of 322 ft (98 m) and two step-up transformers within the substation. Only 74 of the 79 turbines in this analysis are planned to be constructed.

The objective of this assessment was to predict the sound levels generated by the Project WTGs and substation transformers at all receptors within one mile of the Project's sound emitting equipment using the International Organization for Standardization (ISO) standard 9613-2 sound propagation model [1].

2 ENVIRONMENTAL SOUND BACKGROUND

Sound levels are expressed in the decibel unit and are quantified on a logarithmic scale to account for the large range of acoustic pressures to which the human ear is exposed. A decibel (dB) is used to quantify sound levels relative to a 0 dB reference. The reference level of 0 dB is defined as a sound pressure level of 20 micropascals (µPa), which is the typical lower threshold of hearing for humans.

Sound levels can be presented both in broadband (i.e., sound energy summed across the entire audible frequency spectrum) and in octave band spectra (i.e., audible frequency spectrum divided into bands). Frequency is expressed in the Hertz unit (Hz), measuring the cycles per second of the sound pressure waves. The audible range of humans spans from 20 to 20,000 Hz. Since the human ear does not perceive every frequency with equal loudness, spectrally varying sounds are often adjusted with a weighting filter. The A-weighting filter is applied to closely approximate the human ear's response to sound. This scale is commonly used in environmental and industrial sound. Sound expressed in the A-weighted scale is denoted dBA. This is used as the weighting in this report.

A sound source has a certain sound power level rating, which describes the amount of sound energy per unit of time. This is a basic measure of how much acoustical energy it can produce and is independent of its surroundings. Sound pressure is created as sound energy flows away from the source. The measured sound pressure level (SPL) at a given point depends not only on the power rating of the source and the distance between the source and the measurement point (geometric divergence), but also on the amount of sound energy absorbed by environmental elements between the source and the measurement point (attenuation). Sound attenuation factors include meteorological conditions such as wind direction, temperature, and humidity, sound interaction with the ground, atmospheric absorption, terrain effects, diffraction of sound around objects and topographical features, and foliage.

3 APPLICABLE REGULATIONS

Sound emanating from the Project is subject to the *North Dakota Administrative Code Section 69-06-08-01* [2]. The regulations state:

> *a wind energy conversion facility site must **not include** a geographic area where, due to operation of the facility, the **sound levels within one hundred feet** of an inhabited residence or a community building **will exceed forty-five dBA.** The sound level avoidance area criteria may be waived in writing by the owner of the occupied residence or the community building.*

The applicable sound regulation is therefore 45 dBA within 100 feet of an inhabited residence or a community building that is not subject to a waiver.

4 DESCRIPTION OF THE PROJECT SITE

4.1 Site description

The Project is situated in relatively simple terrain, consisting of flat farmland, with project equipment base elevations ranging from approximately 2,000 to 2,200 feet above sea level. The ground cover on and near the site is primarily composed of farmland or open fields. Dwellings are interspersed throughout the Project site.

The Project is located in Logan County and McIntosh County, west of the town of Wishek, North Dakota.

4.2 Project layout

The Project consists of 79 GE3.4-140 WTGs with a hub height of 322 ft (98 m). Two step-up transformers were included at the Project substation. Only 74 of the 79 turbines in this analysis are planned to be constructed.

The coordinates of the Project equipment included in the modeling are presented in Appendix A. The turbine layout and substation transformer locations were provided by the Customer [3] [4].

4.3 Neighboring wind farms

There are no neighboring operational wind or solar farms near the Project.

4.4 Receptor locations

A list of 348 receptors was provided by the Customer [5], most of which were clustered in the nearby town of Wishek over 1 mile from the nearest turbine. Of the total number of identified receptors, results for 45 receptors within one mile of the Project equipment were included in this assessment. Coordinates of each receptor point are presented in Appendix B.

5 SOUND ASSESSMENT

5.1 Description of the sound sources

The sources of sound considered in this analysis are the WTGs and substation transformers. Sound associated with other sources in the vicinity of the Project, such as construction activities, have not been considered in this report.

