APPENDIX A

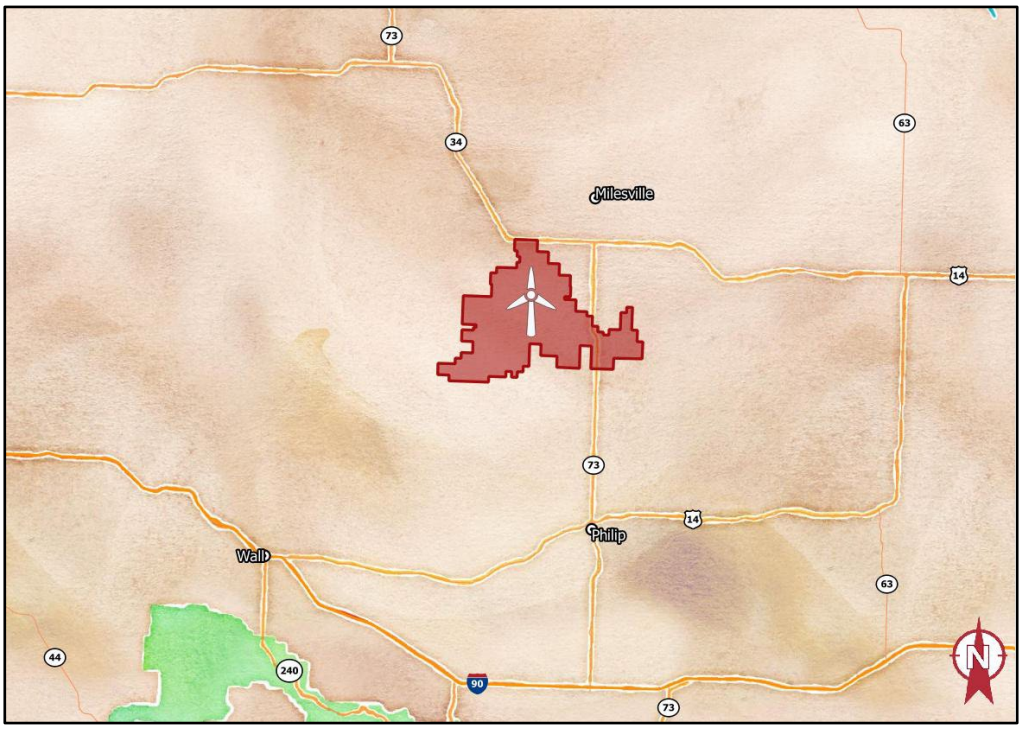
Preconstruction Wind Turbine Noise Analysis

Pre-Construction Wind Turbine Noise Analysis

for the proposed

Philip Wind Project

April 12, 2023



Prepared for:

Philip Wind Partners, LLC
Chicago, Illinois

Prepared by:

Hankard Environmental, Inc.
Verona, Wisconsin

HANKARD ENVIRONMENTAL
ACOUSTICS AND VIBRATION CONSULTING

Contents

Figures

Tables

Appendices

1. Introduction

This report describes a pre-construction noise analysis conducted by Hankard Environmental for the proposed Philip Wind Farm (Project, Facility). The Project will produce up to 300 megawatts (MW) of electrical power using up to 95 wind turbine generators, which will be located in Haakon County, South Dakota. Figure 1-1 shows the general location of the Project, which is situated about 15 miles north of Philip, South Dakota.

The noise analysis was conducted at the request of the Project proponent, Philip Wind Partners, LLC, for the purpose of demonstrating that the Project has been designed to meet the noise level limits historically applied to wind turbine projects by the South Dakota Public Utilities Commission (PUC). Described herein are the applicable noise limits, the Project and its environs, the methods and data used to predict noise levels, and the results of the noise level predictions demonstrating compliance with noise limits typically applied to wind projects in South Dakota.

