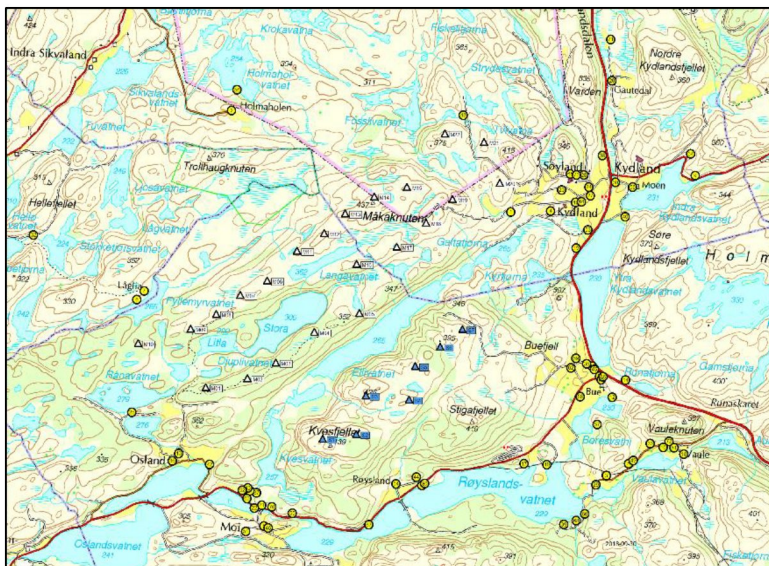


Calculation of noise immission from wind turbines

Case I01-I04 - Wind Farm Måkaknuten



Client Information

Client: Norsk Vind Energi AS

Reference: John Amund Lund

Project Information

Project: Wind Farm Måkaknuten

Project nr: 10-16184

Date: 2018-10-01

Document: 10-16184 Case I01-I04 Noise calculation Wind Farm Måkaknuten 181001

Company Information

Name: Akustikkonsulten i Sverige AB

Address: Ringvägen 45B, 118 63 Stockholm

Telephone: +46(0)8-29 89 00

E-mail: info@akustikkonsulten.se

Table of Contents

Page	Content
3-10	WTG and calculation data
3	Calculation conditions
4	Noise data
5	Wind data
6-7	WTG data
8	Ground absorption map
9	Ground model
10-20	Result noise immission
10-16	Case I01-I04 - Result point calculation
17	Case I01 - Noise map
18	Case I02 - Noise map
19	Case I03 - Noise map
20	Case I04 - Noise map

Wind Farm	WTG type	Number of WTG	Hub height [m]	Total height [m]	Noise emission [dBA]
Måkaknuten	Siemens SWT-DD-130	22	125	190	92,3-107,0
Stigafjellet	Siemens SWT-DD-130	7	115	180	92,3-107,0

Calculation parameters	
Calculation program	SoundPLAN 7.4
Calculation standard	Nord2000
Search radius	20 000 m
Calculation height	1,5 m and 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
Anemometer 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 water	Impedance class H
Coordinate system	UTM WGS84 Zone: 32
Height data	1 m and 10 m height contours

Calculation parameters	
Case I01:	Downwind for all wind directions for 8 m/s at 10 m height, WTG in production 365 days a year.
Case I02:	Downwind for all wind directions for 8 m/s at 10 m height, WTG in production 290 days a year.
Case I03:	Downwind for all wind directions for measured wind speed between 3-31 m/s at hub height according to page 6.
Case I04:	Downwind for all wind directions for measured wind speed between 3-7 m/s at hub height according to page 6. For wind speeds 8-31 m/s at hub height measured wind speed and wind direction in 30 ° sectors is used according to page 6. This represents the most accurate yearly average of L_{den} .

Info 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 DAL-32, which is usually used in Sweden for industrial noise calculations, the relative humidity 70% and temereature 15°C is used for planning purposes. 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 measuements in *Veileder til retningslinje for behandling av støy i arealplanlegging (T-1442/2012)*. The noise level at a positive temperature gradient is usually higher compared to a negative temperature gradient.

