FEHILY TIMONEY

CONSULTANTS IN ENGINEERING, ENVIRONMENTAL SCIENCE & PLANNING

ENVIRONMENTAL IMPACT ASSESSMENT REPORT (EIAR) FOR THE PROPOSED BALLINAGREE WIND FARM

VOLUME 2 – MAIN EIAR

CHAPTER 12 – SHADOW FLICKER

Prepared for: Ballinagree Wind DAC

Ballinagree Wind farm

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TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

12. SHADOW FLICKER

12.1 Introduction

This chapter considers potential shadow flicker effects at nearby buildings associated with the operation of Ballinagree Wind Farm. The specific objectives of the chapter are to:

- describe the assessment methodology and relevant guidance;
- describe the potential impacts;
- describe the need for any mitigation measures, if required; and
- assess the residual impacts remaining, following the implementation of any mitigation measures.

This assessment has been undertaken by Mark Tideswell and reviewed by Jim Singleton, both of TNEI Services Ltd.

Mark Tideswell has seven years' experience of undertaking shadow flicker assessments across Ireland and in the UK and has worked on both planning applications and complaints investigations. He is skilled in shadow flicker prediction and the specification of appropriate mitigation measures. Jim Singleton is the Team Manager of TNEI's Environment and Engineering Team. He has 14 years environmental consultancy experience and has worked on many wind turbine developments, ranging from single turbines to over 300 MW, and including feasibility studies, authoring of ES chapters, compliance surveys, due diligence and appeals.

A detailed description of the project assessed in this EIAR is provided in Chapter 3, which comprises three main elements:

- The wind farm site (also referred to in this EIAR as 'the Site');
- The grid connection;
- The turbine delivery route (also referred to in this EIAR as 'the TDR');
- Biodiversity enhancement and management plan lands (also referred to in this EIAR as 'the BEMP lands').

Only the wind farm element is relevant to the assessment of shadow flicker effects.

12.1.1 Scope of Assessment

12.1.1.1 Conditions required for Shadow Flicker

Under certain combinations of geographical position, wind direction, weather conditions, and times of day and year, the sun may pass behind the rotors of a wind turbine and cast a shadow over the windows of nearby buildings. When the blades rotate and the shadow passes a window, to a person within that room the shadow appears to 'flick' on and off; this effect is known as 'shadow flicker'. The phenomenon occurs only within buildings where shadows are cast across a window aperture, and the effects are typically considered up to a maximum distance of 10 times the rotor diameter from each wind turbine.

This criterion, which effectively sets the size of the study area, is detailed in a number of international publications including the German 'Guideline for Identification and Evaluation of the Optical Emissions of Wind Turbines' (2002), the UK's 'Update of UK Shadow Flicker Evidence Base' (Parsons Brinkerhoff for DECC, 2011) and Ireland's own Wind Energy Development Guidelines (WEDG 2006 and draft WEDG 2019).

Specifically, the WEDG 2006 state that *"At distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low"*.

12.1.1.2 Study Area

A study area of 1550 m from each of the 20 wind turbines was selected for this assessment. This is based upon ten times the maximum rotor diameter (155 m) that would be used within the proposed development, in accordance with the current guidelines. The assessment considers all identified potential shadow flicker sensitive receptors within the study area[1], which includes habitable residential buildings and buildings that are both residential and commercial.

No other sensitive property types were identified within the study area.

The study area is detailed in Figure 12.1.

12.1.1.3 Effects to be Assessed

This chapter presents the results and findings of the potential shadow flicker effects at all the identified receptors. The chapter quantifies the theoretical maximum number of hours per annum and per day where shadow flicker may occur at a building.

12.2 Methodology

It is possible to predict the total theoretical number of hours per year that shadow flicker effects may occur in a building and these predictions can then be used to identify the times when curtailment may be required in order to mitigate the effects. The assessment assumes, during daylight hours, that the sun is shining all day, every day.

[1] The suns path in the sky starts in the morning from the eastern horizon, increases in elevation until it is at its highest in the sky in the afternoon, and then decreases in elevation before setting in the western horizon in the evening. This path differs depending on the time of the year, as the suns angle (or azimuth) and its elevation are higher during the summer months and lower in the winter months. The general path of the sun across the sky, however, will not change, and due to the latitude of the site, the suns azimuth relative to the turbines and receptors is such that the conditions required for shadow flicker to occur in some of the southern areas of the study area never have the potential to occur at any point throughout the year. As such, whilst all receptors have been identified within the study area, this does not necessarily mean that shadow flicker will occur at all locations. The 'Maximum Extent of shadow coverage', where there is potential for shadow flicker to occur, is detailed in Figures 12.2, 12.3 and 12.4.

The potential for shadow flicker to occur and the intensity and duration of any effects depend upon the following factors:

1. the location and orientation of the window relative to the turbines;
2. whether a window has direct, unobstructed line of sight to the turbine rotor;
3. the distance of the building to the turbines;
4. the turbine geometry;
5. the time of year (which impacts the trajectory of the sun's path across the sky);
6. the frequency of cloudless skies (particularly at low elevations above the horizon); and,
7. the wind direction (which impacts on turbine orientation).

Several specialist software packages are available that can take account of variables 1-5 listed above to determine the maximum theoretical number of shadow flicker hours that could occur at each window under worst-case conditions. Weather conditions, however, as detailed in items 6 and 7, cannot be accounted for accurately. Therefore, the software model assumes cloudless skies 100% of the time and that all turbines are face on to all receptors. This cannot happen in reality and the output from the model will be inherently conservative, although estimates of typical weather conditions can be factored into the assessment at a later stage to provide a more realistic estimate of the likely occurrence of shadow flicker.

Where obstructions are present between a window and turbine due to terrain, this is accounted for within the software model, however, the model does not consider other obstructions that may be present.

For this assessment, predictions of shadow flicker effects have been undertaken using industry standard software package ReSoft WindFarm, based on the proposed turbine locations and a range of turbine dimensions that consider the extent of the proposed turbine envelope.

12.2.1.1 Relevant Guidance

'*International Legislation and Regulations for Wind Turbine Shadow Flicker Impact*' (Koppen, 2017) presents an overview of the assessment methodologies most commonly used in countries that have their own specific legislation or guidance with regards to shadow flicker effects. The paper states that nearly all countries base their guidance on the German guidelines *'Guideline for Identification and Evaluation of the Optical Emissions of Wind Turbines'(2002).*

The limit values within the German guidelines are 30 minutes per day and 30 days per year. These limits are, however, based on worst case conditions i.e. the total theoretical number of hours per year that shadow flicker may occur assuming that the sun is always shining during daylight hours. If it is found that mitigation measures are required, then a further limit value of 8 hours per year is set based on the real case shadow flicker i.e. what is actually occurring and not the theoretical maximum that may occur.