5.1.1 Project turbines

Project specific total broadband and octave band sound power levels for the General Electric GE3.4-140 WTG at a hub height of 322 ft (98 m) are contained in the manufacturer documentation [6]. The maximum sound power level for the GE3.4-140 turbine model was 106.8 dBA. A +2 dB adjustment was applied to ensure conservatism in the assessment for a total modeled sound power level of 108.8 dBA. The sound power levels used in the analysis were at hub height wind speeds of 10-15 m/s, which were reported to have the same octave band sound levels for each wind speed within that range. Low Noise Trailing Edge Technology (LNTE) is included in this model as per the manufacturer documentation [6].

Table 5-1 shows the octave band sound power levels associated with the turbines used in this analysis.

Table 5-1 WTG sound power levels [dBA]

WTG Model	Frequency [Hz]									Broadband
	31.5	63	125	250	500	1000	2000	4000	8000	
GE3.4-140 (+2dB)	81.7	90.3	94.2	98.1	101.2	104.2	103.5	95.7	76.9	108.8

5.1.2 Substation transformers

There are two transformers planned at the Project substation, each rated at 167 MVA with a voltage of 230 kV on the high voltage side.

A total broadband sound power level of 111.8 dBA was estimated according to the Institute of Electrical and Electronics Engineers Standards Association (IEEE) standard C57.12.90-2015 [7], based on an audible sound level of 83 dBA each [8] and transformer dimensions [9] provided by the Customer. A tonality penalty of 5 dB is included in this value in accordance with ISO-1996-2 [10].

A typical transformer octave band distribution [11] was used. The octave band sound power levels of the Project transformers are shown in Table 5-2.

Table 5-2 Transformer sound power levels [dBA]

Transformer	Frequency [Hz]									Broadband
	31.5	63	125	250	500	1000	2000	4000	8000	
167 MVA - 230 kV	69.0	88.2	100.3	102.8	108.2	105.4	101.6	96.4	87.3	111.8

5.2 Assessment methodology

The sound pressure level at each receptor for the aggregate of all WTGs and transformers associated with the Project was calculated using CadnaA acoustic modeling software based on the ISO 9613-2 method [1]. The simulation was performed using the maximum sound power level of the turbines and transformers, including upward corrections or safety margins. The Project's turbines were modeled with a 322 ft (98 m) hub height. Substation transformers were modeled at a height of 4.4 m (14.4 ft).

The ISO 9613-2 standard provides a prediction of the equivalent continuous SPL at a distance from one or more point sources. The method consists of octave-band algorithms (i.e., with nominal mid band frequencies from 31.5 Hz to 8 kHz) for calculating the attenuation of the emitted sound. The algorithm takes into account the following physical effects:

- Geometrical divergence – attenuation due to spherical spreading from the sound source
- Atmospheric absorption – attenuation due to absorption by the atmosphere
- Ground absorption – attenuation due to the acoustical properties of the ground

The ISO 9613-2 standard calculates attenuation "under meteorological conditions favorable to propagation from sources of sound emission." These meteorological conditions are for "downwind propagation or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night". In other words, though a physical impracticality, the ISO 9613-2 standard treats every receptor as being downwind from every source of sound emission (i.e., transformers and turbines).

The ISO 9613-2 standard accounts for ground absorption by assigning a numerical coefficient (G) with a value ranging from 0 to 1. A value of G = 0 represents hard ground (e.g., paving, water, ice, concrete, tamped ground, and other ground surfaces with a low porosity), while a G = 1 value represents porous ground (e.g., ground covered by grass, trees, or other vegetation, and other ground surfaces suitable for the growth of vegetation such as farming land). Though the ground use on and around the site is farming, a mixed (i.e., semi-reflective) global ground factor of G = 0.5 was used in this assessment.

Additionally, temperature, barometric pressure, and humidity parameters were selected to represent typical local annual averages, and topographical information to accurately represent terrain in three-dimensions was included in this assessment.

Specifically, the ISO 9613-2 parameters were set as follows:

- Ambient air temperature: 50º F (10º C)
- Ambient barometric pressure: 101.32 kPa
- Humidity: 70%
- Overall ground factor: 0.5
- Topography included (10 m elevation intervals)

Additional attenuation from foliage was not considered in this assessment, implying that lower sound levels are expected in areas where there is foliage present in the line of sight between any turbine and a sound receptor. Similarly, because the model assumes every receptor is downwind of every sound source at all times, lower sound levels are expected at times when a receptor is upwind of any sound source.