WTG type	Noise setting	Wind speed [m/s]	Noise emission [dBA]
Siemens SWT-DD-130	Mode 1	3-4	92,3
Siemens SWT-DD-130	Mode 1	5	95,3
Siemens SWT-DD-130	Mode 1	6	98,3
Siemens SWT-DD-130	Mode 1	7	102,3
Siemens SWT-DD-130	Mode 1	8	105,6
Siemens SWT-DD-130	Mode 1	≥9	107,0

Reference noise data: Frequency spectrum for wind speed 6 m/s and 8 m/s at hub height in octave bands between 63 Hz and 8 kHz and in 1/3-octave bands between 20 Hz and 160 Hz has been taken from the turbine manufacturer document *WP ON PLM&EN EN GS-40-0000-001AA12-00* dated 2017-04-26 supplied by the client. The noise emission is given for wind speeds from 3 m/s up to cut in wind speed. The octave band spectrum for 6 m/s and 8 m/s has been scaled linearly to a 1/3-octave band spectrum between 50 Hz to 10 kHz, for frequencies between 20-160 Hz the given values are used resulting in av 1/3-octave band spectrum with frequencies between 20 Hz to 10 kHz. For wind speeds 3-5 m/s the 1/3-octave band spectrum for 6 m/s is scaled linearly to the corresponding noise emission and in the same way the frequency spectrum for 8 m/s is used for the wind speeds 7 m/s and ≥9 m/s. No uncertainty is given by the document.

The document is classified as restricted by Siemens and thus the frequency data cannot be published.

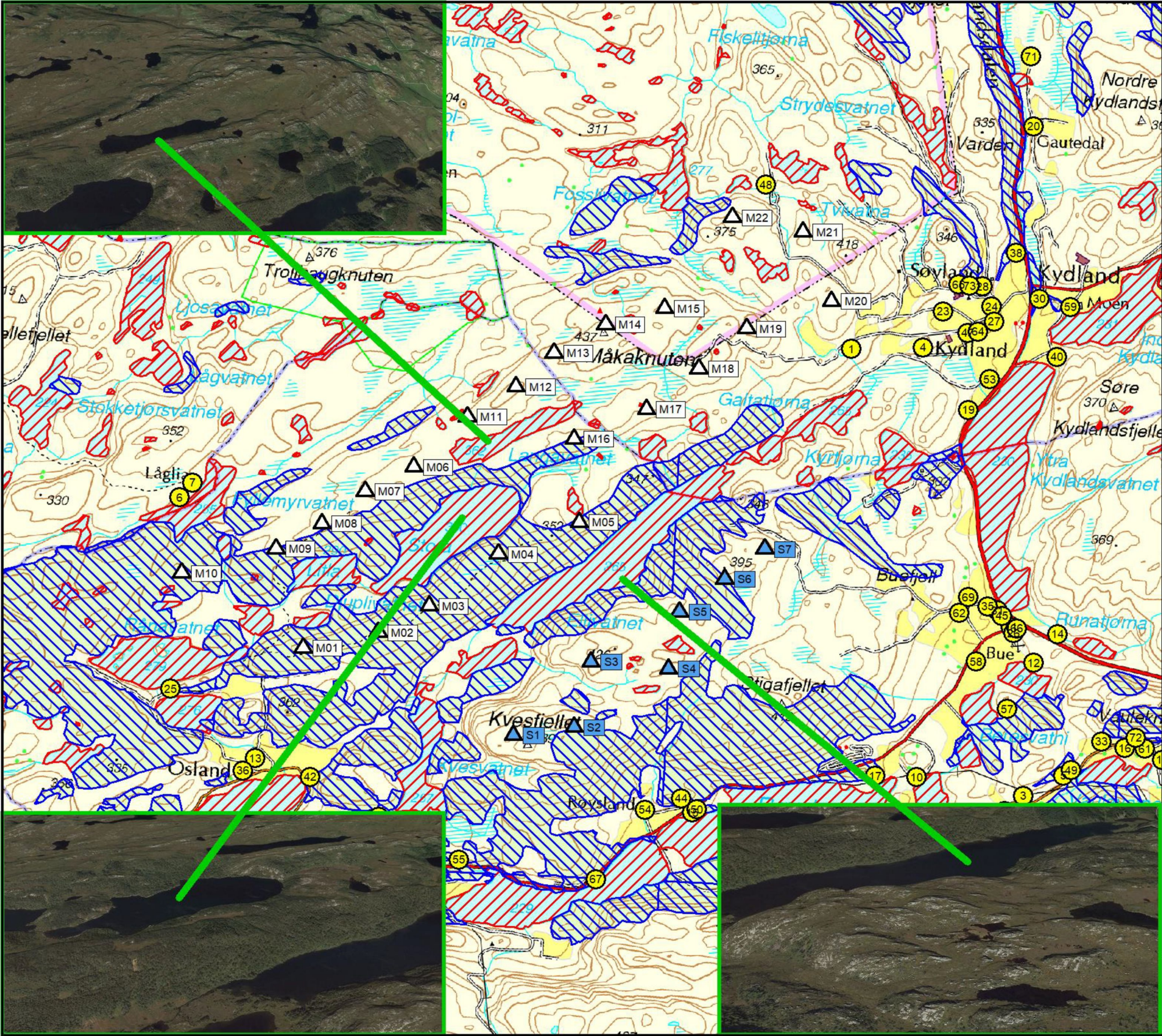
Disclaimer: The calculations are valid for the used noise emission and frequency spectrum. Akustikkonsulten gives no guaranty on the actual noise emission level nor frequency spectrum.