Many countries have adopted the German guideline limits, either directly or with some small adjustments. Australia, Belgium (Walloon region), Brazil, Canada, India, Sweden, and USA all have a worst-case limit of 30 hours a year or 30 minutes a day. The UK has no set limit but also typically adopts these guideline levels for assessment purposes.

Belgium (Flanders region) sets a real case limit of 8 hours a year or 30 mins a day, Denmark a real case limit of 10 hours a day and Netherlands a real case limit of 17 days a year where shadow flicker occurs for more than 20 minutes a day.

There is no standard for the assessment of shadow flicker in Ireland, although a maximum of 30 hours per year and 30 mins per day within 500 m of a wind turbine is recommended, as detailed in *Wind Energy Development Guidelines* (2006).

12.2.1.2 Cork County Development Plan

The Cork County Development Plan (Cork County Council, 2014) includes a Wind Energy Strategy Map, which identifies three categories of 'Wind Development Area' for large scale commercial wind energy developments. The categories are "Acceptable in Principle", "Open to Consideration" and "Normally Discouraged". The proposed Annagh Wind Farm is located within an area marked "Open to Consideration", for which the Cork County Development Plan 2014 states the following:

> *"Commercial wind energy development is open to consideration in these areas where proposals can avoid adverse impacts on … residential amenity particularly in respect of … shadow flicker".*

Also considered as part of this assessment was the DRAFT Cork County Development Plan 2022-2028 which is currently under review and due for public consultation in January 2022.

12.2.1.3 Wind Energy Development Guidelines (2006)

The current guidance provided by the Department of the Environment, Heritage and Local Government (DoEHLG) states;

> *"Careful site selection, design and planning, and good use of relevant software, can help avoid the possibility of shadow flicker in the first instance. It is recommended that shadow flicker at neighbouring offices and dwellings within 500m should not exceed 30 hours per year or 30 minutes per day.*
>
> *At distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low. Where shadow flicker could be a problem, developers should provide calculations to quantify the effect and where appropriate take measures to prevent or ameliorate the potential effect, such as by turning off a particular turbine at certain times."*

12.2.1.4 IWEA Best Practice Guidelines

In March 2012, the Irish Wind Energy Association (IWEA, now Wind Energy Ireland) issued a document detailing best practice guidance for wind farms (IWEA, 2012).

The document provides a preferred methodology to predict the worst-case shadow flicker conditions in order to provide the most robust results from the assessment. With regards to shadow flicker, the IWEA guidelines support those given in the WEDG 2006, stating:

> *"The assessment of potentially sensitive locations or receptors within a distance of ten rotor diameters from proposed turbine locations will normally be suitable for EIA purposes"*

12.2.1.5 Draft Revised Wind Energy Development Guidelines (2019)

The DoEHLG published the Draft Revised Wind Energy Development Guidelines in December 2019. The draft revised guidelines set out a zero shadow flicker policy, encouraging the use of technology for shadow flicker control, to prevent it occurring at sensitive receptors.

The 2019 revised guidelines are currently at draft stage and following consultation are liable to change before the final version is issued.

12.2.1.6 Use of Guidelines in the Assessment

With due consideration of the above, the assessment has been made as follows:

- A study area of 10 rotor diameters has been defined;
- The WEDG 2006 assessment criteria has been adopted but extended out to cover the entire study area; and,
- The Draft 2019 WEDG have been adopted with regard to mitigation i.e. mitigation is proposed to reduce shadow flicker to zero hours.

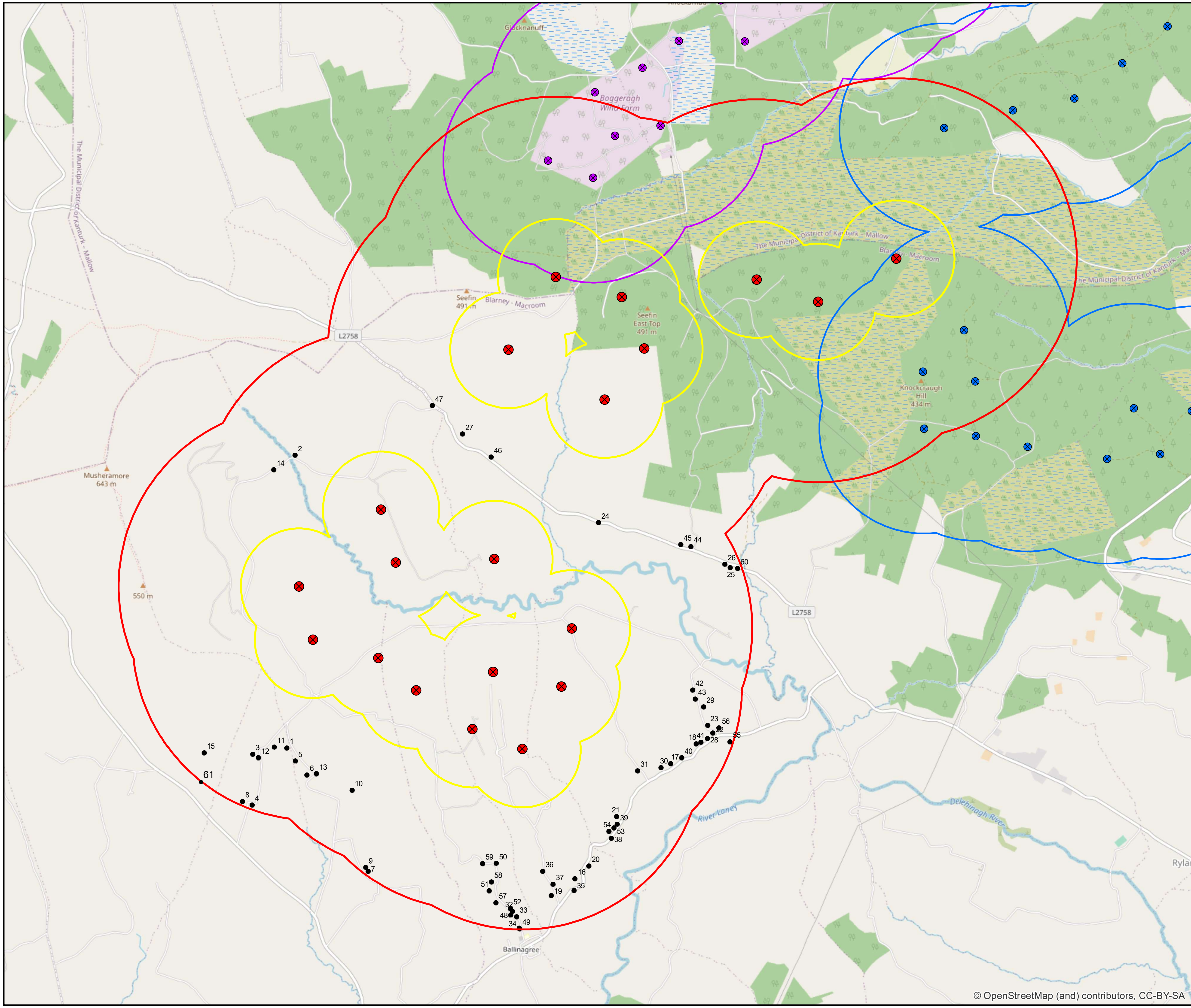
In comparison to both the current WEDG and international recognised guidance, the assessment is therefore inherently conservative.