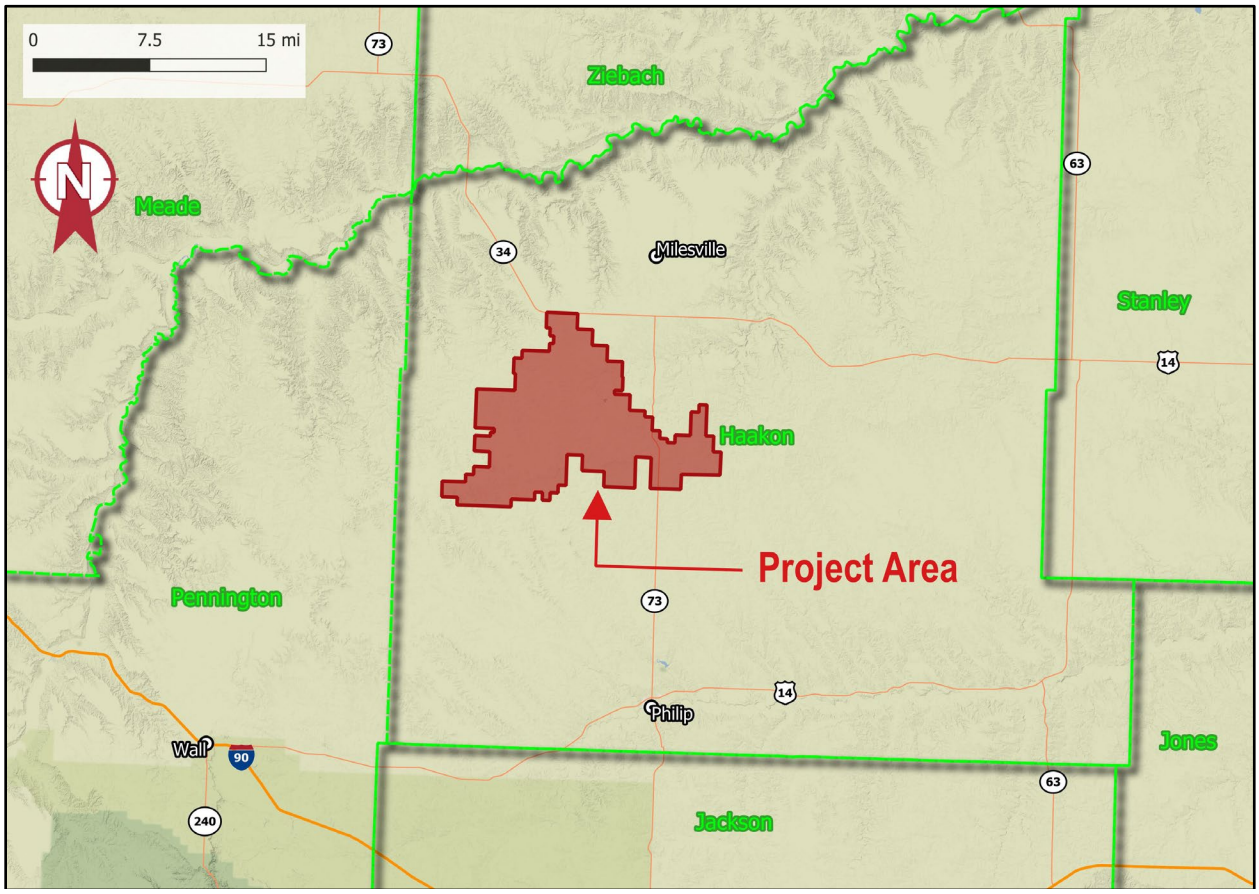


Figure 1-1. General Location of the Philip Wind Farm

2. Applicable Noise Standards

There are no noise-related federal, county, or local regulations that apply to the Project.

At the state level, South Dakota Administrative Rule 20:10:22:33.02 requires that an application for an Energy Facility Permit include "Anticipated noise levels during construction and operation." The noise levels reported herein are those expected during operation. Construction noise levels will be typical of those produced by standard construction equipment.

The South Dakota PUC does not have any specific noise limit that applies to wind turbine projects. In lieu of this, Hankard Environmental reviewed the South Dakota PUC's Wind Energy Siting Dockets to determine what noise limits have been applied to recent projects. Out of 11 dockets we reviewed from 2017 to 2021, eight had county limits of 45 dBA at non-participating residences and three had local limits of 50 dBA.

This range of 45 to 50 dBA is consistent with the limits that are typically applied to wind turbine projects nationally. To be conservative, this Project has been designed to meet the more stringent 45 dBA limit.

3. Project Description

The Project consists of up to 95 wind turbines generating up to 300 MW of electric power. Associated facilities include gravel access roads and underground cabling to collect and transmit the power to the Project substation and its two step-up transformers. The locations of the 95 wind turbine sites under consideration are shown in Figure 3-1. The Project is located entirely in Haakon County. The proposed turbine models under consideration are the Vestas V163-4.5 and the General Electric (GE) Sierra 3.4-140, both with a hub height of 98 meters. The GE turbines used will be fitted with noise-reducing blades, known as Low Noise Trailing Edge (LNTE) blades, and the Vestas turbines will be modeled with and without noise-reducing blades, termed Serrated Trailing Edge (STE) by Vestas. Also shown in Figure 3-1 is the location of the substation, approximately 2,900 meters (9,515 feet) from the nearest residence. The substation will include up to two 140 megavolt ampere (MVA) primary step-up transformers.