Wind speed at hh [m/s]	Annual [Jan-Dec] [%]	Annual 0° [%]	Annual 30° [%]	Annual 60° [%]	Annual 90° [%]	Annual 120° [%]
0-2	7,05	0,72	0,48	0,16	0,31	0,85
3-4	13,21	1,56	0,98	0,52	0,52	0,95
5	8,62	0,98	0,44	0,34	0,32	0,72
6	9,16	1,04	0,28	0,29	0,37	0,84
7	9,26	0,86	0,14	0,21	0,40	1,02
8	8,85	0,60	0,05	0,13	0,44	1,12
9-31	43,85	0,65	0,01	0,10	1,96	12,00
Wind speed at hh [m/s]	Annual 150° [%]	Annual 180° [%]	Annual 210° [%]	Annual 240° [%]	Annual 270° [%]	Annual 300° [%]
0-2	0,75	0,59	0,49	0,47	0,57	0,66
3-4	1,31	1,27	0,91	0,85	0,93	1,37
5	0,94	0,93	0,53	0,50	0,57	0,88
6	1,11	0,99	0,56	0,51	0,58	0,94
7	1,27	1,01	0,56	0,52	0,58	0,89
8	1,38	0,96	0,53	0,49	0,56	0,82
9-31	7,29	3,80	2,20	2,17	2,75	3,49
Wind speed at hh [m/s]	Annual 330° [%]	Wind distribution used in calculation I03: Only wind speed distribution is used in the calculation. For wind direction, downwind for all wind directions is used. This is conservative compared to also include the wind direction distribution. I04: Both wind speed and wind direction distribution is used for wind speed 8 m/s and 9-31 m/s. For lower wind speeds downwind for all wind directions is used. The influence of wind direction distribution compared to the normal downwind conditions for lower wind speeds is marginal as the sound power is low. This case represents the most accurate yearly average of L_{den}. Reference wind data: The wind speed distribution is from document <i>Wind statistics, mast 2604.xcls</i> supplied by the the client. Disclaimer: The calculations are valid for the used wind speed distribution. Akustikkonsulten gives no guaranty that the real wind speeds are the same.				
0-2	1,01					
3-4	2,04					
5	1,46					
6	1,66					
7	1,79					
8	1,77					
9-31	7,35					