12.2.2 Field Assessment

Building location data was supplied by Fehily Timoney & Company, derived from a combination of site surveys and supplementary GIS data. The supplied dataset covered an area 10 rotor diameters from the turbines. The dataset was then further refined through the use of aerial imagery to identify any additional buildings to be omitted from the dataset (though none were identified), as well as identifying building condition (habitable, derelict etc.), and building dimensions. The building centre-point co-ordinates were also refined where required. Any building that was clearly identified as uninhabitable (such as a farm outbuilding) was removed from the assessment, however, where it was not possible to confirm, the building was included for assessment.

Due to the large separation distances between the closest receptors and the proposed development, no sensitive receptors are located within the 2006 WEDG 500 m assessment area. A total of 60 sensitive receptors have been identified within the adopted 1550 m shadow flicker study area. The closest receptor is 809 m from the closest wind turbine.

Figure 12.1 details the identified receptors and Appendix 12.1 contains the model input data for all these receptors .



Legend

- Ballinagree Wind Farm
- 500m from Ballinagree Turbines
- 10RD from Ballinagree Turbines
- Potential Shadow Flicker Receptors

Cumulative Wind Farms

- Knockduff Wind Farm
- 10RD from Knockduff Turbines
- Boggeragh Wind Farm
- 10RD from Boggeragh Turbines

0 500 1,000 Metres

N

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Project	Ballinagree Wind Farm
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Figure No.	12.1
Scale	1:30,000 @A3
Doc. Ref.	14616-002-R1

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12.2.3 Extent of Shadow Flicker Assessment

The shadow flicker model calculates the total theoretical occurrence of shadow flicker at all receptors per year based on a theoretical worst-case scenario that assumes the sky is always clear, the turbines are always aligned face-on to each window and that there is a clear and undisturbed line of sight between the windows and the turbines (except where this is prevented due to topography). In reality this will not occur; the turbines will not always be orientated as described, clouds will obscure the sun and line of sight may be obscured, for example, by leaves on trees. The theoretical worst-case scenario allows predictions of all possible shadow flicker occurrences, however in reality actual shadow flicker effects will only be possible for some of this time and only experienced when a room where shadow flicker effects are present is occupied.

In order to provide a more realistic prediction of potential shadow flicker effects, historical weather data can be used to apply a correction factor to predicted annual shadow flicker, which considers the frequency of clear skies when shadows may be cast. Met Éireann provide 30 year average weather data, the most recent of which is from the time period 1981 to 2010. Data has been taken from the nearest long-term weather station to Ballinagree Wind Farm, which is at Cork Airport, to determine the average sunshine hours. This is presented in Table 12-1.

Table 12-1: Average Monthly Sunshine Hours at Cork Airport Weather Station (1981-2010)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
Sunshine Hours: Mean Daily Duration[i]	1.8	2.4	3.3	5.3	6.2	5.8	5.4	5.2	4.3	3	2.3	1.7	3.9
Daylight Hours[ii]	8.4	9.9	11.9	13.9	15.6	16.6	16.1	14.5	12.6	10.6	8.8	7.8	12.2
% Sunshine	21	24	28	38	40	35	34	36	34	28	26	22	32

i Based on meteorological data from Cork Airport 1981-2010 (https://www.met.ie/climate-ireland/1981-2010/cork.html)

ii Based on sunrise and sunset times for Cork 2021 (https://www.sunrise-and-sunset.com/en/sun/ireland/cork/2021)

The annual average percentage of sunshine hours is 32 %, therefore a correction factor of 32 % can be applied to the annual total theoretical predicted levels of shadow flicker to account for the amount of time when the correct meteorological conditions are present for shadows to be cast. It is worth noting that this correction does not account for the additional reductions that would occur as a result of variations in wind speed, wind direction, or by determining whether there is line of sight between a turbine and receiver. Therefore, these 'likely' levels of shadow flicker are still considered to be a conservative estimate.

12.2.4 Modelling Parameters

The levels of shadow flicker at each receptor have been calculated based on a 'greenhouse' modelling approach, where the full length of each façade of a building is modelled as a window (and is therefore sensitive to shadow flicker). Each modelled window is assumed to have a height of 2 m. This approach presents a worst case estimate of shadow flicker; in reality, only the window area of a façade would be sensitive to shadow flicker effects, so the modelling of the full façade will result in higher predicted levels than would normally occur.

Three scenarios have been assessed to consider the extent of the proposed range of turbine dimensions, which is detailed in Table 12-2.

Table 12-2: Proposed Range of Turbine Dimensions

Hub Height (m)		Rotor Diameter (m)		Tip Height (m)	
Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
110.5	102.5	155	149	185	179

Specifically, the following scenarios are considered:

- Scenario 01: Largest Rotor, Highest Tip Height– Considers a rotor diameter of 155 m and a hub height of 107.5 m
- Scenario 02: Highest Hub - Considers the smallest rotor diameter (149 m) on the maximum hub height (110.5 m); and,
- Scenario 03: Largest Rotor - Considers the largest rotor diameter (155 m) on the smallest hub height (102.5 m).

Assessing shadow flicker effects using the scenarios above covers the full range of potential shadow flicker impacts that may occur. Changes in hub height may have a relatively small impact on the predicted levels, however, having a smaller tower does not necessarily mean that the impacts will decrease at all properties (or vice versa). Rather it will result in changes to the time of day and time of year that flicker is predicted at a given property. Using the largest possible rotor diameter to determine the study area for all three scenarios ensures the maximum number of sensitive properties are accounted for.

