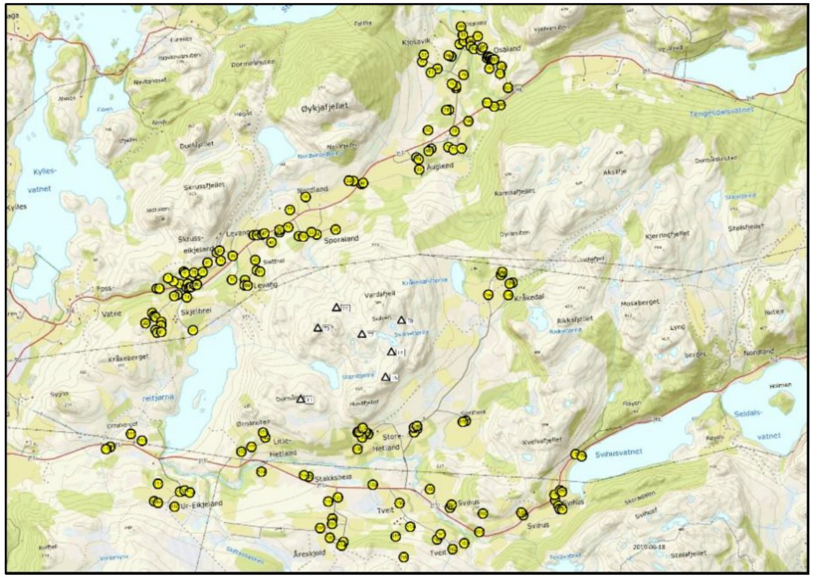
Calculation of noise immission from wind turbines

Wind farm Vardafjellet



Client information

Project: Wind farm Vardafjellet
Client: Nordisk Vindkraft Norge AS
Client reference: Gudmund S. Sydness

Project information

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Calculation conditions

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Wind Farm	WTG type	Number of WTG	Hub height [m]	Total height [m]	Noise emission [dBA]
Vardafjellet	Vestas V117 HWO	7	91,5	150	92,8-106,0

Calculation parameters	
Calculation program	SoundPLAN 7.4
Calculation standard	Nord2000
Search radius	20 000 m
Calculation height	4,0 m
Air absorbtion	ISO 9613-1
Air pressure	1013,25 mbar
Relative humidity	70%
Temperature	15 °C
Temperature gradient	+0,05 °C/m
Roughness length	0,3 m
Anemomenter height	10 m
Wind speed	8 m/s
Standard deviation wind speed	0,5 m/s
Wind direction	Downwind and wind statistics
Turbulence strength parameter wind	0,12 m4/3/s2
Turbulence strength parameter temperature	0,008 K/s2
Effective flow resistivity forrest	Impedance class D
Effective flow resistivity other	Impedance class E
Effective flow resistivity mountain	Impedance class F
Effective flow resistivity water	Impedance class H
Coordinate system	UTM WGS84 Zone: 32
Height data	5 m height contours

Calculation cases	
A01:	"Worst case støyberegninger" with downwind from all wind directions for 8 m/s at 10 m height with noise emission 106,0 dBA. WTG in operation 365 days a year (8760 hours).
A02:	"Støyutredning basert på lokale vindforhold" for 2,5-30,5 m/s at hub height measured wind speed and wind direction distribution in 30° sectors is used according to Table 2. Noise emission for each wind speed at hub height according to Table 1, 92,8-106,0 dBA. This represents a yearly average of L_{den} based on wind speeds on situ, "lokale vindforhold".

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Calculation conditions

Information on calculation parameters
As the weather conditions varies during a normal year, weather parameters according to standard noise calculation methods are used, which are also identical to the values given in the ISA-Standard (International Standard Atmosphere) for air pressure and temperature. The applied relative humidity 70 % and temperature 15 °C is also recommended in the new Finish guidelines for calculation of wind turbine noise with Nord2000 as well as in the Danish regulations on industrial noise. In the Nordic calculation method for external industrial noise report General Prediction Method, DAL-32, the relative humidity 70 % and temperature 15 °C is used for planning purposes. DAL-32 is an approved method for calculation of wind turbine noise according to chapter 9.8.1 in the Norwegian guidelines on wind turbine noise M-128/2014, Veileder til retningslinje for behandling av støy i arealplanlegging (T-1442/2016) (revised August 2018).

It shall be noted that the calculations are performed for a positive temperature gradient which is comparable to moderate inversion. The used value +0,05 °C/m is also the highest approved value according to the measurement method for noise immission from wind turbines Elforsk 98:24 as recommended for measurements in M-128/2014. The noise level at a positive temperature gradient is usually higher compared to a negative temperature gradient.

The effective flow resistivity in Nord2000 represent the ground impedance or hardness of the ground. In the guidelines for Nord2000 seven impedance classes are defined, impedance class A-H, where A represents the softest ground for example snow and H represents the hardest ground for example water. In the performed calculations areas with different impedance classes has been specified based on maps and satellite images as well as information from the client. The different areas are shown in page 8 in a ground absorption map. During the winter period, when the ground and trees are covered with snow, a lower noise immission could be expected. See for example the article Impact of snow on sound propagating from wind turbines (Conrady et al), which for example shows that the average noise level is 2 dB lower with snow covered trees.

The calculations are performed with the assumption that the noise sensitive areas (NSP) are located 4,0 m above ground. The height of 4,0 m should be considered decisive according to M-128/2014. Although it shall be noted that sound immission measurements according to the measurement standard Elforsk 98:24, recommended in chapter 9.8.5 in M-128/2014, should be performed at 1,2-1,5 m above ground. According to the European directive on environmental noise it is also possible to use calculations on 1,5 m above ground for recreational areas and areas with one-story housing as an additional indicator. The result on 1,5 m above ground should also be considered more representative to the exposure of noise outside of a dwelling.

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Method description

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The calculations are performed with the Nordic environmental noise prediction method Nord2000 which is an approved method for calculation of wind turbine noise according to chapter 9.8.1. in the guidelines M-128/2014. Nord2000 takes into account different aspects of noise spreading for example ground impedance, topography and wind direction. The calculations are performed both as "worst case støyberegninger" (Case A01) and "støyutredning basert på lokale vindforhold" (Case A02) in accordance with chapter 9.8.2-9.8.3 in M-128/2014.

The "worst case støyberegninger" assumes specific weather conditions with a conservative transmission loss, high noise emission and the wind turbines in operation 8760 hours a year (365 days). This is equal to the noise immission during a day with downwind conditions and wind speed 8 m/s at 10 m height. The Calculations according to "støyutredning basert på lokale vindforhold" are based on long term wind measurements and also considering the wind speed dependence of the noise emission, both high and low noise emission depending on the wind speed. Such calculations represent a more accurate value of a yearly average L_{den}. The level of Lden based on "lokale vindforhold" is, according to Akustikkonsultens experience, always lower than L_{den} for "worst case". This is also mentioned in chapter 9.8.3 in M-128/2014 were for example calculations considering different wind directions (Vindretning) is said to affect the calculation result with ±1-2 dB while different wind speed and noise emission (Vindhastighet og kildestøy) could affect the calculation result with up to 8 dB, both cases in comparison to "worst case støyberegninger" calculations.