Wind Farm Måkaknuten							
WTG	X [m]	Y [m]	Hub height [m]	Hub height level [mas]	Ground level [mas]	Noise emission [dBA]	Noise setting
M01	320750	6506633	125	479	354	92,3-107,0	Mode 1
M02	321233	6506735	125	486	361	92,3-107,0	Mode 1
M03	321558	6506908	125	480	355	92,3-107,0	Mode 1
M04	322003	6507249	125	480	355	92,3-107,0	Mode 1
M05	322521	6507459	125	475	350	92,3-107,0	Mode 1
M06	321460	6507821	125	502	377	92,3-107,0	Mode 1
M07	321149	6507661	125	493	368	92,3-107,0	Mode 1
M08	320872	6507450	125	477	352	92,3-107,0	Mode 1
M09	320576	6507284	125	454	329	92,3-107,0	Mode 1
M10	319973	6507124	125	446	321	92,3-107,0	Mode 1
M11	321805	6508152	125	514	389	92,3-107,0	Mode 1
M12	322117	6508349	125	534	409	92,3-107,0	Mode 1
M13	322359	6508569	125	536	411	92,3-107,0	Mode 1
M14	322692	6508756	125	547	422	92,3-107,0	Mode 1
M15	323070	6508863	125	543	418	92,3-107,0	Mode 1
M16	322490	6508006	125	516	391	92,3-107,0	Mode 1
M17	322953	6508200	125	514	389	92,3-107,0	Mode 1
M18	323290	6508466	125	524	399	92,3-107,0	Mode 1
M19	323596	6508729	125	530	405	92,3-107,0	Mode 1
M20	324141	6508910	125	500	375	92,3-107,0	Mode 1
M21	323959	6509365	125	477	352	92,3-107,0	Mode 1
M22	323507	6509459	125	491	366	92,3-107,0	Mode 1

Wind Farm Stigafjellet							
WTG	X [m]	Y [m]	Hub height [m]	Hub height level [mas]	Ground level [mas]	Noise emission [dBA]	Noise setting
S1	322100	6506060	115	539	424	92,3-107,0	Mode 1
S2	322488	6506113	115	530	415	92,3-107,0	Mode 1
S3	322598	6506542	115	516	401	92,3-107,0	Mode 1
S4	323096	6506496	115	515	400	92,3-107,0	Mode 1
S5	323167	6506869	115	508	393	92,3-107,0	Mode 1
S6	323455	6507086	115	502	387	92,3-107,0	Mode 1
S7	323711	6507282	115	490	375	92,3-107,0	Mode 1