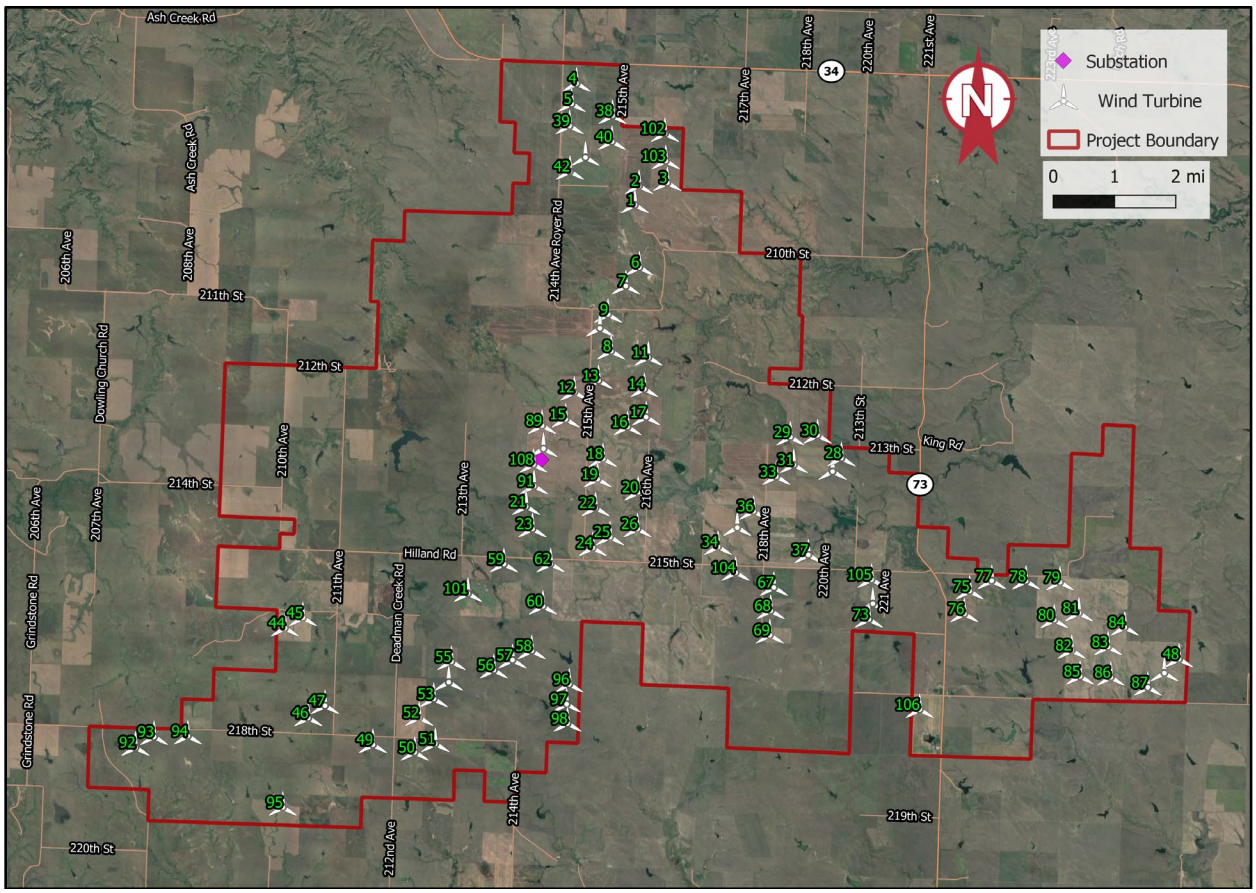


Figure 3-1. Philip Wind Project Layout (L027)

4. Noise Modeling Method

Noise levels from the proposed Project were predicted using the modeling method set forth in International Organization for Standardization (ISO) Standard 9613-2:1996 - *Attenuation of Sound During Propagation Outdoors*. The method was implemented using the SoundPLAN v8.2 acoustical modeling program. Figure 4-1 shows a representative three-dimensional view of the SoundPLAN model of the Project.

The ISO 9613-2:1996 method requires input data and the setting of certain parameters, including the locations of the noise sources and receivers, noise emission factors including frequency characteristics, terrain and ground type, and atmospheric propagation conditions. In general, the ISO method assumes optimal acoustic propagation in all directions, specifically that a "well-developed, moderate ground-based temperature inversion" is present or, equivalently, that all receptors are downwind of all noise sources at all times. The specific ISO 9613-2:1996 settings and input data used in this analysis are described below.