Unfortunately, M-128/2014 do not present any detailed instructions on how to perform calculations assuming "lokale vindforhold". Akustikkonsulten suggests the method below to perform "støyutredning basert på lokale vindforhold" based on long term wind measurements:

1. Sort the wind speed data so it corresponds to the wind speed dependency of the noise emission. For example, the cut-in wind speed, when the blades start to rotate and emit noise, is normally around 3 m/s at hub height for modern wind turbines. Based on wind and noise data for the current project the wind turbines has been assumed to not emit noise for wind speeds below 1,5 m/s, approx. 5,6 % of the year, and the highest noise emission occurs for wind speeds above 9,5 m/s, approx. 36,6 % of the year. For wind speeds between 2,5-8,5 m/s the noise emission is assumed to vary between 92,8-105,1 dBA. The wind speed dependent noise emission is given in Table 1. A conservative approach has been chosen, for example all wind data above 9,5 m/s has been assumed to have the highest noise emission 106,0 dBA.

2. Divide the wind direction data in 30° sectors and calculate the percentual distribution for the wind speeds between 2,5 m/s to ≥9,5 m/s separately, similar to a wind rose, according to Table 2. The percentage for each wind direction is used for the calculations in step 4, were NSP:s in a dominant wind direction gets more noise during a year.

3. Calculate the noise immission for each wind direction in 30° sectors for wind speeds between 2,5 m/s to ≥9,5 m/s, a total of 84 calculations. The 12 results, for each wind speed, are then weighted using the wind direction distribution calculated in step 2.

4. The last step is to calculate the yearly average based on the result in step 2-3. The yearly average is weighted using the wind speed distribution between 0,5-30,5 m/s according to Table 2. The result is given in calculation Case A02.

The calculations in Case A02 are performed according to the method described above.

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Calculation uncertainty

The use of the prediction model Nord2000 on wind turbine noise has been evaluated and validated by a Danish research project PSO-07 F & U project no 7389. Noise and energy optimization of wind farms. Validation of the Nord2000 propagation model for use on wind turbine noise., Delta, rapport AV 1236/09 Hörsholm, Danmark 2009. In general, the conclusion is that the calculation results of Nord2000 show good agreement with sound measurements, for simple plain terrain with simple meteorological parameters as well as for complex hilly terrain with complex meteorological conditions. In comparison with ISO 9613-2, Nord2000 is an improvement, especially for the more complex situations.

Based on the above study it is believed that, with a confidence interval of 90 %, the calculated value is within the interval of (-5, +3 dB) from a measured value for complex norweigan terrain for distances up to 4 km from the wind farm. This confidence interval includes the uncertainty on the noise emission. It shall be noted that the uncertainty increases with the distance from the wind farm. This uncertainty is also expected to include a variation of the meteorological parameter's temperature, air pressure and humidity relative to the assumed values.

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Wind shadow

Wind shadow
The former guide lines for wind turbine noise in Norway, Veileder til Miljøverndepartementets retningslinje for behandling av støy i arealplanlegging (støyretningslinjen) (TA-2115/2005), had special recommendations for dwellings situated in wind shielded areas (wind shadow). The recommended noise limit for wind shielded areas was L_{den}=45 dBA and outside wind shielded areas the noise limit was set to L_{den}=50 dBA. But in the latest revision of the guidelines M-128/2014, dated August 2018, no special noise limits are given for these situations. The following recommendation is mentioned about wind shadow:

"Hvis en vindturbin er plassert høyt i terrenget og støymottaker ligger i le i dalformasjoner, kan maskeringen fra vindsuset reduseres vesentlig fordi mottaker er skjermet for vinden. Mottakeren ligger da i vindskygge, og vil høre støy fra vindturbinene bedre. Det finnes ikke spesielle støykrav ved vindskygge, men spesielt i detaljprosjekteringsfasen bør utreder være oppmerksom på støyfølsom bebyggelse som ligger i vindskygge. I slike tilfeller kanstøy fra vindturbiner ofte høres best ved vindstyrker i 10 –12 m/s. Dette bør da legges til grunn for støyberegninger. "

Although it can here be noted that in the new guidelines M-128/2014 the old noise limit for wind shielded areas, L_{den}=45 dBA, is used for all areas. This could assume that the updated noise limit considers areas with wind shadows.

All noise calculations and reports produced by Akustikkonsulten undergoes a quality assurance check in accordance with Akustikkonsultens quality system. It could be noted that Akustikkonsulten is one of few noise consultants in the Nordic region that are accredited (by SWEDAC and in compliance with ILAC, International Laboratory Accreditation Cooperation) according to ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories as well as for the measurement standard for noise emission from wind turbines IEC 61400-11. Akustikkonsultens consultants have more than 10 years of experience from noise calculations of wind turbine noise and have performed calculations for more than 500 wind farms over the years.

The performed "worst case støyberegninger" calculations are to be considered as conservative compared to the calcualtions based on "lokale vindforhold". In addition, the highest noise emission for wind speeds between 3 m/s-20 m/s is assumed in the "worst case støyberegninger" calculations, as recommended in M-128/2014 when there could be a risk for wind shadow. This noise emission also corresponds to the warranted noise emission according to the wind turbine manufacturer.

The calculations for **Case A01** has also been verified against the method in M-128/2014, chapter 11.5 Metode for å beregne støy fra vindturbiner. This method is a linear calculation method and can only calculate the "worst case støyberegninger" downwind case. The result for values above L_{den}=40 dBA are in average 0,5 dBA higher calculated with Nord2000, which shows that an conservative approach has been used for the settings in Nord2000.

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Noise data

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Table 1

WTG type	Noise setting[3)]	Wind speed at hub height [m/s][1)]	Noise emission [dBA]
Vestas V117 HWO	PO1/PO2	3	92,2[2)]
	PO1/PO2	4 (2,5-3,5)	92,8
	PO1/PO2	5 (4,5)	94,0
	PO1/PO2	6 (5,5)	97,0
	PO1/PO2	7 (6,5)	100,0
	PO1/PO2	8 (7,5)	102,8
	PO1/PO2	9 (8,5)	105,1
	PO1/PO2	≥10 (≥9,5)	106,0

Reference noise data: Frequency spectrum at hub height in 1/3-octave bands between 31,5-10 000 Hz has been taken from the WTG manufacturer document *DMS 0081-4480_00* dated 2018-12-17 and *DMS 0067-7587 V02* dated 2017-12-03, supplied by the client. As the documents are restricted the frequency data cannot be shown. According to the client the noise emission corresponds to the warranted noise emission for the WTG type.

For Case A01 the noise emission 106,0 dBA is used which corresponds to the value for 11 m/s at hub height or 8 m/s on 10 m height, assuming reference conditions with a roughness length of 0,05 m. This is the highest noise emission for any wind speed according to the document.

For Case A02 the noise emission corresponding to the wind speed/s within the parenthesis is used. For example, 106,0 dBA is used for all measured wind speeds above 9,5 m/s and 102,8 dBA for the wind speed 7,5 m/s.

1)The value within the parenthesis is the measured wind speed ranges according to Table 2. The other wind speed is according to the WTG manufacturer document.
2)Just for information, not used in calculation.
2)Both noise setting PO1 and PO2 have the same noise emission for all wind speeds according to the WTG manufacturer document.

Disclaimer: The calculations are valid for the used noise emission and frequency spectrum. Akustikkonsulten gives no guaranty on the actual noise emission level nor frequency spectrum.