Ground Absorption Map



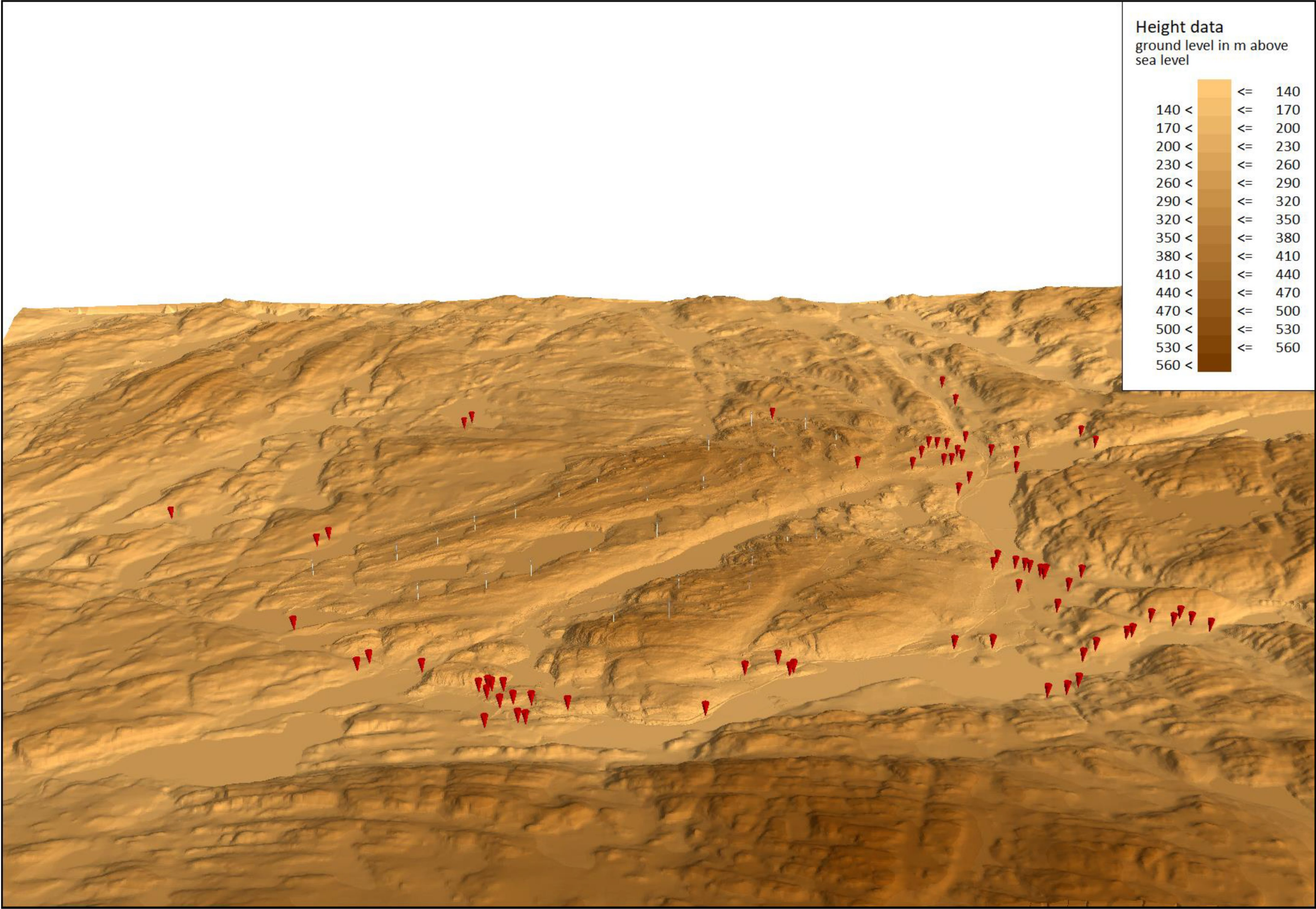
- Noise Sensitive Area (NSA)
 - ▲ WTG Stigafjellet
 - ▲ WTG Måkaknuten
 - ▨ Impedance class H 1)
 - ▨ Impedance class D 2)
- 1) Impedance class H -
Very hard and dense surface (dense asphalt, concrete, water)
2) Impedance class D -
Normal uncompacted ground (forest floors, pasture fields)
3) All other areas Impedance class E -
Compact field and gravel (compacted lawns, park area)



Wind Farm Måkaknuten
Nord2000 impedance classes in
calculations



Beräknad med SoundPLAN 7.4 uppdatering 2017-06-30		www.akustikkonsulten.se	
Handläggare	Paul Appelqvist	Kvalitetsgranskare	Jens Fredriksson
Projekt nr.	10-16184	Ritning	
Datum	2018-10-01		