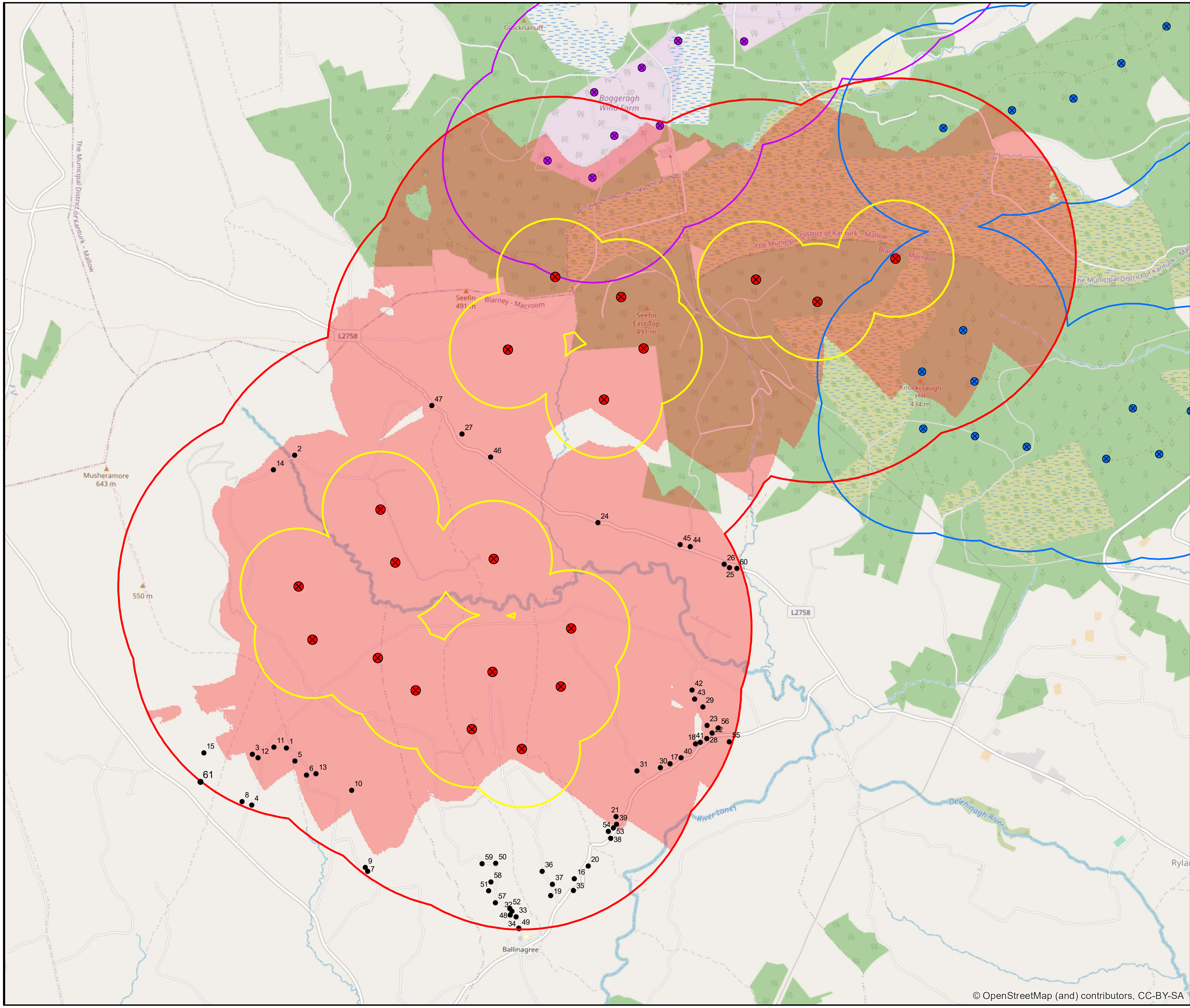
The closest receptor to a proposed turbine is located at a distance of 809m.

12.3 Potential Impacts

The shadow flicker model calculates all possible instances of shadow flicker that may occur throughout the year, based on the sun's path across the sky relative to the turbine and receptor locations, i.e. the total theoretical amount of shadow flicker that may be possible.

The calculated areas over which shadows from the turbines may be cast (resulting in the potential for shadow flicker to occur) are shown in Figures 12.2 (for Scenario 01), 12.3 (Scenario 02) and 12.4 (Scenario 03). The impacts of any other turbine dimensions within the range proposed will fall within the range of potential impacts assessed here.

There is the potential for shadow flicker to occur at up to 35 of the 60 receptors considered within the overall study area for Scenario 01 & Scenario 02 and 38 receptors for Scenario 03. For the remaining receptors there is no potential for shadow flicker effects to occur because the suns angle relative to the turbines and receptors never reaches the required position e.g. at some locations south of proposed turbines. See footnote 1 of section 12.1.1.2 for more detail.



Legend

- Ballinagree Wind Farm
- 500m from Ballinagree Turbines
- 10RD from Ballinagree Turbines
- Maximum Extent of Shadow Coverage from Ballinagree Wind Turbines Within Study Area (Scenario 1)
- Potential Shadow Flicker Receptors

Cumulative Wind Farms

- Knockduff Wind Farm
- 10RD from Knockduff Turbines
- Boggeragh Wind Farm
- 10RD from Boggeragh Turbines

0 500 1,000 Metres

N

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Project	Ballinagree Wind Farm
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Title	Extent of Shadow Coverage (Scenario 1)
Figure No.	12.2
Scale	1:30,000 @A3
Doc. Ref.	14616-003-R1