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Wind data

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Table 2

Wind speed at hh [m/s]	Totalt 8766 hours [%]	0° [%]	30° [%]	60° [%]	90° [%]	120° [%]
0,5-1,5	5,6	0,3	0,2	0,1	0,4	0,9
2,5-3,5	13,4	1,6	1,1	0,4	0,8	1,2
4,5	9,4	1,3	0,8	0,3	0,5	0,8
5,5	9,4	1,1	0,5	0,2	0,6	1,0
6,5	9,0	0,9	0,3	0,1	0,5	1,1
7,5	8,5	0,6	0,2	0,1	0,5	1,1
8,5	8,0	0,5	0,1	0,1	0,4	1,1
9,5-30,5	36,6	1,0	0,2	0,1	1,6	8,5
All wind speeds	**100,0**	**7,3**	**3,4**	**1,3**	**5,2**	**15,6**
Wind speed at hh [m/s]	**150° [%]**	**180° [%]**	**210° [%]**	**240° [%]**	**270° [%]**	**300° [%]**
0,5-1,5	0,5	0,5	0,4	0,4	0,5	0,6
2,5-3,5	1,0	1,0	0,8	0,9	1,2	1,4
4,5	0,7	0,7	0,5	0,5	0,7	0,9
5,5	0,8	0,8	0,5	0,5	0,7	0,9
6,5	1,0	1,0	0,5	0,5	0,6	0,8
7,5	1,2	1,1	0,6	0,5	0,6	0,8
8,5	1,2	1,1	0,6	0,5	0,5	0,7
9,5-30,5	8,3	4,7	2,1	1,6	1,9	2,3
All wind speeds	**14,8**	**10,9**	**5,9**	**5,3**	**6,7**	**8,4**
Wind speed at hh [m/s]	**330° [%]**					
0,5-1,5	0,8					
2,5-3,5	2,2					
4,5	1,7					
5,5	1,8					
6,5	1,6					
7,5	1,5					
8,5	1,3					
9,5-30,5	4,3					
All wind speeds	**15,2**					

Wind distribution used in calcualtion
A02**:** Both wind speed and wind direction distribution is used for wind speed 0,5-30,5 m/s, green values. This case represents an accurate yearly average of L_{den}.

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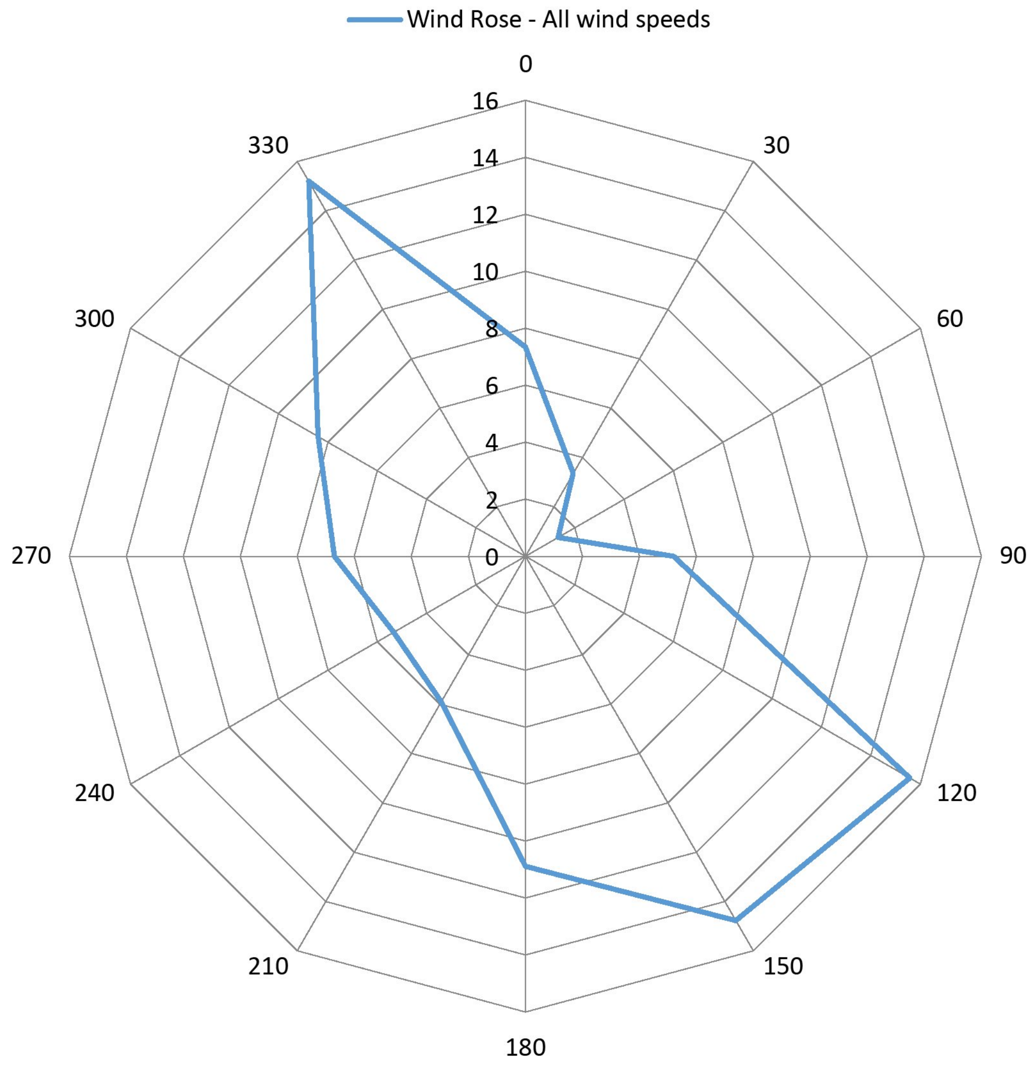
Wind data



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WTG data

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Wind Farm Vardafjellet							
WTG	**X [m]**	**Y [m]**	**Hub height [m]**	**Hub height level [mas]**	**Ground level [mas]**	**Noise emission [dBA]**	**Noise setting**
T1	320377	6525309	91,5	360	268	92,8-106,0	PO2
T3	320572	6526115	91,5	387	295	92,8-106,0	PO2
T5	321340	6525559	91,5	412	321	92,8-106,0	PO2
T6	320783	6526348	91,5	392	300	92,8-106,0	PO2
T7	321074	6526045	91,5	405	314	92,8-106,0	PO1
T8	321406	6525846	91,5	419	327	92,8-106,0	PO2
T9	321520	6526202	91,5	430	338	92,8-106,0	PO2