Point Calculations

Date of calculation 2018-10-01					L_{den} [dBA]			
NSA	X [m]	Y [m]	Z,ground [mas]	Calculation height [m]	I01	I02	I03	I04
1	324269	6508597	322	1,5 m	51	50	49	48
1	324269	6508597	322	4,0 m	51	50	49	49
2	321051	6509727	308	1,5 m	43	42	40	39
2	321051	6509727	308	4,0 m	43	42	40	40
3	325370	6505663	251	1,5 m	37	36	34	32
3	325370	6505663	251	4,0 m	37	36	35	33
4	324729	6508608	292	1,5 m	47	46	44	43
4	324729	6508608	292	4,0 m	47	46	44	43
5	325627	6505795	252	1,5 m	27	26	24	21
5	325627	6505795	252	4,0 m	28	27	26	22
6	319960	6507622	295	1,5 m	51	50	48	48
6	319960	6507622	295	4,0 m	51	50	48	48
7	320042	6507720	298	1,5 m	51	50	48	48
7	320042	6507720	298	4,0 m	51	50	48	48
8	321425	6505102	255	1,5 m	44	43	42	41
8	321425	6505102	255	4,0 m	45	44	42	41
9	326395	6509002	244	1,5 m	38	37	36	36
9	326395	6509002	244	4,0 m	39	38	37	36
10	324685	6505785	237	1,5 m	40	39	37	34
10	324685	6505785	237	4,0 m	40	39	37	34
11	325294	6506770	237	1,5 m	42	40	39	37
11	325294	6506770	237	4,0 m	42	41	39	37
12	325437	6506535	239	1,5 m	40	39	38	37
12	325437	6506535	239	4,0 m	41	40	38	37
13	320442	6505910	262	1,5 m	46	45	43	41
13	320442	6505910	262	4,0 m	46	45	44	42
14	325590	6506725	240	1,5 m	40	39	38	37
14	325590	6506725	240	4,0 m	41	40	38	38
15	323246	6505552	233	1,5 m	46	44	43	39

Point Calculations

Date of calculation 2018-10-01					L_{den} [dBA]			
NSA	X [m]	Y [m]	Z,ground [mas]	Calculation height [m]	I01	I02	I03	I04
15	323246	6505552	233	4,0 m	45	44	43	39
16	326024	6505976	236	1,5 m	37	36	34	32
16	326024	6505976	236	4,0 m	37	36	34	32
17	324420	6505794	238	1,5 m	41	40	39	35
17	324420	6505794	238	4,0 m	41	40	39	36
18	326264	6505900	224	1,5 m	36	35	33	31
18	326264	6505900	224	4,0 m	35	34	33	31
19	325021	6508196	238	1,5 m	43	41	40	37
19	325021	6508196	238	4,0 m	43	41	40	37
20	325436	6510058	224	1,5 m	37	36	34	31
20	325436	6510058	224	4,0 m	37	36	34	31
21	321399	6505333	247	1,5 m	42	40	39	38
21	321399	6505333	247	4,0 m	42	41	39	38
22	321312	6505301	243	1,5 m	44	42	41	39
22	321312	6505301	243	4,0 m	44	43	41	39
23	324856	6508843	281	1,5 m	47	46	44	43
23	324856	6508843	281	4,0 m	47	46	44	43
24	325169	6508875	265	1,5 m	44	43	41	40
24	325169	6508875	265	4,0 m	43	42	41	40
25	319901	6506366	293	1,5 m	45	44	42	42
25	319901	6506366	293	4,0 m	46	45	43	43
26	325310	6506730	239	1,5 m	41	40	39	37
26	325310	6506730	239	4,0 m	42	41	39	38
27	325185	6508778	267	1,5 m	43	42	41	39
27	325185	6508778	267	4,0 m	43	42	40	39
28	325111	6509008	273	1,5 m	44	43	41	40
28	325111	6509008	273	4,0 m	44	43	42	41
29	325251	6505560	234	1,5 m	39	38	36	35
29	325251	6505560	234	4,0 m	39	38	36	35