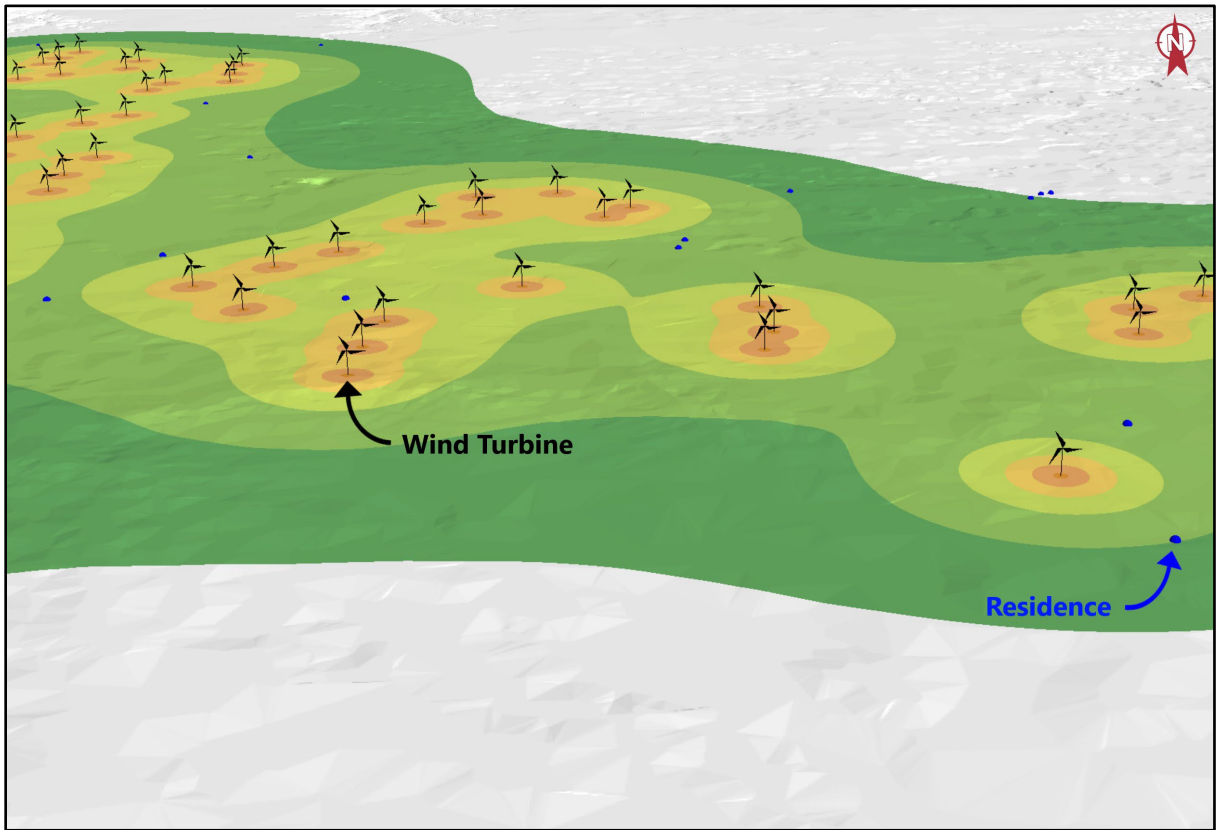


Figure 4-1. Three-Dimensional View of the SoundPLAN Noise Model

Noise Sources

In the SoundPLAN model, each of the wind turbines was represented as an acoustical point source located at its hub height. No directivity was applied to any noise source thus assuming maximum acoustic output in all directions. All turbines were assumed to be operating in normal mode (versus noise-reduced mode). The acoustic model includes two 140 MVA step-up transformers located at the Project's electrical substation. The locations of each turbine and the substation are shown in Figure 3-1 (layout L027). The geographic coordinates and ground elevation of each turbine and step-up transformer are listed in Appendix A.

Table 4-1 lists, for the wind turbine models under consideration and the step-up transformers, the height above the ground at which each source was located in the acoustic model, and each source's noise emission level (sound power level) expressed both in octave bands levels[1] and the overall level. All of the noise emission levels are expressed in terms of A-weighted decibels (dBA). The noise emission levels for the turbines were provided by the manufacturers and were determined according to International Electrotechnical Commission Standard 61400-11. Wind turbine noise emissions increase with increasing wind speeds up to approximately 10 m/s at hub-height. Noise levels do not increase when hub-height wind speeds exceed 10 m/s because the turbines reach a maximum rotational speed, and the sound emission of a turbine is directly proportional to its rotational speed. This analysis used the octave band noise levels reported by the manufacturer for a wind speed of 10 m/s at hub height.

The Project includes a substation containing two step-up transformers which are the only significant noise-producing components of the substation. The analysis assumed the simultaneous operation of both step-up transformers at their maximum rating (140 MVA), including the operation of cooling fans. The sound power levels of the step-up transformers are listed in Table 4-1 and were estimated using the methodology published in the Edison Electric Institute, "Electric Power Plant Environmental Noise Guide," 2nd Edition, BBN, 1984. The step-up transformers were modeled as point sources located three meters (10 feet) above the ground, with no barriers or directivity reductions.

Table 4-1. Source Sound Power Levels

Source	Source Height (m)	Octave Band Sound Power Level (dBA)									Overall Level (dBA)
		31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	
GE Sierra 3.4-140	98	78.8	88.2	92.5	96.1	99.2	102.2	101.6	93.6	74.0	106.8
Vestas V163-4.5 Standard	98	71.2	85.8	96.1	102.1	104.2	102.6	96.9	88.3	76.8	108.4
Vestas V163-4.5 STE	98	74.0	86.5	95.4	100.3	101.9	100.1	94.7	86.8	76.6	106.3
140 MVA Transformer	3	57.4	76.6	88.7	91.2	96.6	93.8	90.0	84.8	75.7	100.2

[1] Nine standard frequency octave bands, as defined by the American National Standards Institute (ANSI) Standard S1.11: Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters.

Noise Level Metric

The noise levels predicted using this method are in the form of the energy equivalent average noise level (L_{eq}) over a one-hour period of maximum acoustic emissions from the turbines.

Receptors

In the model, prediction points were located at each of the 37 residences identified in the vicinity of the Project, all in Haakon County. Of these 37 residences, 24 are non-participating in the Project and 13 are participating. The geographic locations and participation status of the receptors were obtained from the Project and Hankard Environmental reviewed the receptors for accuracy using aerial photography. Each receptor's height was set to 4 meters (13 feet) above the ground in the acoustic model.

Atmospheric Conditions

The air temperature, relative humidity, and atmospheric pressure were set to conditions of 10°C, 70%, and 1 atmosphere, respectively. These values represent the lowest amount of atmospheric absorption of sound available in the ISO 9613-2:1996 method and result in the highest levels of sound reaching the receptors.

Terrain and Ground Effect

The ground elevations in the Project area were established by importing data from the National Elevation Dataset (USGS National Map) for the state of South Dakota at a resolution of 1 arc-second (30 meters). The acoustical effect of the ground was modeled using the ISO 9613-2:1996 General Method. All reductions due to terrain acting as a barrier were removed from the analysis resulting in a more conservative model and higher predicted noise levels. The ground absorption factors for the ground near the source, near the receiver, and in between can range from 0.0 to 1.0 and represent the proportion of sound that is absorbed or reflected when sound waves interact with the ground. A value of 0.0 represents completely reflective ground material such as pavement, and results in a higher level of sound reaching a receptor. A value of 1.0 represents highly absorptive material such as thick grass or fresh snow, and results in a lower level of sound reaching a receptor. For this noise analysis, the most conservative ground factor, 0.0 (completely reflective), has been assumed. Actual ground conditions could at times be 0.0 when the ground is completely frozen but would generally be closer to 0.5 when the ground is covered with crops or new snow, or when the ground is bare and unfrozen.

Model Validation

This noise level prediction method employed on this Project is consistent with the requirements of ANSI/ACP-111-11[2]. This method has been validated by Hankard Environmental and other acoustic professionals by comparing predicted noise levels to those measured at operating wind farms. The results show that this modeling approach consistently over-predicts the measured noise level. That is, actual noise level emissions from the Project, if measured, are expected to be less than those reported herein.