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Ground absorption map

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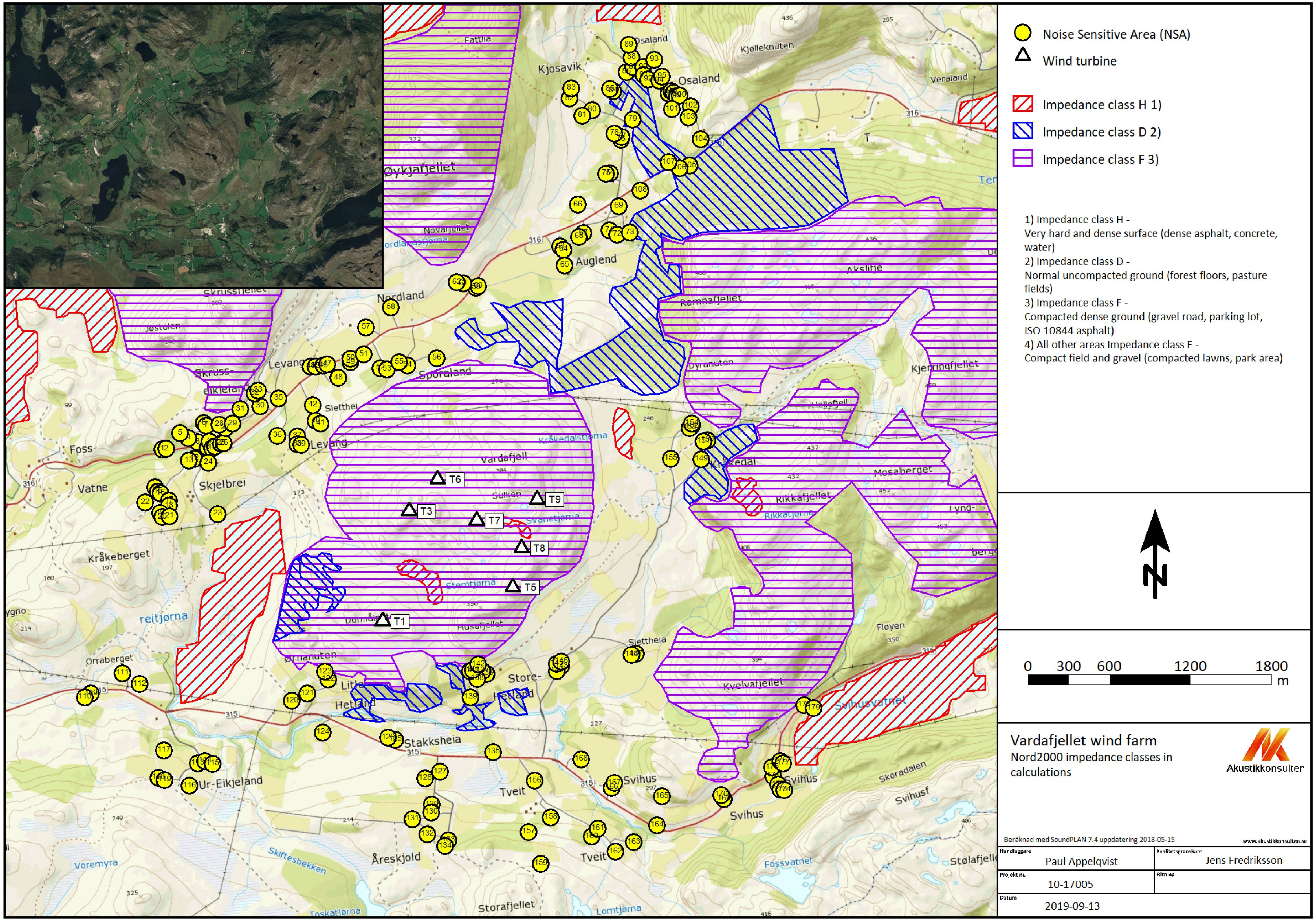

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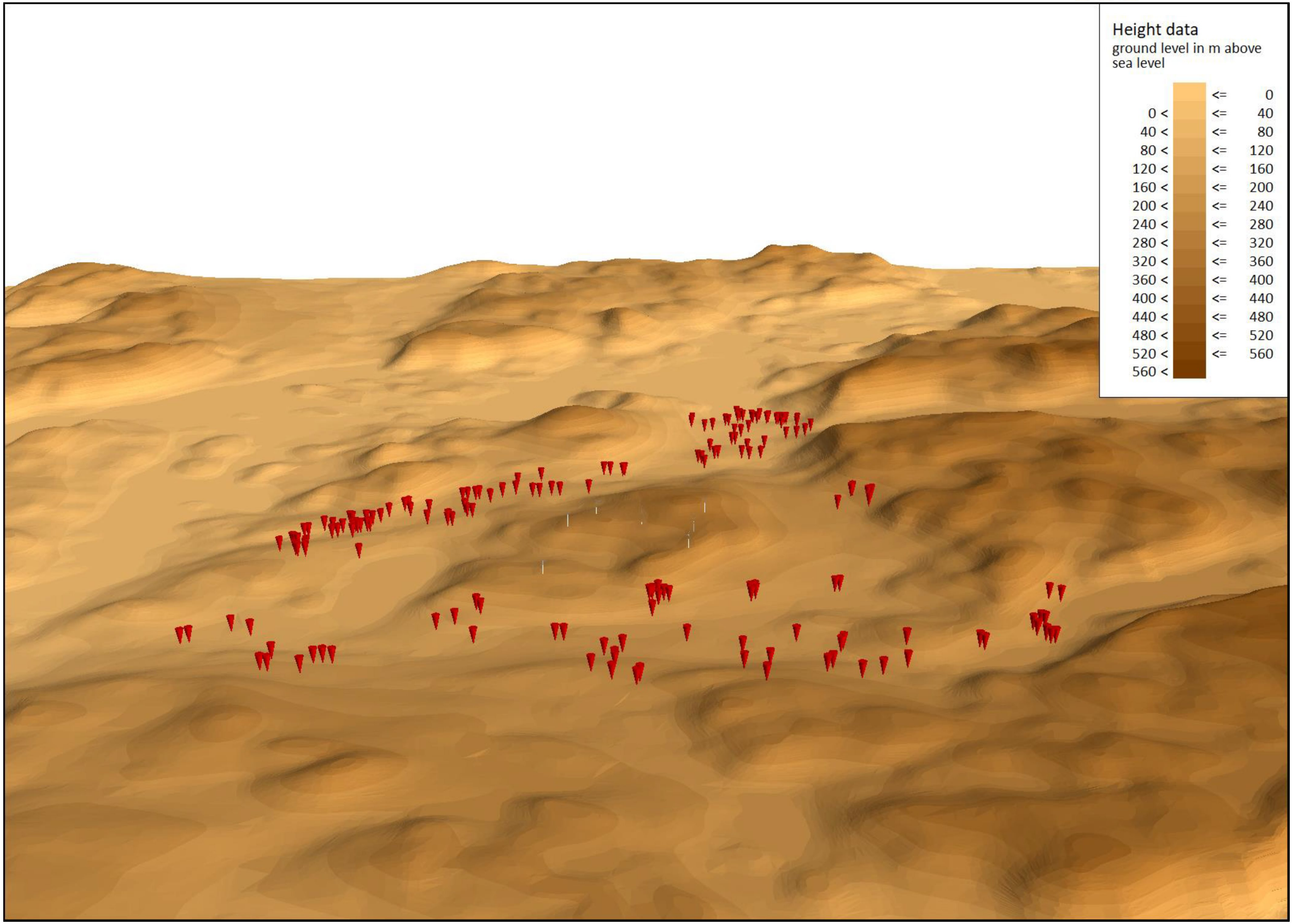
Ground model