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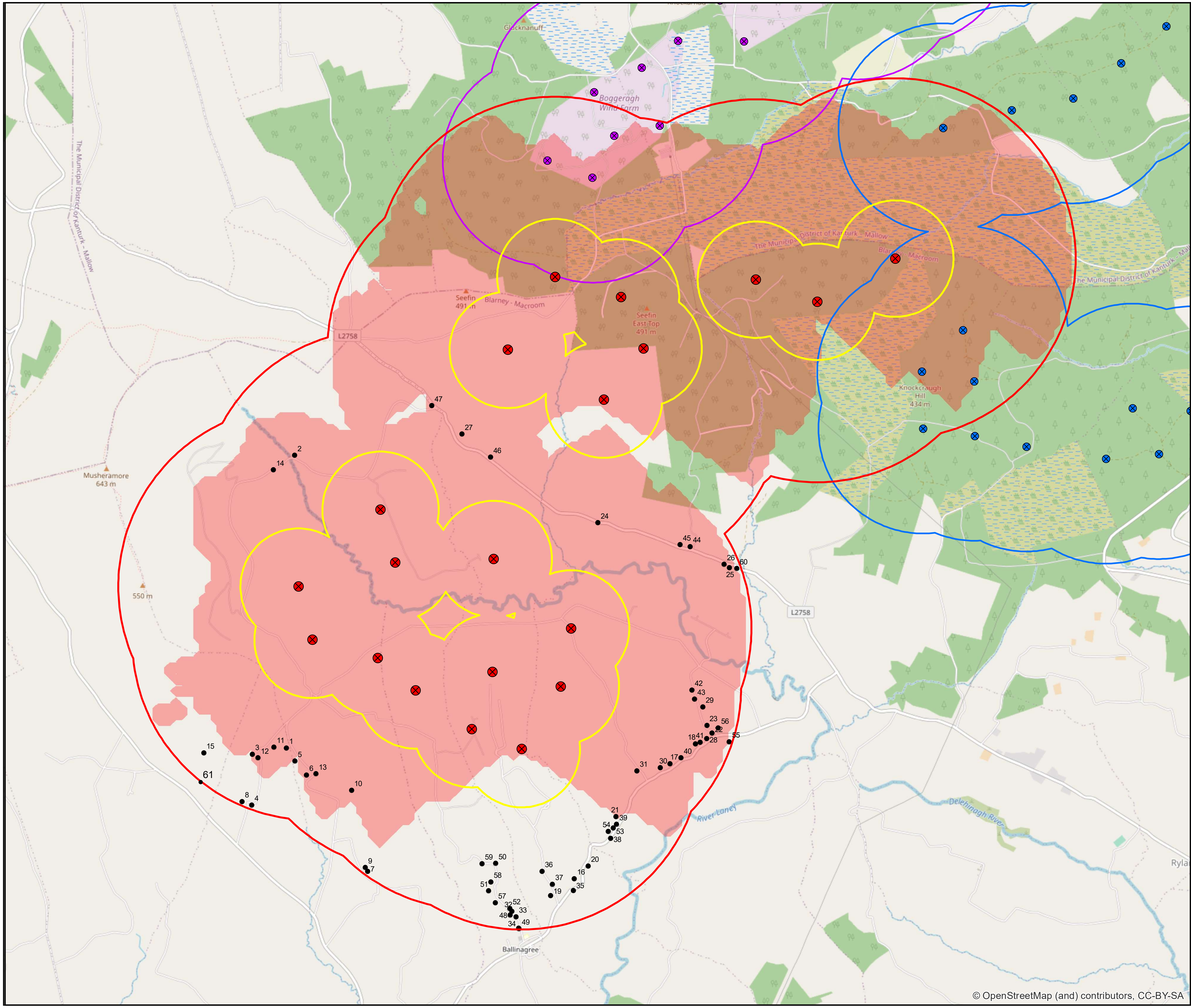

Legend

- Ballinagree Wind Farm
- 500m from Ballinagree Turbines
- 10RD from Ballinagree Turbines
- Maximum Extent of Shadow Coverage from Ballinagree Wind Turbines Within Study Area (Scenario 2)
- Potential Shadow Flicker Receptors

Cumulative Wind Farms

- Knockduff Wind Farm
- 10RD from Knockduff Turbines
- Boggeragh Wind Farm
- 10RD from Boggeragh Turbines

0 500 1,000 Metres

N

REV.	DETAILS	DRAWN	CHK'D	APP'D	DATE
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Project	Ballinagree Wind Farm
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Title	Extent of Shadow Coverage (Scenario 2)
Figure No.	12.3
Scale	1:30,000 @A3
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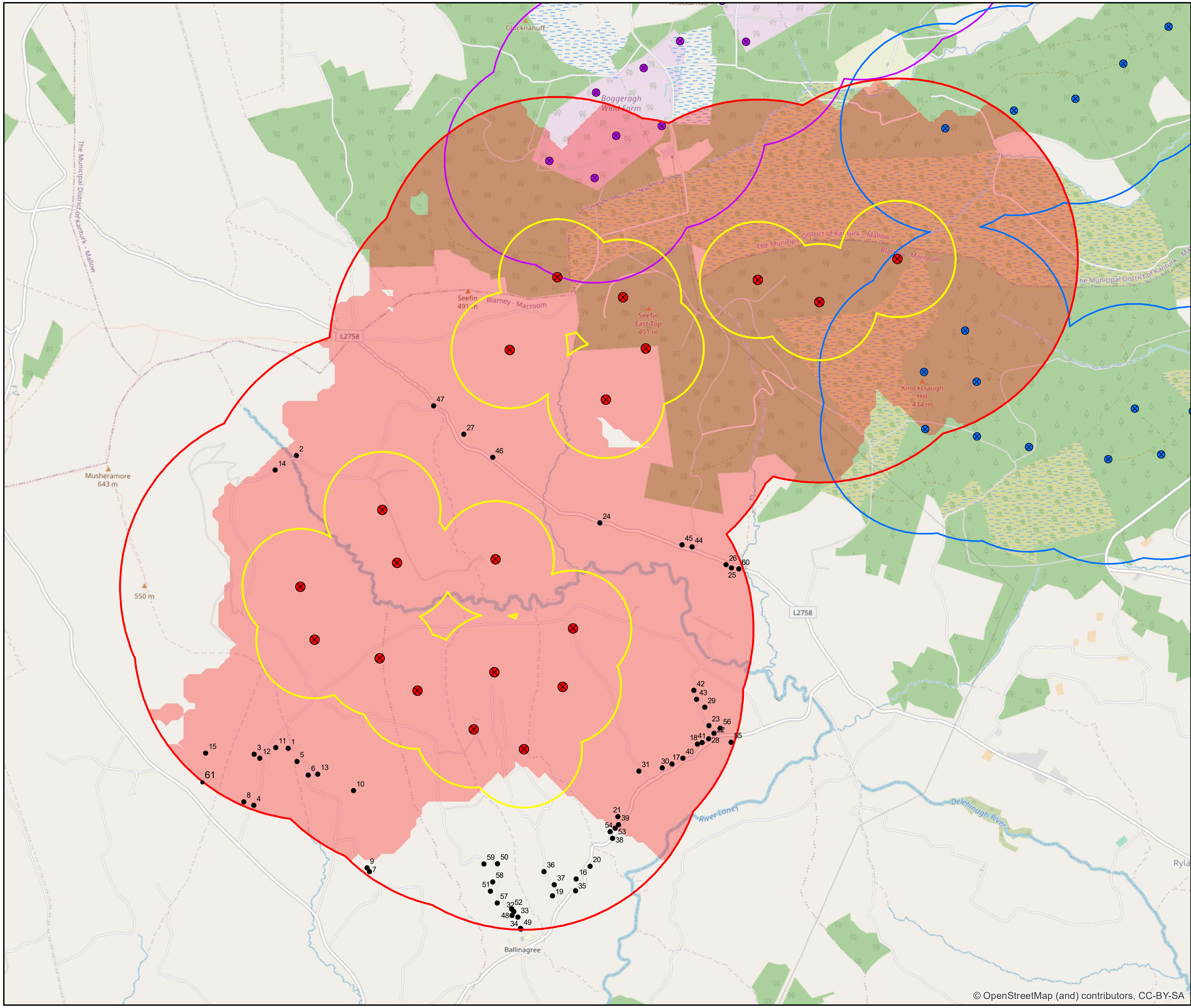