6 RESULTS

A detailed map illustrating predicted sound pressure levels at receptors located in the vicinity of the Project is presented in Figure 6-1, at 4 m height only, representing the receptor location**.**

The predicted sound levels at each of the receptors located within 1 mile of the Project equipment are presented in Appendix B.

For each receptor, the following information is provided:

- ID
- Coordinates in UTM projection and NAD83 Datum
- Closest noise generating equipment
- Distance to the closest noise generating equipment
- Sound pressure levels (SPL) in dBA for each receptor

Two sets of results were calculated for each receptor:

1. At a distance of 100 feet from the receptor in the loudest direction, at a height of 5 ft (1.5 m)

2. At the building location at a height of 13 ft (4 m).

The greater of the two sound levels was reported in the results in Appendix B for each receptor and compared to the prescribed sound level limits in accordance with North Dakota Administrative Code Section 69-06-08-01.

The highest modelled sound level throughout the Project area is 47.5 dBA at receptor 258 and at participant receptor 263. The substation transformers are the main sound contributors at this receptor. It is understood that a waiver is currently in progress at this location, as well as for other potential non-compliant receptors.

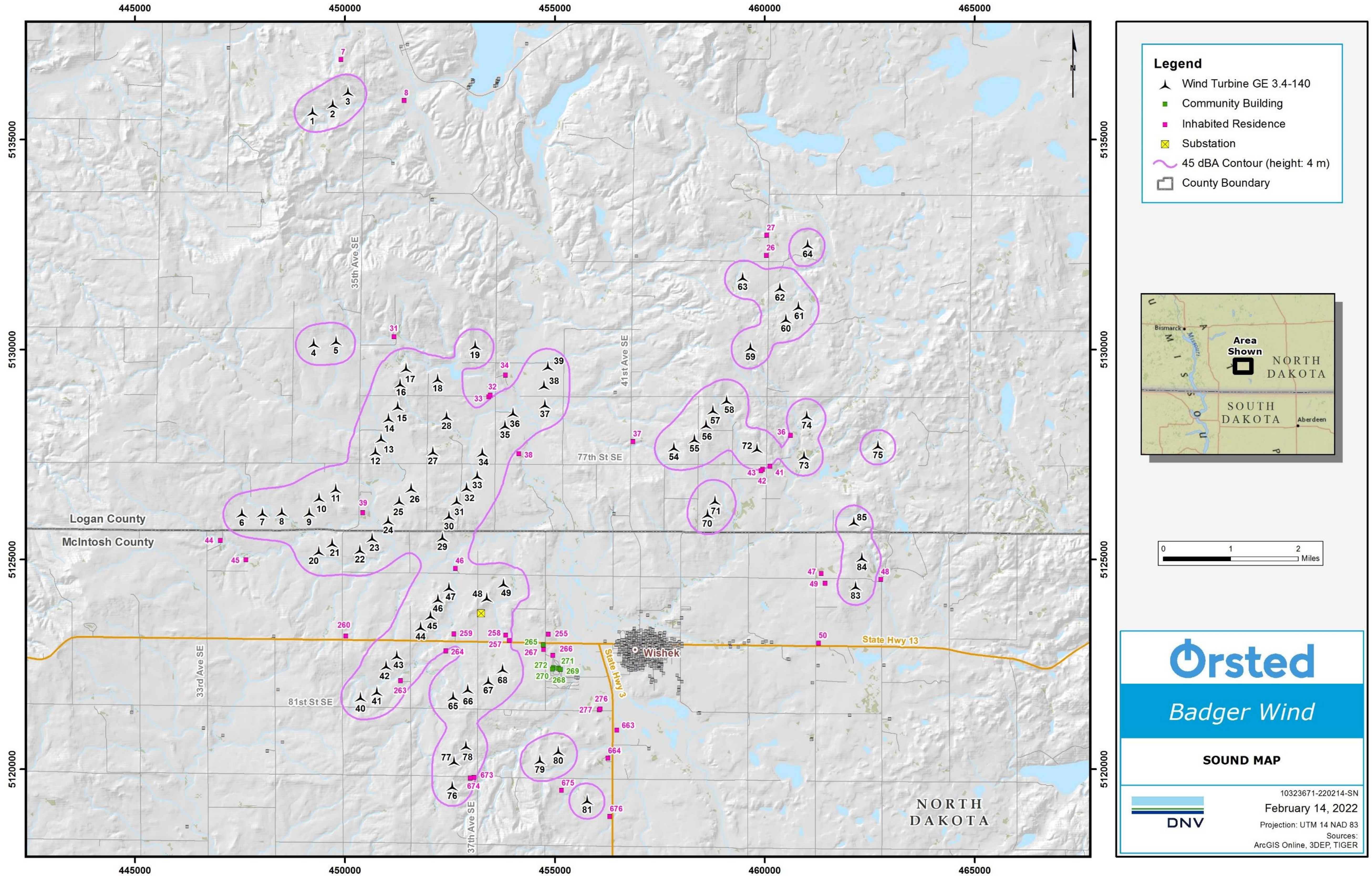

Figure 6-1 Modeled sound levels at the Badger Wind Farm

7 CONCLUSION

DNV has conducted an analysis to determine the maximum predicted sound levels at receptors in the vicinity of the Badger Wind Farm in Logan County and McIntosh County, North Dakota. The Project equipment considered in the analysis were 79 GE 3.4-140 WTGs with a hub height of 322 ft (98 m) and two step-up transformers within the substation. Only 74 of the 79 turbines in this analysis are planned to be constructed. Sound levels in this report may be overestimated in areas where no turbines will eventually be built.

Results are presented for receptors within one mile of a sound source. The loudest cumulative sound pressure level is 47.5 dBA at receptor 258, which is close to the substation transformers, and at participant receptor 263..