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Point calculations

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					L_{den} [dBA]		Horizontal distance NSP-WTG [m][1)]						
NSP	X [m]	Y [m]	Z,ground [mas]	Calculation height [m]	A01	A02	T1	T3	T5	T6	T7	T8	T9
1	318747	6526569	108	4,0 m	40	36	2060	1881	2783	2048	2385	2756	2797
2	318775	6526571	109	4,0 m	40	37	2039	1854	2757	2020	2358	2729	2770
3	319010	6526620	115	4,0 m	41	38	1894	1642	2560	1794	2143	2518	2545
4	318939	6526652	115	4,0 m	41	38	1968	1719	2638	1869	2220	2595	2620
5	318877	6526686	115	4,0 m	40	37	2036	1789	2709	1936	2289	2665	2687
6	319053	6526760	125	4,0 m	41	38	1964	1650	2583	1778	2144	2524	2529
7	319070	6526741	124	4,0 m	42	38	1939	1627	2559	1758	2121	2502	2509
8	319085	6526582	122	4,0 m	41	38	1814	1559	2476	1714	2060	2435	2464
9	319097	6526625	121	4,0 m	41	38	1836	1561	2483	1709	2060	2437	2460
10	319115	6526579	125	4,0 m	41	39	1790	1529	2448	1684	2030	2405	2434
11	319136	6526589	124	4,0 m	41	38	1783	1512	2433	1665	2013	2389	2415
12	318983	6526500	126	4,0 m	41	38	1833	1635	2538	1806	2140	2510	2554
13	318945	6526486	126	4,0 m	41	38	1854	1669	2568	1843	2174	2543	2591
14	318695	6526290	148	4,0 m	40	37	1947	1885	2744	2089	2392	2747	2826
15	318715	6526258	151	4,0 m	41	37	1914	1862	2716	2070	2369	2722	2806
16	318734	6526247	151	4,0 m	41	37	1892	1843	2695	2051	2349	2702	2786
17	318798	6526194	151	4,0 m	41	38	1810	1776	2620	1991	2281	2631	2722
18	318795	6526154	151	4,0 m	42	38	1794	1777	2614	1997	2282	2629	2725
19	318733	6526101	154	4,0 m	41	38	1825	1839	2663	2065	2342	2685	2789
20	318749	6526073	153	4,0 m	41	39	1798	1823	2641	2053	2325	2667	2774
21	318800	6526079	150	4,0 m	42	39	1755	1772	2593	2001	2274	2616	2723
22	318619	6526178	156	4,0 m	41	38	1961	1954	2791	2171	2459	2807	2901
23	319156	6526096	118	4,0 m	43	40	1453	1416	2249	1646	1919	2264	2366
24	319087	6526471	134	4,0 m	42	39	1736	1527	2431	1700	2032	2402	2448
25	319181	6526611	125	4,0 m	42	39	1768	1477	2402	1623	1976	2353	2374
26	319200	6526612	125	4,0 m	42	39	1756	1459	2385	1605	1958	2335	2356
27	319213	6526726	131	4,0 m	43	39	1834	1490	2426	1615	1982	2363	2366
28	319168	6526749	131	4,0 m	42	39	1880	1541	2477	1664	2032	2413	2415
29	319268	6526756	135	4,0 m	43	40	1823	1453	2393	1569	1941	2324	2319

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Point calculations

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					L_{den} [dBA]		Horizontal distance NSP-WTG [m] 1)						
NSP	X [m]	Y [m]	Z,ground [mas]	Calculation height [m]	A01	A02	T1	T3	T5	T6	T7	T8	T9
30	319474	6526884	133	4,0 m	43	40	1815	1341	2289	1414	1807	2193	2157
31	319323	6526863	139	4,0 m	42	39	1878	1456	2402	1548	1933	2318	2294
32	319430	6526978	140	4,0 m	42	39	1919	1431	2379	1492	1890	2277	2229
33	319457	6527000	139	4,0 m	43	40	1925	1424	2371	1478	1878	2265	2212
35	319606	6526941	130	4,0 m	43	40	1805	1271	2217	1318	1720	2107	2052
36	319600	6526668	145	4,0 m	44	41	1565	1118	2063	1226	1600	1984	1976
37	319748	6526664	150	4,0 m	45	42	1494	990	1938	1082	1463	1849	1831
38	319745	6526607	150	4,0 m	45	42	1444	962	1908	1070	1443	1827	1821
39	319777	6526603	150	4,0 m	46	42	1426	933	1880	1038	1412	1796	1789
40	319881	6526776	153	4,0 m	46	43	1549	956	1900	998	1399	1786	1737
41	319918	6526759	154	4,0 m	46	44	1521	918	1861	958	1359	1746	1696
42	319863	6526893	146	4,0 m	46	43	1665	1053	1990	1069	1478	1865	1795
43	319845	6527175	136	4,0 m	44	41	1940	1285	2201	1251	1670	2050	1937
44	319845	6527175	136	4,0 m	44	41	1940	1285	2201	1251	1670	2050	1937
45	319882	6527175	138	4,0 m	45	41	1931	1265	2177	1223	1642	2022	1905
46	319941	6527181	141	4,0 m	45	41	1922	1239	2142	1184	1604	1982	1858
47	319967	6527192	142	4,0 m	45	42	1927	1235	2133	1174	1594	1970	1842
48	320048	6527092	148	4,0 m	45	42	1813	1109	2005	1046	1466	1843	1720
49	320138	6527206	149	4,0 m	45	42	1912	1174	2039	1073	1491	1859	1708
50	320138	6527234	148	4,0 m	45	42	1940	1200	2062	1096	1513	1880	1725
51	320238	6527263	149	4,0 m	46	42	1959	1196	2029	1065	1477	1836	1664
52	320359	6527162	161	4,0 m	46	43	1853	1068	1879	918	1326	1682	1506
53	320410	6527154	161	4,0 m	48	44	1845	1052	1846	888	1293	1644	1462
54	320562	6527183	155	4,0 m	46	43	1883	1068	1801	864	1248	1581	1371
55	320501	6527207	155	4,0 m	47	44	1902	1094	1849	904	1296	1634	1431
56	320778	6527236	149	4,0 m	46	42	1968	1140	1769	888	1227	1525	1273
57	320256	6527461	145	4,0 m	45	42	2155	1383	2189	1231	1635	1983	1784
58	320437	6527607	135	4,0 m	44	41	2299	1498	2238	1306	1687	2010	1774
59	321071	6527753	110	4,0 m	41	38	2541	1712	2210	1434	1708	1936	1615

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Point calculations

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					L_{den} [dBA]		Horizontal distance NSP-WTG [m][1)]						
NSP	X [m]	Y [m]	Z,ground [mas]	Calculation height [m]	A01	A02	T1	T3	T5	T6	T7	T8	T9
60	321086	6527763	109	4,0 m	41	37	2554	1726	2219	1447	1718	1944	1620
61	320976	6527784	110	4,0 m	41	38	2546	1717	2255	1449	1742	1985	1673
62	320927	6527791	110	4,0 m	41	38	2542	1713	2270	1450	1752	2003	1696
63	321691	6528053	105	4,0 m	39	35	3042	2238	2519	1932	2101	2225	1859
64	321716	6528030	105	4,0 m	39	35	3033	2231	2499	1923	2086	2206	1838
65	321726	6527917	101	4,0 m	39	35	2936	2140	2389	1831	1982	2096	1727
66	321823	6528360	97	4,0 m	38	34	3376	2570	2842	2265	2433	2548	2179
67	321862	6528152	108	4,0 m	38	34	3207	2411	2645	2102	2250	2351	1980
68	321831	6528126	109	4,0 m	38	35	3170	2373	2614	2064	2214	2319	1949
69	322125	6528351	95	4,0 m	36	33	3508	2722	2900	2411	2534	2606	2233
71	322056	6528172	96	4,0 m	37	34	3319	2536	2709	2224	2343	2415	2042
72	322112	6528142	93	4,0 m	37	33	3322	2546	2696	2233	2340	2402	2028
73	322206	6528156	92	4,0 m	37	33	3384	2615	2738	2301	2395	2445	2071
74	322061	6528593	80	4,0 m	36	33	3691	2891	3118	2583	2732	2824	2451
75	322031	6528588	80	4,0 m	36	33	3673	2871	3107	2564	2717	2812	2440
76	322142	6528837	68	4,0 m	35	32	3945	3142	3375	2836	2989	3080	2707
77	322144	6528859	67	4,0 m	35	32	3965	3162	3397	2856	3011	3102	2729
78	322094	6528883	66	4,0 m	35	32	3965	3159	3408	2854	3016	3114	2742
79	322227	6528986	63	4,0 m	34	31	4116	3314	3540	3007	3159	3246	2872
80	321930	6529055	67	4,0 m	34	31	4055	3238	3545	2940	3129	3252	2882
81	321857	6529013	69	4,0 m	35	31	3989	3170	3492	2873	3070	3199	2831
82	321759	6529138	75	4,0 m	35	32	4071	3248	3603	2956	3168	3311	2946
83	321775	6529214	74	4,0 m	34	31	4148	3324	3681	3033	3246	3388	3023
84	322086	6529194	60	4,0 m	34	31	4244	3431	3711	3130	3308	3416	3045
85	322060	6529208	60	4,0 m	34	31	4247	3432	3719	3132	3313	3425	3054
86	322183	6529334	47	4,0 m	33	30	4412	3600	3868	3298	3471	3573	3201
87	322232	6529368	44	4,0 m	33	30	4463	3652	3912	3350	3519	3618	3245
88	322219	6529439	37	4,0 m	32	29	4522	3710	3978	3408	3582	3684	3312
89	322199	6529532	32	4,0 m	32	29	4599	3785	4065	3485	3664	3770	3399