Legend

- Ballinagree Wind Farm
- 500m from Ballinagree Turbines
- 10RD from Ballinagree Turbines
- Maximum Extent of Shadow Coverage from Ballinagree Wind Turbines Within Study Area (Scenario 3)
- Potential Shadow Flicker Receptors

Cumulative Wind Farms

- Knockduff Wind Farm
- 10RD from Knockduff Turbines
- Boggeragh Wind Farm
- 10RD from Boggeragh Turbines

0 500 1,000 Metres

N

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Title	Extent of Shadow Coverage (Scenario 3)
Figure No.	12.4
Scale	1:30,000 @A3
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12.3.1 Annual Impacts

The shadow flicker model for potential annual impacts sets out the total theoretical hours per year that each receptor can potentially receive shadow flicker; however, it does not account for weather conditions, which have a significant impact upon the amount of shadow flicker that may actually occur.

To consider a more realistic situation , annual average sunshine hours for the region have also been taken into account (as detailed in section 12.2.3) and the resultant 'likely' levels of shadow flicker for each scenario also predicted.

12.3.2 Daily Impacts

It is not appropriate to apply the annual average sunshine hours correction to the predicted daily totals as the sunshine data is based upon monthly averages that cannot be applied to daily levels with sufficient accuracy. Accordingly, the calculated daily impacts consider the maximum theoretical amount of shadow flicker only and are, therefore, inherently conservative.

12.3.3 Summary of Annual and Daily Impacts

Table 12-3 presents a summary of the impacts for each modelled scenario. Specifically, it details the number of receptors where shadow flicker effects exceed the WEDG 2006 recommendations for 30 minutes a day and / or 30 hours per year.

Table 12-3: Number of Receptors Exceeding WEDG 2006 Recommendations

	Assessment of Maximum Theoretical Minutes per Day	Assessment of Maximum Theoretical Hours per Year	Assessment of 'Likely' Theoretical Hours per Year
Scenario	**Numbers of Receptors Exceeding Recommended Limits**		
Scenario 01	16	13	1
Scenario 02	16	11	0
Scenario 03	17	23	2

Up to 17 receptors (Scenario 3) may exceed the criteria of 30 minutes a day.

Up to 23 receptors (Scenario 3) may exceed the criteria for 30 hours a year, however, based on historical sunshine data, this is reduced to 2 receptors for a 'likely' scenario.

Table 12-4, Table 12-5 and Table 12-6 present a list of the predicted levels of shadow flicker by receptor for each scenario in turn. Shaded cells represent receptors where the WEDG 2006 guideline levels may be exceeded.

Table 12-4: Shadow Flicker Predicted Levels by Receptor – Scenario 01

Receptor ID	Easting (IRENET 95)	Northing (IRENET 95)	Total Theoretical Days Per Year	Maximum Theoretical Hours Per Day	Total Theoretical Hours Per Year	'Likely' Hours Per Year
1	534395	582655	85	0.59	44.2	14.1
2	534466	585170	79	0.79	47	15.0
3	534103	582603	64	0.48	23.2	7.4
4	534100	582164	0	0	0	0.0
5	534471	582544	81	0.47	29.3	9.4
6	534569	582425	46	0.48	16.7	5.3
7	535095	581596	0	0	0	0.0
8	534015	582195	0	0	0	0.0
9	535075	581629	0	0	0	0.0
10	534957	582291	115	0.64	56.1	18.0
11	534290	582662	95	0.56	40.5	13.0
12	534152	582571	90	0.5	34.2	10.9
13	534649	582434	48	0.49	18.5	5.9
14	534284	585045	54	0.69	29.2	9.3
15	533686	582614	0	0	0	0.0
16	536871	581532	0	0	0	0.0
17	537693	582520	46	0.54	19	6.1
18	537912	582691	81	0.47	24	7.7
19	536667	581388	0	0	0	0.0
20	536990	581642	0	0	0	0.0
21	537229	582067	46	0.46	17.1	5.5
22	538055	582785	34	0.47	10.4	3.3
23	538010	582850	28	0.42	7.5	2.4
24	537075	584592	55	0.71	30.4	9.7
25	538205	584205	38	0.49	14.5	4.6
26	538160	584233	40	0.49	15.2	4.9
27	535906	585354	147	0.7	81.5	26.1
28	538008	582737	37	0.4	9.3	3.0
29	537977	583007	90	0.59	38	12.2
30	537610	582487	49	0.57	21.9	7.0
31	537410	582459	95	0.84	46.4	14.8
32	536334	581252	0	0	0	0.0
33	536370	581205	0	0	0	0.0
34	536394	581108	0	0	0	0.0
35	536864	581431	0	0	0	0.0
36	536593	581595	0	0	0	0.0
37	536682	581484	0	0	0	0.0
38	537183	581881	0	0	0	0.0
39	537234	582000	26	0.27	5.5	1.8
40	537788	582572	72	0.49	20.2	6.5
41	537953	582705	82	0.45	20	6.4
42	537882	583153	115	0.62	58.6	18.8
43	537905	583076	88	0.6	39.2	12.5

Receptor ID	Easting (IRENET 95)	Northing (IRENET 95)	Total Theoretical Days Per Year	Maximum Theoretical Hours Per Day	Total Theoretical Hours Per Year	'Likely' Hours Per Year
44	537867	584386	56	0.58	25	8.0
45	537780	584403	66	0.61	30.6	9.8
46	536153	585155	190	0.67	97.2	31.1
47	535647	585597	29	0.47	11.2	3.6
48	536319	581221	0	0	0	0.0
49	536395	581102	0	0	0	0.0
50	536194	581665	0	0	0	0.0
51	536134	581427	0	0	0	0.0
52	536318	581277	0	0	0	0.0
53	537207	581970	0	0	0	0.0
54	537163	581939	0	0	0	0.0
55	538202	582709	38	0.47	12	3.8
56	538108	582828	71	0.46	18	5.8
57	536192	581326	0	0	0	0.0
58	536154	581506	0	0	0	0.0
59	536078	581661	0	0	0	0.0
60	538268	584198	36	0.45	12.8	4.1
61	533660	582363	0	0	0	0
TOTALS				**Number of Receptors That May Experience:**		
				> 30 Minutes/Day	**> 30 Hours/Year**	
				16	13	1

Appendix 12-2 presents the calculated shadow flicker times that could occur on a turbine by turbine basis for Scenario 01.