[2] *Wind Turbine Sound Modeling,* ANSI/American Clean Power (ACP) Standard 111-1-2022

5. Predicted Noise Levels

Noise levels were predicted for the full, continuous, and normal operation of the proposed Facility at the 24 non-participating and 13 participating residences located near the Project. Table 5-1 lists the non-participating residences with the highest predicted noise levels. The full list of predicted noise levels at each receptor is provided in Appendix B. The highest predicted noise level at a non-participating residence 44.7 dBA, which is less than the 45 dBA noise level goal. Predicted noise levels at all participating residences are less than 48 dBA. To provide a visual demonstration of compliance, the predicted noise levels are shown in the form of noise level contours for the loudest turbine model (Vestas V163-4.5 with standard blades) in Figures 5-1 to 5-3. Contours for all other turbine models would be smaller than those shown in these Figures. For example, areas between the turbines or the substation and the 45 dBA contour have a predicted noise level above 45 dBA. Areas beyond, or outside of, the 45 dBA contour have a predicted noise level less than 45 dBA. No non-participating residences are located within the 45 dBA contours.

Table 5-1. Highest Predicted Noise Levels at Non-Participating Residences

Receptor	Overall L_{eq} (dBA)		
	Vestas V163-4.5 Standard	Vestas V163-4.5 STE	GE Sierra 3.4-140
R-011	44.7	42.8	41.0
R-012	44.0	42.1	40.2
R-248	41.3	39.3	37.6
R-027	39.9	38.1	36.0
R-008	39.2	37.5	35.2
R-033	37.0	35.3	32.9
R-004	36.0	34.3	31.8
R-028	36.0	34.4	31.9
R-007	35.3	33.7	31.1
R-006	34.8	33.3	30.7
R-005	34.7	33.2	30.5
R-001	34.3	32.7	30.2
R-269	33.9	32.2	29.7
R-017	33.0	31.6	29.0
R-029	32.4	31.0	28.4
R-018	30.9	29.6	27.1
R-024	30.9	29.6	27.1
R-179	30.8	29.5	27.0
R-030	29.1	28.0	25.6
R-022	29.0	27.4	24.9
R-163	28.4	27.1	24.7
R-020	26.3	25.2	22.9
R-019	25.9	24.9	22.7
R-021	24.2	23.1	21.0