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Point calculations

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					L_{den} [dBA]		Horizontal distance NSP-WTG [m][1)]						
NSP	X [m]	Y [m]	Z,ground [mas]	Calculation height [m]	A01	A02	T1	T3	T5	T6	T7	T8	T9
90	322307	6529368	44	4,0 m	33	29	4494	3687	3930	3383	3544	3635	3262
91	322311	6529311	49	4,0 m	33	30	4445	3638	3876	3334	3492	3581	3208
92	322343	6529280	52	4,0 m	33	30	4431	3627	3854	3321	3475	3560	3186
93	322387	6529424	39	4,0 m	33	29	4580	3774	4004	3469	3625	3710	3337
94	322425	6529269	54	4,0 m	33	29	4458	3658	3865	3351	3496	3571	3198
95	322443	6529299	51	4,0 m	33	29	4493	3693	3899	3386	3530	3605	3232
96	322495	6529178	67	4,0 m	34	31	4411	3617	3799	3308	3440	3505	3132
97	322514	6529193	68	4,0 m	34	30	4433	3639	3819	3330	3462	3526	3152
98	322532	6529182	70	4,0 m	34	31	4432	3640	3814	3330	3459	3521	3147
99	322557	6529158	73	4,0 m	34	31	4423	3633	3799	3323	3448	3506	3133
100	322576	6529162	75	4,0 m	34	31	4436	3647	3809	3337	3460	3516	3143
101	322519	6529061	67	4,0 m	34	31	4320	3531	3695	3221	3344	3402	3029
102	322658	6529082	87	4,0 m	34	31	4409	3627	3761	3315	3425	3470	3097
103	322641	6529001	85	4,0 m	34	31	4331	3551	3680	3239	3346	3388	3015
104	322731	6528839	106	4,0 m	35	32	4243	3476	3563	3162	3248	3273	2902
105	322649	6528647	122	4,0 m	36	32	4038	3275	3354	2961	3042	3064	2693
106	322575	6528629	108	4,0 m	35	32	3982	3214	3309	2901	2988	3019	2646
107	322495	6528672	91	4,0 m	35	32	3974	3199	3320	2887	2987	3029	2655
108	322283	6528464	82	4,0 m	35	32	3686	2906	3054	2594	2704	2761	2387
109	318221	6524778	103	4,0 m	38	35	2220	2705	3215	3005	3122	3359	3593
110	318173	6524753	104	4,0 m	37	34	2273	2759	3268	3059	3176	3413	3647
111	318453	6524927	103	4,0 m	39	36	1962	2429	2955	2729	2849	3093	3321
112	318579	6524848	105	4,0 m	39	36	1856	2362	2851	2666	2767	2998	3238
113	319011	6524268	160	4,0 m	40	37	1717	2418	2663	2732	2723	2868	3168
114	319063	6524285	157	4,0 m	40	37	1666	2372	2609	2686	2672	2815	3116
115	319120	6524264	159	4,0 m	40	37	1635	2353	2570	2666	2644	2780	3085
116	318950	6524103	179	4,0 m	40	37	1868	2584	2799	2898	2878	3012	3318
117	318761	6524362	157	4,0 m	39	36	1873	2520	2843	2834	2860	3033	3316
118	318718	6524163	177	4,0 m	39	35	2016	2692	2970	3006	3015	3171	3465

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Point calculations

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					L_{den} [dBA]		Horizontal distance NSP-WTG [m] [1)]						
NSP	X [m]	Y [m]	Z,ground [mas]	Calculation height [m]	A01	A02	T1	T3	T5	T6	T7	T8	T9
119	318762	6524145	178	4,0 m	39	36	1991	2675	2940	2990	2993	3144	3441
120	319707	6524725	151	4,0 m	44	40	889	1637	1834	1947	1900	2035	2338
121	319820	6524779	158	4,0 m	45	41	769	1533	1708	1841	1782	1912	2217
122	319977	6524884	178	4,0 m	47	45	584	1367	1521	1671	1597	1723	2029
123	319951	6524939	185	4,0 m	47	44	564	1330	1521	1636	1576	1715	2014
124	319933	6524495	155	4,0 m	45	42	927	1741	1764	2039	1925	1999	2331
125	320470	6524440	176	4,0 m	45	42	874	1678	1417	1934	1715	1689	2051
126	320419	6524455	173	4,0 m	45	42	855	1667	1438	1928	1720	1706	2065
127	320803	6524206	192	4,0 m	44	41	1182	1923	1456	2142	1859	1747	2121
128	320692	6524158	196	4,0 m	44	41	1193	1961	1544	2192	1925	1833	2205
129	320740	6523964	223	4,0 m	42	39	1393	2158	1704	2384	2108	1996	2370
130	320737	6523908	226	4,0 m	42	39	1447	2213	1758	2440	2163	2050	2424
131	320599	6523860	230	4,0 m	42	39	1466	2255	1854	2495	2236	2144	2517
132	320709	6523750	228	4,0 m	40	36	1594	2369	1916	2599	2324	2209	2583
133	320863	6523703	232	4,0 m	42	38	1678	2429	1916	2646	2351	2211	2584
134	320841	6523661	231	4,0 m	41	38	1712	2469	1962	2688	2395	2257	2630
135	321197	6524351	181	4,0 m	45	42	1261	1871	1216	2039	1698	1510	1879
136	321147	6524925	205	4,0 m	48	45	860	1322	663	1469	1122	957	1330
137	321117	6524944	207	4,0 m	48	45	825	1292	654	1443	1102	947	1321
138	321078	6524886	199	4,0 m	48	44	819	1329	722	1491	1159	1014	1388
139	321027	6524753	181	4,0 m	47	43	855	1436	865	1614	1293	1157	1531
140	321026	6524944	210	4,0 m	48	44	745	1256	691	1425	1102	979	1352
141	321044	6524950	210	4,0 m	48	44	757	1257	677	1422	1095	966	1339
142	321084	6524991	217	4,0 m	47	43	775	1235	623	1390	1054	914	1287
143	321700	6524979	184	4,0 m	48	44	1364	1601	683	1648	1236	915	1236
144	321668	6524944	182	4,0 m	48	44	1342	1604	697	1660	1251	939	1267
145	321668	6524998	187	4,0 m	48	45	1328	1565	650	1614	1204	888	1213
146	321701	6525013	187	4,0 m	48	45	1357	1578	655	1620	1208	884	1203
147	322253	6525070	179	4,0 m	45	42	1891	1979	1036	1948	1530	1149	1349