Point Calculations

Date of calculation 2018-10-01					L_{den} [dBA]			
NSA	X [m]	Y [m]	Z,ground [mas]	Calculation height [m]	I01	I02	I03	I04
30	325474	6508926	235	1,5 m	42	41	40	39
30	325474	6508926	235	4,0 m	43	42	40	39
31	325207	6506881	235	1,5 m	41	40	39	36
31	325207	6506881	235	4,0 m	41	40	39	37
32	318766	6508342	221	1,5 m	39	38	37	35
32	318766	6508342	221	4,0 m	40	39	37	36
33	325875	6506020	251	1,5 m	38	37	35	33
33	325875	6506020	251	4,0 m	38	37	35	33
34	326342	6509243	238	1,5 m	39	38	36	35
34	326342	6509243	238	4,0 m	39	38	37	36
35	325143	6506907	240	1,5 m	42	41	39	36
35	325143	6506907	240	4,0 m	42	41	39	37
36	320366	6505828	257	1,5 m	45	44	43	41
36	320366	6505828	257	4,0 m	45	44	43	41
37	321338	6505473	264	1,5 m	46	44	43	42
37	321338	6505473	264	4,0 m	46	45	43	43
38	325326	6509228	228	1,5 m	42	40	38	34
38	325326	6509228	228	4,0 m	41	40	38	34
39	324880	6505118	244	1,5 m	39	38	36	35
39	324880	6505118	244	4,0 m	40	39	37	36
40	325587	6508545	245	1,5 m	42	41	39	39
40	325587	6508545	245	4,0 m	43	42	40	39
41	321262	6505491	258	1,5 m	45	44	42	40
41	321262	6505491	258	4,0 m	45	44	42	41
42	320797	6505787	249	1,5 m	46	45	43	41
42	320797	6505787	249	4,0 m	47	46	44	42
43	321237	6505523	253	1,5 m	43	42	40	39
43	321237	6505523	253	4,0 m	44	42	41	39
44	323179	6505647	272	1,5 m	47	46	45	43

Point Calculations

Date of calculation 2018-10-01					L_{den} [dBA]			
NSA	X [m]	Y [m]	Z,ground [mas]	Calculation height [m]	I01	I02	I03	I04
44	323179	6505647	272	4,0 m	48	47	45	44
45	325234	6506844	235	1,5 m	41	40	38	36
45	325234	6506844	235	4,0 m	42	41	39	37
46	321474	6505079	254	1,5 m	44	43	42	41
46	321474	6505079	254	4,0 m	45	43	42	41
47	325014	6508703	269	1,5 m	45	44	43	42
47	325014	6508703	269	4,0 m	46	45	43	42
48	323720	6509676	321	1,5 m	54	53	52	52
48	323720	6509676	321	4,0 m	55	54	52	52
49	325679	6505830	249	1,5 m	29	28	26	22
49	325679	6505830	249	4,0 m	31	30	28	24
50	323275	6505574	239	1,5 m	46	45	43	40
50	323275	6505574	239	4,0 m	46	45	43	40
51	321214	6505041	265	1,5 m	44	43	41	40
51	321214	6505041	265	4,0 m	44	43	42	41
52	321176	6505501	250	1,5 m	42	41	40	38
52	321176	6505501	250	4,0 m	43	42	40	39
53	325157	6508398	242	1,5 m	44	43	41	41
53	325157	6508398	242	4,0 m	44	43	42	41
54	322946	6505572	244	1,5 m	47	46	45	43
54	322946	6505572	244	4,0 m	47	46	45	44
55	321749	6505243	243	1,5 m	34	33	31	27
55	321749	6505243	243	4,0 m	35	34	32	28
56	321113	6509957	260	1,5 m	42	41	39	38
56	321113	6509957	260	4,0 m	42	41	39	38
57	325266	6506232	242	1,5 m	40	39	37	36
57	325266	6506232	242	4,0 m	40	39	38	36
58	325069	6506543	240	1,5 m	42	40	39	37
58	325069	6506543	240	4,0 m	42	41	39	37