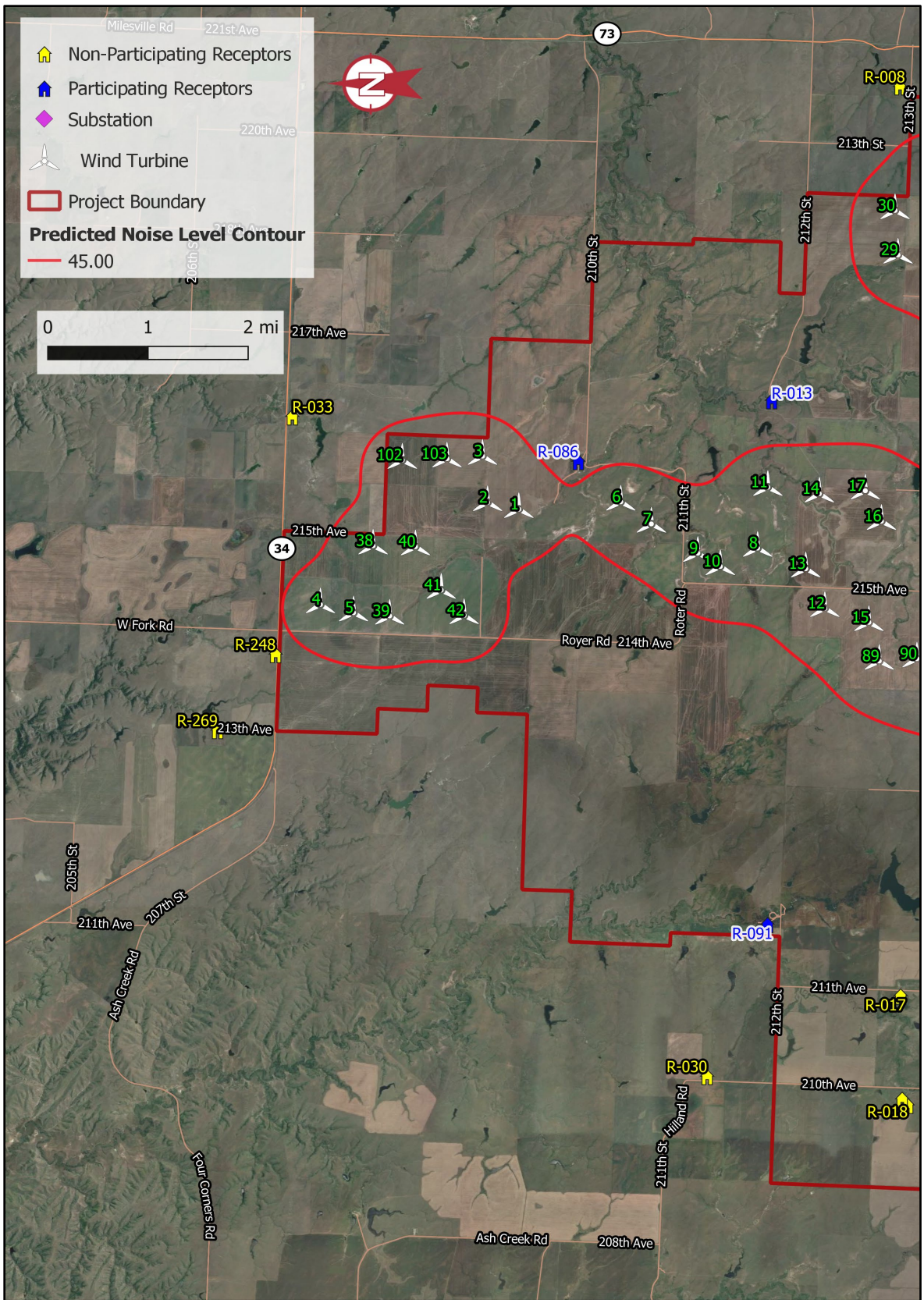


Figure 5-1. Predicted Noise Level Contours – North Area

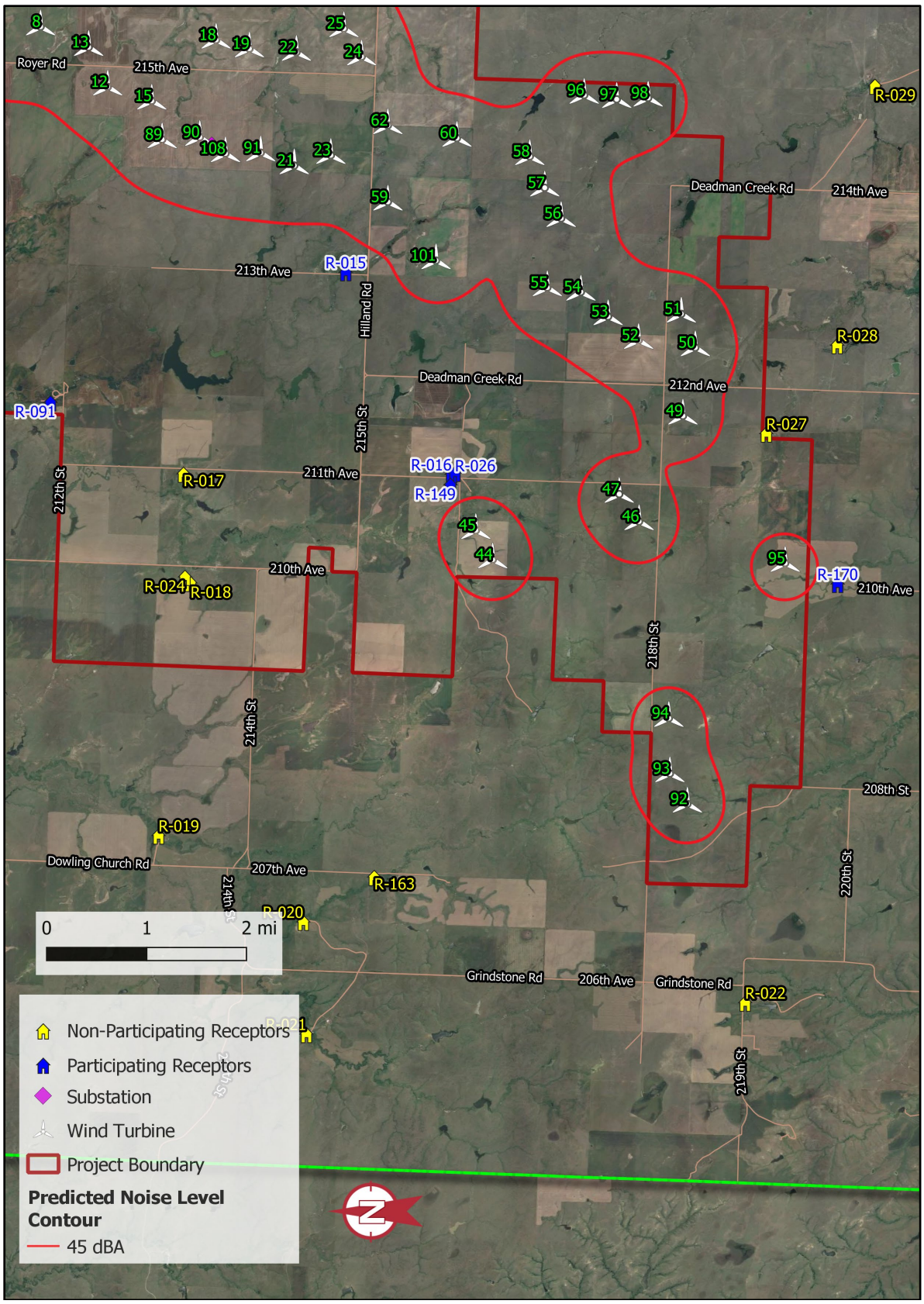


Figure 5-2. Predicted Noise Level Contours – Southwest Area

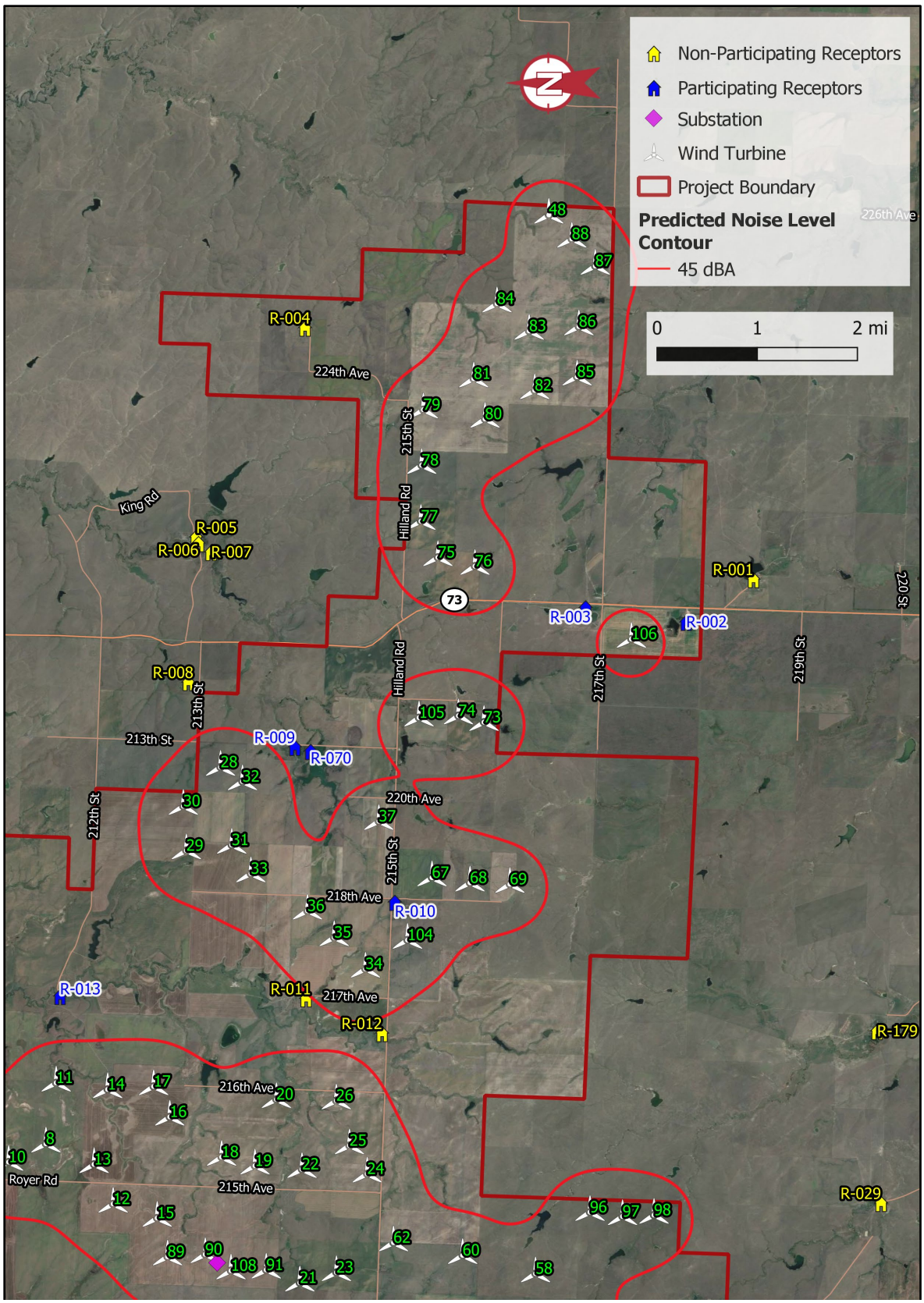


Figure 5-3. Predicted Noise Level Contours – Southeast Area

6. Conclusions

Noise levels were predicted for the full, continuous, and normal operation of turbines operating at all 95 potential sites in the proposed Facility. Noise levels were predicted at the 24 non-participating and 13 participating residences located nearest to the Project in Haakon County, South Dakota. The highest predicted noise level at a non-participating residence is 44.7 dBA, which is less than the 45 dBA Project noise level goal.

Predicted noise levels at all participating residences are 48 dBA or less for the loudest turbine model under consideration, the Vestas V163-4.5 with standard blades.

The noise level prediction method employed for this analysis is consistent with ACP-111-1 (2022) and has been validated by Hankard Environmental and other acoustic professionals by comparing predicted noise levels to those measured at operating wind farms. The results show that the modeling approach employed here consistently overpredicts measured noise levels. That is, actual noise level emissions from this Project, if measured, are expected to be less than those reported herein.

Furthermore, the noise levels reported herein are the very highest turbine noise levels expected, as they represent the case where all turbines are operating fully. A majority of the time turbine noise levels will be lower than those reported herein, when the turbines are not producing full acoustic output due to low winds, and/or atmospheric conditions not being as conducive to sound propagation as assumed by the acoustic model (e.g., an unstable atmosphere or receptors located crosswind to the nearest turbines). Additionally, during very windy periods, the noise of the wind blowing through vegetation would be louder than that from the turbines and could in many cases render noise from the turbines inaudible.

The results described herein are valid for the receptor locations analyzed, the turbine and substation layout described above, the wind turbine sound power levels provided by the manufacturer, and the mode of turbine operation. If the Project makes any significant changes, including turbine layout, turbine type, or operational mode, this noise analysis should be updated accordingly.