Appendix 12-3 presents the calculated shadow flicker times that could occur at individual receptors for Scenario 01.

Table 12-5: Shadow Flicker Predicted Levels by Receptor – Scenario 02

Receptor ID	Easting (IRENET95)	Northing (IRENET95)	Total Theoretical Days Per Year	Maximum Theoretical Hours Per Day	Total Theoretical Hours Per Year	'Likely' Hours Per Year
1	534395	582655	83	0.57	41.8	13.4
2	534466	585170	75	0.76	43.8	14.0
3	534103	582603	62	0.46	21.7	6.9
4	534100	582164	0	0	0	0.0
5	534471	582544	76	0.44	25.8	8.3
6	534569	582425	44	0.46	15.7	5.0
7	535095	581596	0	0	0	0.0
8	534015	582195	0	0	0	0.0
9	535075	581629	0	0	0	0.0
10	534957	582291	112	0.62	52.7	16.9
11	534290	582662	95	0.54	38.4	12.3
12	534152	582571	89	0.48	32.5	10.4
13	534649	582434	47	0.48	17.3	5.5
14	534284	585045	52	0.66	27.1	8.7
15	533686	582614	0	0	0	0.0
16	536871	581532	0	0	0	0.0
17	537693	582520	45	0.52	17.7	5.7
18	537912	582691	81	0.45	23.5	7.5
19	536667	581388	0	0	0	0.0
20	536990	581642	0	0	0	0.0
21	537229	582067	44	0.43	15	4.8
22	538055	582785	34	0.46	10.2	3.3
23	538010	582850	27	0.42	7.3	2.3
24	537075	584592	52	0.68	28.2	9.0
25	538205	584205	37	0.47	13.5	4.3
26	538160	584233	38	0.48	14.1	4.5
27	535906	585354	146	0.69	77.2	24.7
28	538008	582737	36	0.4	9	2.9
29	537977	583007	89	0.57	36.8	11.8
30	537610	582487	48	0.55	20.6	6.6
31	537410	582459	89	0.82	43.3	13.9
32	536334	581252	0	0	0	0.0
33	536370	581205	0	0	0	0.0
34	536394	581108	0	0	0	0.0
35	536864	581431	0	0	0	0.0
36	536593	581595	0	0	0	0.0
37	536682	581484	0	0	0	0.0
38	537183	581881	0	0	0	0.0
39	537234	582000	20	0.21	3.5	1.1
40	537788	582572	69	0.48	18.7	6.0
41	537953	582705	82	0.44	19.4	6.2
42	537882	583153	114	0.6	56.8	18.2
43	537905	583076	88	0.58	38.1	12.2

Receptor ID	Easting (IRENET95)	Northing (IRENET95)	Total Theoretical Days Per Year	Maximum Theoretical Hours Per Day	Total Theoretical Hours Per Year	'Likely' Hours Per Year
44	537867	584386	54	0.56	23.1	7.4
45	537780	584403	62	0.59	28.2	9.0
46	536153	585155	184	0.65	91.4	29.2
47	535647	585597	29	0.45	10.8	3.5
48	536319	581221	0	0	0	0.0
49	536395	581102	0	0	0	0.0
50	536194	581665	0	0	0	0.0
51	536134	581427	0	0	0	0.0
52	536318	581277	0	0	0	0.0
53	537207	581970	0	0	0	0.0
54	537163	581939	0	0	0	0.0
55	538202	582709	38	0.46	11.6	3.7
56	538108	582828	71	0.45	17.4	5.6
57	536192	581326	0	0	0	0.0
58	536154	581506	0	0	0	0.0
59	536078	581661	0	0	0	0.0
60	538268	584198	34	0.44	11.8	3.8
61	533660	582363	0	0	0	0.0
TOTALS				**Number of Receptors That May Experience:**		
				> 30 Minutes/Day	**> 30 Hours/Year**	
				16	11	0

Appendix 12-4 presents the calculated shadow flicker times that could occur on a turbine by turbine basis for Scenario 02.

Appendix 12-5 presents the calculated shadow flicker times that could occur at individual receptors for Scenario 02.

Table 12-6: Shadow Flicker Predicted Levels by Receptor – Scenario 03

Receptor ID	Easting (IRENET95)	Northing (IRENET95)	Total Theoretical Days Per Year	Maximum Theoretical Hours Per Day	Total Theoretical Hours Per Year	'Likely' Hours Per Year
1	534395	582655	137	0.59	61.3	19.6
2	534466	585170	82	0.79	47.4	15.2
3	534103	582603	91	0.48	30.8	9.9
4	534100	582164	36	0.36	10	3.2
5	534471	582544	141	0.49	47.3	15.1
6	534569	582425	133	0.48	42.6	13.6
7	535095	581596	0	0	0	0.0
8	534015	582195	33	0.3	7.9	2.5
9	535075	581629	0	0	0	0.0
10	534957	582291	117	0.64	59.3	19.0
11	534290	582662	142	0.56	54.2	17.3
12	534152	582571	121	0.5	42.4	13.6
13	534649	582434	132	0.49	45.2	14.5
14	534284	585045	55	0.69	29.3	9.4
15	533686	582614	104	0.41	29.3	9.4
16	536871	581532	0	0	0	0.0
17	537693	582520	120	0.72	49.2	15.7
18	537912	582691	93	0.47	25.5	8.2
19	536667	581388	0	0	0	0.0
20	536990	581642	0	0	0	0.0
21	537229	582067	48	0.47	18.4	5.9
22	538055	582785	43	0.45	12.5	4.0
23	538010	582850	26	0.4	6.6	2.1
24	537075	584592	130	0.99	61.6	19.7
25	538205	584205	80	0.49	27.9	8.9
26	538160	584233	111	0.49	36.7	11.7
27	535906	585354	220	0.7	108.3	34.7
28	538008	582737	49	0.41	12.3	3.9
29	537977	583007	88	0.59	37.1	11.9
30	537610	582487	120	0.74	55.7	17.8
31	537410	582459	96	0.83	46.2	14.8
32	536334	581252	0	0	0	0.0
33	536370	581205	0	0	0	0.0
34	536394	581108	0	0	0	0.0
35	536864	581431	0	0	0	0.0
36	536593	581595	0	0	0	0.0
37	536682	581484	0	0	0	0.0
38	537183	581881	0	0	0	0.0
39	537234	582000	30	0.3	7	2.2
40	537788	582572	120	0.69	37.2	11.9
41	537953	582705	77	0.44	18.1	5.8
42	537882	583153	115	0.72	58.8	18.8
43	537905	583076	87	0.6	38	12.2