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Point calculations

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					L_{den} [dBA]		Horizontal distance NSP-WTG [m][1)]						
NSP	X [m]	Y [m]	Z,ground [mas]	Calculation height [m]	A01	A02	T1	T3	T5	T6	T7	T8	T9
148	322221	6525062	178	4,0 m	46	43	1860	1957	1012	1929	1511	1131	1338
149	322735	6526495	245	4,0 m	45	41	2639	2196	1680	1958	1721	1479	1250
150	322782	6526635	255	4,0 m	44	41	2746	2270	1799	2019	1807	1586	1334
151	322752	6526626	251	4,0 m	44	41	2716	2239	1770	1989	1776	1556	1303
152	322664	6526739	243	4,0 m	43	40	2697	2183	1774	1921	1735	1543	1264
153	322651	6526725	242	4,0 m	43	40	2679	2167	1755	1906	1717	1524	1246
154	322667	6526758	243	4,0 m	42	40	2710	2191	1788	1928	1745	1556	1275
155	322510	6526499	226	4,0 m	45	42	2442	1976	1501	1734	1506	1283	1034
156	321501	6524140	185	4,0 m	43	40	1622	2183	1428	2322	1952	1709	2062
157	321457	6523765	257	4,0 m	41	38	1884	2511	1798	2669	2312	2082	2438
158	321622	6523873	223	4,0 m	42	39	1901	2476	1709	2613	2240	1985	2331
159	321549	6523531	287	4,0 m	40	37	2130	2763	2039	2919	2558	2319	2671
160	321925	6523730	238	4,0 m	41	38	2211	2742	1920	2856	2466	2179	2505
161	321968	6523790	228	4,0 m	41	38	2200	2712	1877	2819	2426	2131	2453
162	322102	6523620	239	4,0 m	40	37	2414	2927	2083	3030	2634	2332	2647
163	322236	6523689	224	4,0 m	40	37	2466	2942	2074	3030	2627	2311	2613
164	322406	6523815	205	4,0 m	39	35	2520	2942	2044	3008	2598	2264	2546
165	322445	6524026	251	4,0 m	39	36	2434	2806	1890	2856	2440	2096	2364
166	322073	6524090	194	4,0 m	41	38	2089	2521	1642	2601	2195	1878	2183
167	322093	6524123	198	4,0 m	42	39	2086	2506	1621	2582	2175	1855	2157
168	321845	6524298	179	4,0 m	43	40	1782	2219	1358	2309	1910	1609	1932
169	322905	6524006	212	4,0 m	36	29	2844	3145	2205	3160	2740	2373	2596
170	322884	6524036	216	4,0 m	37	29	2812	3109	2169	3124	2704	2337	2560
171	323267	6524174	217	4,0 m	36	29	3105	3321	2373	3301	2883	2502	2677
172	323303	6524112	209	4,0 m	36	30	3161	3387	2439	3369	2950	2570	2747
173	323320	6524074	207	4,0 m	36	30	3192	3423	2475	3407	2988	2608	2787
174	323348	6524073	208	4,0 m	36	30	3218	3446	2498	3429	3010	2630	2806
175	323261	6524238	225	4,0 m	36	29	3076	3279	2331	3255	2837	2455	2625
176	323322	6524286	225	4,0 m	36	29	3118	3303	2356	3271	2854	2471	2630

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Point calculations

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					L_{den} [dBA]		Horizontal distance NSP-WTG [m][1)]						
NSP	**X [m]**	**Y [m]**	**Z,ground [mas]**	**Calculation height [m]**	**A01**	**A02**	**T1**	**T3**	**T5**	**T6**	**T7**	**T8**	**T9**
177	323343	6524270	222	4,0 m	36	29	3143	3329	**2382**	3297	2881	2497	2656
178	323497	6524694	233	4,0 m	27	18	3180	3252	**2324**	3178	2774	2387	2486
179	323567	6524673	221	4,0 m	28	19	3253	3324	**2397**	3249	2846	2459	2555

[1)]The distance corresponds to the horizontal distance in m between the NSP and the WTG. The WTG with the shortest distance to each NSP are marked with blue color. Note that in previous calculations from 2017 the values represented the distance between WTG hub height and the NSP calculation height.

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Information on results

The calculations are performed with the assumption that the noise sensitive points (NSP) are located 4,0 m above ground. The height of 4,0 m should be considered decisive according to M-128/2014. According to the European directive on environmental noise it is also possible to use calculations on 1,5 m above ground for recreational areas and areas with one-storey housing as an additional indicator. For indexing of NSP:s see the noise maps.

Note that if the point calculation and noise map show contradictory results, it is primary the point calculation that should be used. The noise map should be considered as a compliment to the point calculation.

The calculation result is rounded to the nearest integer value according to the guidelines M-128/2014, chapter 2.5.4:

"Når det skal rundes av til nærmeste hele tall ser vi på første siffer rett etter kommaet.
-er sifferet 0, 1, 2, 3 eller 4 tar vi vekk alle desimalsifrene og beholder det hele tallet slik som det var
-er sifferet 5, 6, 7, 8 eller 9 tar vi vekk alle desimalsifrene og øker det hele tallet med 1

Eksempel; 54,499 = 54
54,511 = 55"

L_{den} has been calculated with a penalty of 5 dB for L_e (evening 19-23) and 10 dB for L_n (night 23-07) which is resulting in an addition of 6,4 dBA to the calculated equivalent sound level. The noise limit has been assumed to be L_{den}=45 dBA according to Retningslinje for behandling av støy i arealplanlegging (T-1442/2016) and if the calculated value is above the limit 45 dBA it is marked with red.

The calculations for Case A01 have also been verified against the method in M-128/2014, chapter 11.5 Metode for å beregne støy fra vindturbiner. This method is a linear calculation method and can only calculate the "worst case støyberegninger" downwind case. The result for values above L_{den}=40 dBA is in average 0,5 dBA higher calculated with Nord2000, which shows that an conservative approach has been used for the settings in Nord2000. Below is a point list of some conservative assumptions that has been assumed in the calculations:

1. For Case A02 the noise emission for the upper wind speed is used due to the measured wind speed being offset by 0,5 m/s. Example, the noise emission for 6 m/s is used for the measured wind speed 5,5 m/s. For this case the highest noise emission 106,0 dBA is also used for all wind speeds above 9,5 m/s at hub height.
2. If there is a doubt of the ground impedance, i.e. hardness of the ground, the higher impedance class has been used. Example, impedance class F is used for the whole area below the wind farm area although some areas are probably softer according to the satellite images.
3. For Case A01 downwind from all wind directions at the same time has been assumed, i.e. downwind from all WTG to each NSP is assumed. That probably overestimates the noise level in NSP:s surrounded by WTG for example the cluster of NSP:s (142...) located at Store-Hetland.
4. For Case A02 the stand still time of the wind farm is only assumed for wind speeds of 1,5 m/s and below corresponding to approximately 21 days, which probably underestimates the real stand still time during a year.