APPENDIX A
Noise Source Locations – Layout L027

Source Name	UTM 14N		Ground Elevation (m asl)
	Easting (m)	Northing (m)	
1	278952	4916433	760
2	279061	4916934	760
3	279805	4917016	759
4	277420	4919622	765
5	277289	4919089	770
6	279070	4914794	752
7	278715	4914302	758
8	278327	4912593	760
9	278246	4913554	760
10	278033	4913193	767
11	279306	4912429	759
12	277360	4911513	790
13	277996	4911820	770
14	279201	4911601	760
15	277133	4910805	790
16	278759	4910603	770
17	279249	4910862	770
18	278114	4909769	783
19	277974	4909233	790
20	279041	4908888	780
21	276093	4908512	799
22	277917	4908477	785
23	276259	4907924	800
24	277844	4907429	790
25	278298	4907714	790
26	279020	4907926	780
28	284381	4909787	768
29	283040	4910336	764
30	283754	4910385	770
31	283130	4909607	770
32	284150	4909434	770
33	282670	4909299	777
34	281138	4907457	778
35	281644	4907959	780

Source Name	UTM 14N		Ground Elevation (m asl)
	Easting (m)	Northing (m)	
36	282071	4908389	780
37	283511	4907242	780
38	278366	4918775	763
39	277237	4918509	780
40	278350	4918094	770
41	277653	4917680	770
42	277246	4917312	773
44	269752	4905320	802
45	270224	4905591	797
46	270367	4902964	830
47	270807	4903284	830
48	293256	4904508	770
49	272066	4902259	808
50	273165	4902059	801
51	273707	4902285	806
52	273282	4902972	830
53	273665	4903462	821
54	274060	4903901	810
55	274130	4904440	810
56	275244	4904218	810
57	275736	4904482	810
58	276240	4904723	811
59	275509	4907005	797
60	276535	4905895	810
62	276738	4907006	800
67	282605	4906387	791
68	282522	4905776	800
69	282500	4905135	818
73	285103	4905552	781
74	285208	4905963	776
75	287752	4906292	773
76	287611	4905697	777
77	288334	4906566	780
78	289233	4906553	780

Source Name	UTM 14N		Ground Elevation (m asl)
	Easting (m)	Northing (m)	
79	290126	4906526	775
80	289977	4905535	776
81	290624	4905716	780
82	290436	4904736	770
83	291391	4904825	771
84	291829	4905342	770
85	290654	4904054	768
86	291461	4904026	760
87	292435	4903763	770
88	292871	4904139	772
89	276512	4910638	790
90	276549	4910032	790
91	276300	4909052	797
92	265823	4902187	840
93	266312	4902468	847
94	267201	4902486	840
95	269696	4900614	799
96	277227	4903847	790
97	277159	4903324	790
98	277182	4902818	780
101	274565	4906231	794
102	279742	4918306	764
103	279764	4917587	763
104	281602	4906781	783
105	285175	4906596	770
106	286440	4903181	775
108	276287	4909619	796
Substation Transformer 1	276491	4909841	791
Substation Transformer 2	276480	4909841	791

APPENDIX B
Receptor Locations and Predicted Noise Levels

Receiver	Participation Status	UTM 14N		Ground Elevation (m asl)	Overall Predicted Noise Level (L_{eq}, dBA)		
		Easting (m)	Northing (m)		Vestas V163-4.5 Standard	Vestas V163-4.5 STE	GE Sierra 3.4-140
R-001	NP	287469	4901219	750	34.3	32.7	30.2
R-002	P	286782	4902300	764	40.1	38.2	36.6
R-003	P	287014	4903916	786	41.5	39.6	37.9
R-004	NP	291512	4908428	762	36.0	34.3	31.8
R-005	NP	288146	4910178	730	34.7	33.2	30.5
R-006	NP	288048	4910140	730	34.8	33.3	30.7
R-007	NP	287905	4909939	740	35.3	33.7	31.1
R-008	NP	285815	4910305	760	39.2	37.5	35.2
R-009	P	284772	4908591	760	43.1	41.2	39.3
R-010	P	282281	4906984	786	47.5	45.6	44.3
R-011	NP	280731	4908411	770	44.7	42.8	41.0
R-012	NP	280173	4907190	771	44.0	42.1	40.2
R-013	P	280769	4912366	743	41.1	39.3	37.0
R-015	P	274442	4907683	784	42.2	40.4	38.3
R-016	P	271191	4905981	802	40.8	38.9	37.1
R-017	NP	271201	4910294	770	33.0	31.6	29.0
R-018	NP	269445	4910181	775	30.9	29.6	27.1
R-019	NP	265381	4910695	760	25.9	24.9	22.7
R-020	NP	263992	4908366	780	26.3	25.2	22.9
R-021	NP	262186	4908316	790	24.2	23.1	21.0
R-022	NP	262691	4901258	840	29.0	27.4	24.9
R-024	NP	269542	4910270	771	30.9	29.6	27.1
R-026	P	271214	4905926	802	40.8	39.0	37.1
R-027	NP	271847	4900917	801	39.9	38.1	36.0
R-028	NP	273270	4899777	790	36.0	34.4	31.9
R-029	NP	277443	4899168	760	32.4	31.0	28.4
R-030	NP	269907	4913405	770	29.1	28.0	25.6
R-033	NP	280511	4920074	750	37.0	35.3	32.9
R-070	P	284707	4908337	760	42.6	40.7	38.7
R-086	P	279791	4915476	750	43.5	41.6	39.8
R-091	P	272350	4912433	750	33.2	31.9	29.3
R-149	P	271023	4905998	799	41.8	39.9	38.2
R-163	NP	264713	4907225	790	28.4	27.1	24.7
R-170	P	269428	4899770	788	40.3	38.4	37.0
R-179	NP	280207	4899231	750	30.8	29.5	27.0
R-248	NP	276690	4920342	762	41.3	39.3	37.6
R-269	NP	275468	4921275	753	33.9	32.2	29.7