Point Calculations

Date of calculation 2018-10-01					L_{den} [dBA]			
NSA	X [m]	Y [m]	Z,ground [mas]	Calculation height [m]	I01	I02	I03	I04
59	325673	6508873	237	1,5 m	41	40	39	38
59	325673	6508873	237	4,0 m	42	41	39	39
60	325123	6505235	238	1,5 m	38	37	35	35
60	325123	6505235	238	4,0 m	39	38	36	35
61	326151	6505972	241	1,5 m	36	35	34	32
61	326151	6505972	241	4,0 m	36	35	34	32
62	324962	6506863	262	1,5 m	41	40	38	35
62	324962	6506863	262	4,0 m	41	40	39	36
63	321229	6505407	251	1,5 m	44	43	42	40
63	321229	6505407	251	4,0 m	44	43	42	40
64	325082	6508711	268	1,5 m	45	44	42	41
64	325082	6508711	268	4,0 m	45	44	42	42
65	324956	6509020	290	1,5 m	45	44	43	42
65	324956	6509020	290	4,0 m	45	44	43	43
66	325331	6506761	240	1,5 m	41	40	39	37
66	325331	6506761	240	4,0 m	42	41	39	38
67	322631	6505115	231	1,5 m	40	39	38	34
67	322631	6505115	231	4,0 m	41	40	38	36
68	325023	6505160	231	1,5 m	38	37	36	34
68	325023	6505160	231	4,0 m	39	38	36	35
69	325020	6506967	263	1,5 m	42	41	39	36
69	325020	6506967	263	4,0 m	42	41	39	37
70	321517	6505314	249	1,5 m	42	41	39	35
70	321517	6505314	249	4,0 m	43	42	40	37
71	325422	6510518	211	1,5 m	38	37	35	32
71	325422	6510518	211	4,0 m	38	37	35	32
72	326093	6506044	251	1,5 m	35	34	33	30
72	326093	6506044	251	4,0 m	35	34	33	30
73	325026	6509011	284	1,5 m	45	44	42	42

Date: 2018-10-01

Project: Wind Farm Måkaknuten

Point Calculations



Date of calculation 2018-10-01					L_{den} [dBA]			
NSA	X [m]	Y [m]	Z,ground [mas]	Calculation height [m]	I01	I02	I03	I04
73	325026	6509011	284	4,0 m	45	44	43	42

Info on result

The calculations are performed with the assumption that the noise sensitive area (NSA) are 1,5 m and 4,0 m above ground. The height of 4,0 m should be considered decisive according to the norwegian guidelines on noise. Although it shall be noted that sound immission measurements according to the measurement standard Elforsk 98:24, recommended in chapter 9.8.4 in *Veileder til retningslinje for behandling av støy i arealplanlegging (T-1442/2012)*, should be performed at 1,2-1,5 m above ground. For indexing of NSA:s see the noise maps. 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.

Note that if the point calculation and noise map shows 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 *Veileder til retningslinje for behandling av støy i arealplanlegging (T-1442/2012)*:

"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. For the Case I01 the WTG:s are assumed to run 365 days a year and for Case I02 290 days which result in a -1,0 dB decrease of the calculated sound level compared to Case I01. For Case I03-I04 the real wind distribution is used which includes the real stand still time for the wind farm.

The noise limit has been assumed to be $L_{den}=45$ dBA for both wind shielded areas and normal areas. If the calculated value is above the limit 45 dBA it is marked with red.

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 belived that, with a confidence intervall of 90 %, the calculated value is within the intervall of **(-5, +3 dB)** from a measured value for complex norwegian terrain for distances up to 4 km from the wind farm. This confidence interval includes the uncertainty on the noise emission. It shall be nooted that the uncertainty increases with the distance from the wind farm.