Calculations were performed at the receptor location and at a distance of 100 feet from the building in the loudest direction as per North Dakota Administrative Code Section 69-06-08-01. Badger Wind has obtained or is in the process of obtaining waivers from the owners of receptors modeled above the 45 dBA sound limit.

8 REFERENCES

[1] International Organization for Standardization. *ISO 9613-2: Acoustics – Attenuation of Sound During Propagation Outdoors – Part 2: General Method of Calculation*. 15 December 1996.

[2] North Dakota Administrative Code Section 69-06-08-01 Energy Conversion Facility Siting Criteria item 4 Additional Avoidance Areas for Wind Energy Conversion Facilities

[3] Turbine locations accessed in dataroom by DNV on 20 December 2021, filenames "*V17_Turbines_PRIMARYS.shp*" and "*V17_Turbines_ALTS.shp*"

[4] Substation location sent by email on 9 February 2022, filename "*20220208_BADGER_SUBSTATION.kmz*"

[5] Receptor locations sent by email, by Orsted to DNV on 23 September 2021, "*Badger_ReceptorSurvey_FieldVerify.zip*"

[6] One-third octave band sound power levels sent by email, by Orsted to DNV on 22 September 2021, "*2.3 - Noise_Emissions_Sierra 140-60Hz_IEC_EN_r05.pdf"*

[7] C57.12.90-2015 IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers. 11 March 2016.

[8] NEMA TR-2013, Transformers, Step Voltage Regulators and Reactors. National Electrical Manufacturers Association, 2014.

[9] Transformer dimensions and specifications sent by email, by Orsted on 9 February 2022.

[10] International Organization for Standardization. *ISO 1996-2: Acoustics – Description, measurement and assessment of environmental noise -Part 2: Determination of sound pressure levels*. July 2017

[11] *Handbook of Acoustics*. Edited by Malcolm J. Crocker. John Wiley & Sons. 1998.

APPENDIX A – SOUND SOURCE LOCATIONS

ID	UTM Zone 14, NAD 83 Datum	
	Easting [m]	Northing [m]
TR1	453247	5123735
TR2	453246	5123700
T1	449232	5135639
T2	449715	5135813
T3	450072	5136112
T4	449261	5130118
T5	449789	5130171
T6	447551	5126070
T7	448036	5126080
T8	448497	5126099
T9	449154	5126085
T10	449387	5126438
T11	449782	5126653
T12	450729	5127537
T13	450861	5127853
T14	451042	5128333
T15	451257	5128621
T16	451315	5129161
T17	451454	5129529
T18	452210	5129271
T19	453100	5130066
T20	449377	5125160
T21	449699	5125357
T22	450360	5125201
T23	450646	5125479
T24	451033	5125893
T25	451295	5126363