Receptor ID	Easting (IRENET95)	Northing (IRENET95)	Total Theoretical Days Per Year	Maximum Theoretical Hours Per Day	Total Theoretical Hours Per Year	'Likely' Hours Per Year
43	537905	583076	0	0	0	0.0
44	537867	584386	145	0.58	64.2	20.5
45	537780	584403	143	0.72	72.1	23.1
46	536153	585155	221	0.67	109.7	35.1
47	535647	585597	108	0.47	32.4	10.4
48	536319	581221	0	0	0	0.0
49	536395	581102	0	0	0	0.0
50	536194	581665	0	0	0	0.0
51	536134	581427	0	0	0	0.0
52	536318	581277	0	0	0	0.0
53	537207	581970	0	0	0	0.0
54	537163	581939	0	0	0	0.0
55	538202	582709	61	0.46	19.1	6.1
56	538108	582828	78	0.45	19.7	6.3
57	536192	581326	0	0	0	0.0
58	536154	581506	0	0	0	0.0
59	536078	581661	0	0	0	0.0
60	538268	584198	73	0.45	24.3	7.8
61	533660	582363	0	0	0	0
TOTALS				**Number of Receptors That May Experience:**		
				> 30 Minutes/Day	**> 30 Hours/Year**	
				17	23	2

Appendix 12-6 presents the calculated shadow flicker times that could occur on a turbine by turbine basis for Scenario 03.

Appendix 12-7 presents the calculated shadow flicker times that could occur at individual receptors for Scenario 03.

12.3.4 Potential Cumulative Impacts

The IWEA Guidelines recommend that all existing and / or permitted wind farm developments within 2 km of a proposed development should be considered in a cumulative shadow flicker assessment, however, the key factor to determine whether cumulative effects may occur is whether receptors are located within overlapping 10 rotor diameter areas around multiple wind farms.

There are two wind farms in the immediate vicinity of the proposed development, Boggeragh Wind Farm (Cork County Council planning ref. 085944) to the north, and Knockduff Wind Farm (Cork County Council planning ref. 108067, also referred to as Boggeragh 2 in this EIAR) to the north east. Boggeragh Wind Farm consists of 19 no. Vestas V90/3000 turbines, and Knockduff Wind Farm consists of 26 Nordex N90/2500 turbines. Both developments are operational, and have been considered in relation to potential cumulative impacts of shadow flicker.

Study areas have been defined based on 10 rotor diameters from each of the developments – 900 m for both the Boggeragh turbines and the Knockduff turbines – and these are shown on Figure 12.1. Due to the close proximity of Boggeragh and Knockduff to the proposed development, there is considerable overlap between the two study areas, however, no shadow flicker receptors have been identified within the areas where the study areas overlap. Therefore, it can be concluded that the potential cumulative impact of shadow flicker is negligible when considering the potential impacts of Ballinagree Wind Farm in combination with other developments.

12.4 Mitigation Measures

Shadow flicker control modules, consisting of light sensors and specialised software, will be installed on the turbines as part of a system to prevent operation during periods when shadow flicker may occur. The calculated potential shadow flicker periods will be input into the turbine control software and when the correct conditions are met e.g. the light intensity is sufficient, turbine orientation is correct etc. during these periods, individual turbines will cease operation until the conditions for shadow flicker are no longer present. These are standard, widely accepted control modules that are installed in most wind turbines.

When the conditions for shut down are met the turbines will gradually come to a stop, however, it should be recognized there will be a short period of time before complete shutdown occurs. This will depend on the reaction time of the shadow flicker control modules and the particular turbine type, as well as a gradual reduction in rpm i.e. the blades will not come to a sudden stop.

The proposed method of mitigation will be used to mitigate all shadow flicker effects resulting in zero shadow flicker, allowing for a short time for the rotor to come to a stop. Appendices 12.2, 12.4 and 12.6 contains all calculated potential shadow flicker periods for each turbine for each scenario, which covers the range of shadow flicker effects that may occur across the range of proposed turbine dimensions. The relevant data (depending on which scenario is constructed) will be input into the turbine control software. Where the final turbine specification does not match exactly with one of the three modelled scenarios an additional shadow flicker model will be run with the finalised dimensions.

12.5 Residual Impacts

The results of the shadow flicker assessment predict that Ballinagree Wind Farm has the potential to result in shadow flicker at a maximum of 38 receptors surrounding the site. The implementation of mitigation to cease operation of the turbines during periods of potential shadow flicker will ensure that no shadow flicker effects are experienced at any sensitive receptor within 10 rotor diameters of a turbine.

It is therefore considered that Ballinagree Wind Farm will comply with the recommended limits of 30 hours per year and 30 minutes per day detailed within the Wind Energy Development Guidelines (2006) and the zero shadow flicker policy as set out in the Draft Revised Wind Energy Development Guidelines (2019). Following implementation of mitigation measures described in Section 12.4, the residual impact as a result of shadow flicker will be imperceptible. Accordingly, it is considered that there will be no residual impact as a result of shadow flicker.

12.6 Do-Nothing Scenario

In the 'Do-Nothing' Scenario, Ballinagree Wind Farm would not be constructed and the potential impacts from shadow flicker on receptors within the study area would not occur. No mitigation measures would be required.

12.7 Conclusion

A shadow flicker assessment has been undertaken on all receptors within 10 rotor diameters of the proposed Ballinagree Wind Farm. The assessment considers a number of turbine specifications to address potential variations in turbine envelope including maximum and minimum rotor diameter, hub height and tip height and covers the full range of shadow flicker effects that may occur.

Based on the WEDG 2006 thresholds, the predicted 'Maximum Theoretical Hours Per Day' of shadow flicker exceeds 30 minutes at up to 17 receptors.

When considering the 'Total Theoretical Hours Per Year', up to 23 receptors are predicted to exceed the WEDG 2006 threshold of more than 30 hours per year. However, when accounting for a more *'likely'* scenario, where the average annual sunshine hours are taken into account, the levels are predicted to exceed more than 30 hours per year at no more than 2 receptors.

A scheme of mitigation would be implemented using turbine control software to cease turbine operation during periods when shadow flicker is predicted, therefore, zero shadow flicker will occur (allowing for a short time for the rotor to come to a stop) within 10 rotor diameters of the wind farm. As such, the proposed development would meet the requirements of both WEDG 2006 and the draft WEDG 2019.

No cumulative impacts with other proposed or operational wind farms in the area are predicted to occur on any receptors in the study area.

12.8 References

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