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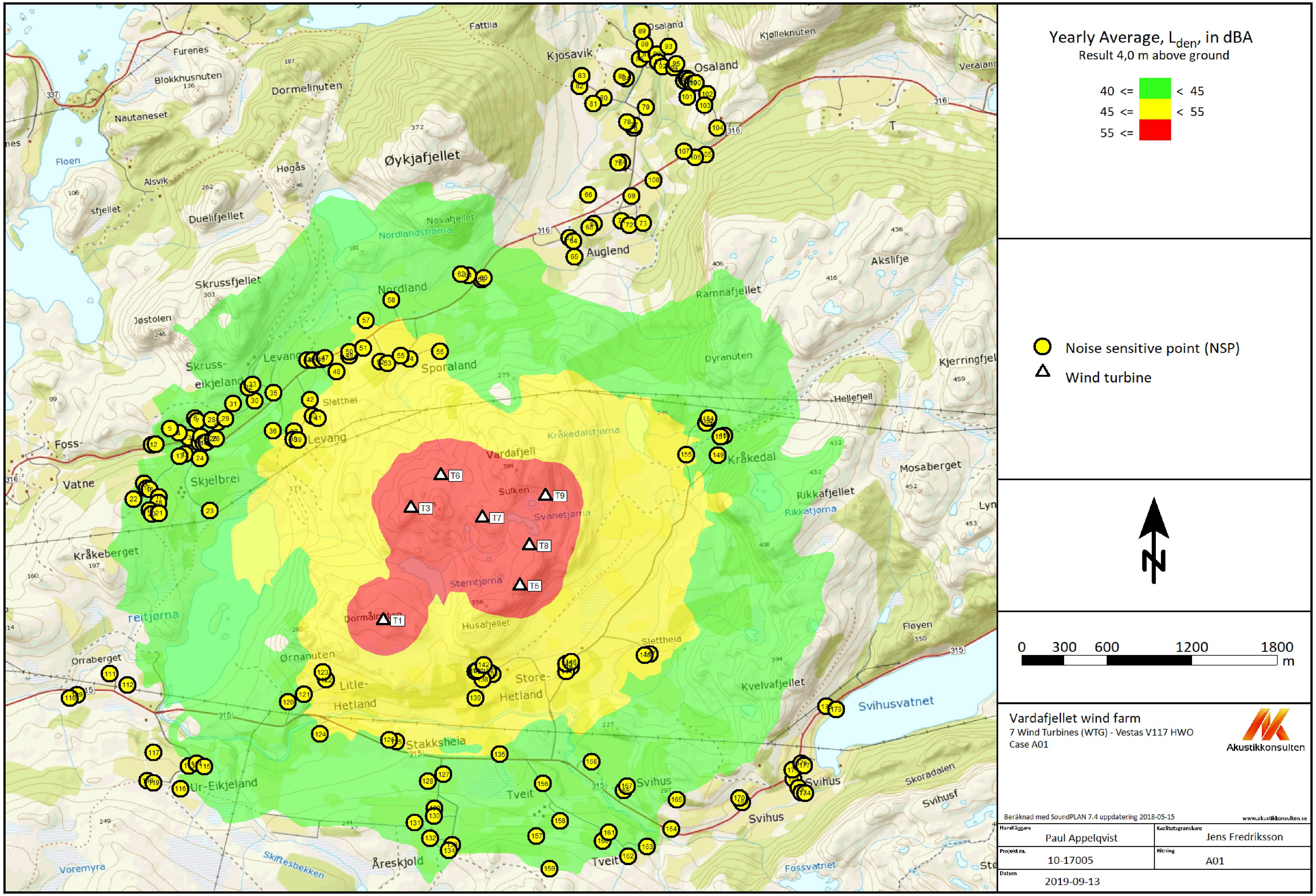
Noise map - Case A01



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Noise map - Case A02

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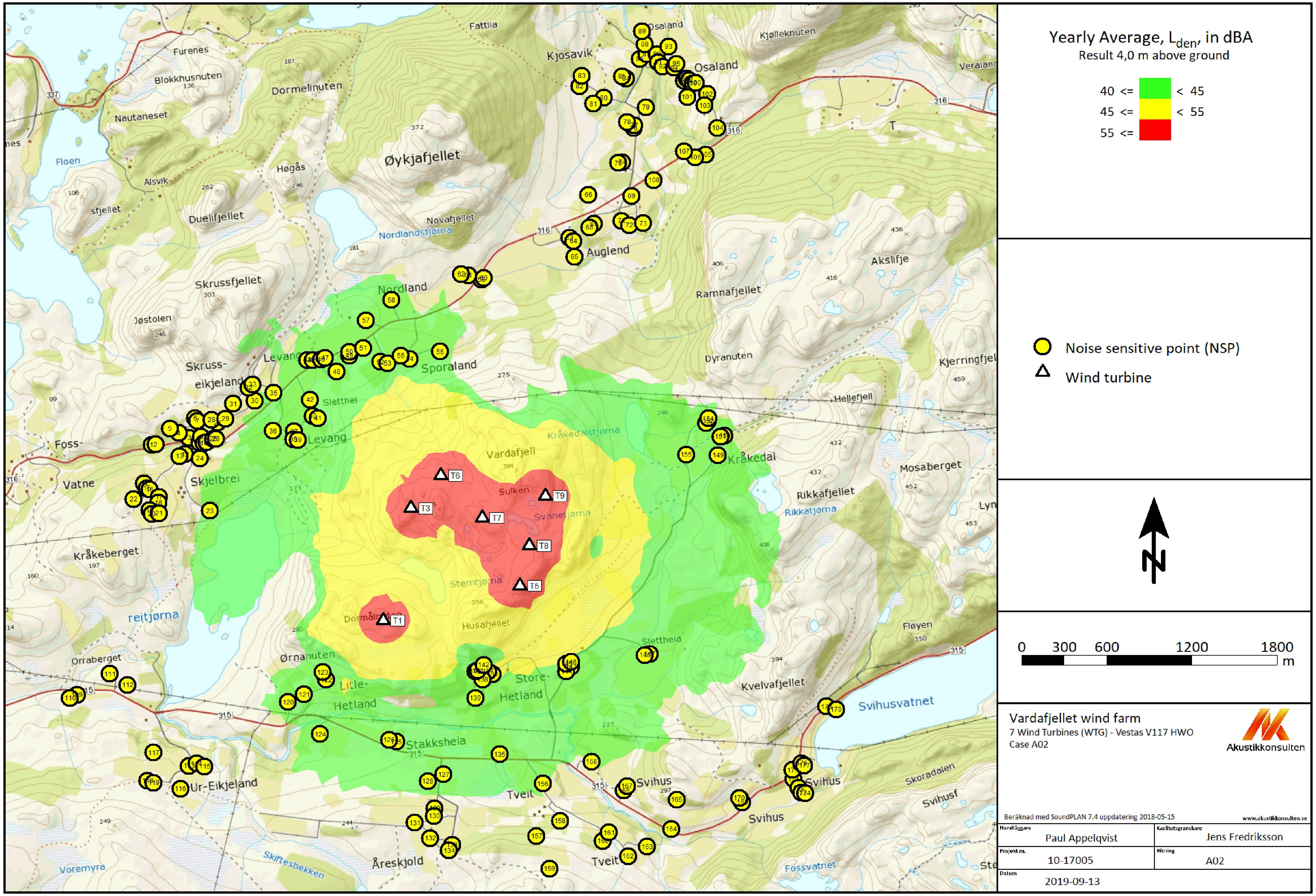

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