ID	UTM Zone 14, NAD 83 Datum	
	Easting [m]	Northing [m]
T26	451577	5126667
T27	452098	5127542
T28	452421	5128376
T29	452324	5125495
T30	452479	5126005
T31	452664	5126362
T32	452894	5126680
T33	453151	5126962
T34	453276	5127510
T35	453813	5128161
T36	454004	5128462
T37	454764	5128664
T38	454742	5129113
T39	454835	5129567
T40	450371	5121682
T41	450761	5121823
T42	450983	5122435
T43	451235	5122677
T44	451804	5123359
T45	452037	5123629
T46	452217	5124027
T47	452482	5124307
T48	453381	5124054
T49	453779	5124395
T54	457835	5127638
T55	458325	5127835
T56	458602	5128176

ID	UTM Zone 14, NAD 83 Datum	
	Easting [m]	Northing [m]
T57	458765	5128526
T58	459095	5128759
T59	459657	5130026
T60	460506	5130695
T61	460804	5130994
T62	460359	5131442
T63	459474	5131694
T64	461020	5132473
T65	452577	5121697
T66	452929	5121877
T67	453416	5122072
T68	453759	5122358
T70	458635	5126052
T71	458816	5126368
T72	459815	5127608
T73	460934	5127436
T74	461003	5128392
T75	462699	5127680
T76	452558	5119564
T77	452597	5120163
T78	452882	5120526
T79	454642	5120186
T80	455082	5120402
T81	455774	5119232
T83	462165	5124334
T84	462316	5125016
T85	462125	5125862

Transformer IDs (TR1 and TR2) have been arbitrarily added for the purpose of this report.

APPENDIX B – RECEPTOR RESULTS

Receptor ID	UTM Coordinates Zone 14, NAD 83 Datum		Nearest Sound Source [ID]	Distance to Nearest Sound Source [feet]	Sound Pressure Level at Receptor [dBA]
	Easting [m]	Northing [m]			
P7	449910	5136911	T3	2675	39.4
8	451414	5135938	T3	4440	34.0
P26	460040	5132243	T63	2587	42.2
P27	460052	5132724	T64	3281	39.1
P31	451171	5130311	T17	2729	41.5
32	453428	5128874	T36	2320	44.6
33	453463	5128918	T36	2319	44.5
P34	453827	5129394	T36	3113	43.1
P36	460620	5127961	T74	1893	45.2
P37	456860	5127809	T54	3246	39.2
P38	454147	5127522	T35	2368	44.2
P39	450426	5126113	T24	2119	47.0
P41	459950	5127152	T72	1562	44.9
P42	460131	5127219	T72	1645	44.8
P43	459917	5127112	T72	1663	44.4
44	447037	5125452	T6	2635	40.2
45	447643	5124993	T6	3545	39.8
P46	452631	5124788	T47	1652	46.8
P47	461350	5124665	83	2887	39.9
P48	462767	5124527	T83	2073	43.2
P49	461444	5124433	T83	2389	40.8
50	461281	5123004	T83	5239	32.0
255	454849	5123219	T68	4559	38.6
257	453922	5123072	T68	2402	45.4
258	453837	5123201	TR1	2493	47.5
259	452598	5123225	T45	2266	46.1
260	450024	5123180	T42	3984	40.3
P263	451329	5122110	T42	1558	47.5
264	452406	5122819	T44	2653	45.0
265	454729	5122962	T68	3748	40.0
266	454738	5122856	T68	3604	39.9
267	454957	5122712	T68	4098	38.5
268	454969	5122422	T68	3977	38.4
269	455092	5122408	T68	4378	37.7
270	455124	5122382	T68	4479	37.6
271	455138	5122382	T68	4526	37.5
272	454951	5122389	T68	3913	38.5
276	456064	5121418	T80	4635	35.4
277	456081	5121438	T80	4721	35.3
663	456482	5120937	T80	4917	34.5
P664	456265	5120265	T81	3750	37.7
P673	453076	5119807	T76	1879	45.5
P674	452989	5119794	T76	1605	46.5
675	455159	5119498	T81	2200	42.8
676	456308	5118878	T81	2101	40.6

Receptor IDs with a “P” prefix indicate a participating receptor.

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