Draft Environment and Social Impact Assessment

Project Number: 55205-001
29 April 2022

Lao PDR: Monsoon Wind Power Project
Part 7: Main Report

Prepared by Impact Energy Asia Development Limited (IEAD) for the Asian Development Bank.

Monsoon Wind Power Project, Sekong and Attapeu Provinces, Lao PDR

Environmental and Social Impact Assessment

29 April 2022

Project No.: 0598121

The business of sustainability

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2	2.1	As above	As above	Kamonthip Ma-Oon	29-04-22	Final ESIA Report

Significance of Impact				
Receptor Sensitivity	The receptors are Low to medium sensitivity.			
Impact Significance	**Negligible**	**Minor**	**Moderate**	**Major**
	The moderate to major impacts are for VSR 5, 7, 17, 18, and 19.			
Residual Impact Magnitude	Positive	Negligible	Small	**Medium**
Residual Magnitude Significance	**Negligible**	**Minor**	**Moderate**	Major
	Upon considering the mitigation measure, the residual impact is assessed to be Moderate, at worst.			

8.3.8 Impacts Associated with Shadow Flicker

Shadow flicker is "*the flickering effect caused when rotating wind turbine blades periodically cast shadows through constrained openings such as the windows of neighboring properties*".[94] Its occurrence in a specific location can be modelled and assessed[95] taking into account the relative positions of the sun throughout the year (dependent on the latitude of the site), the wind turbine layout and orientation, and the presence of sensitive receptors (e.g., inhabitants of residential buildings).

8.3.8.1 Scope of Assessment

The likelihood and duration of the flicker effect depends upon a number of factors, including:

- Direction of the property relative to the turbine;
- Turbine height and rotor diameter;
- Time of day and year;
- Distance from the turbine (the further the observer is from the turbine, the less pronounced the effect will be);
- Wind direction (that affects potential wind turbine orientation); and
- Weather conditions (presence of cloud cover, fog, and humidity reduces the occurrence of shadow flicker as the visibility itself of the turbine is reduced).

In general, shadow flicker occurs during clear sky conditions, when the sun is low on the horizon. As the angle of the sun on the horizon changes throughout the year, the locations experiencing the phenomenon changes, so specific shadow receptors can be affected in different periods.

The theoretical number of hours of shadow flicker experienced annually at a given location can be calculated using modelling packages incorporating the sun path, topographic variation over the wind farm site, and wind turbine details, such as rotor diameter and hub height.

When assessing shadow flicker impacts, the worst case and/or real case impacts are determined by:

- ***Worst Case Scenario***: the astronomical maximum possible shadow flicker duration is defined as the shadow flicker duration which occurs when the sun is always shining during daylight hours (i.e., the sky is always clear), the wind turbine is always rotating and the rotor plane is always perpendicular to the line from the WTG to the sun;

94 https://www.gov.uk/government/news/wind-turbine-shadow-flicker-study-published

95 It should be noted that modelling methods tend to be conservative and typically result in an over-estimation of the number of hours of shadow flicker likely to be experienced at the identified receptors.

- ***Real Case Scenario***: the expected shadow flicker duration is when the average sunshine hour probabilities and wind statistics of the particular region are taken into account.

The following section briefly describes the modelling package used, as well as the input criteria for assessing the shadow flicker throughout the different scenarios identified in the introduction.

Applicable Standards

In August 2015, the World Bank Group published the Environmental, Health and Safety (EHS) Guidelines for Wind Energy. These are technical reference documents containing examples of good industry practice.

The definition adopted in the EHS guidelines states that shadow flicker occurs when the sun passes behind the wind turbine and casts a shadow. As the rotor blades rotate, shadows pass over the same point causing an effect termed shadow flicker. Shadow flicker may become a problem when potentially sensitive receptors (e.g., residential properties, workplaces, learning and/or health care spaces/facilities) are located nearby, or have a specific orientation to the wind energy facility.

Key points identified in the guidelines include:

- Potential shadow flicker issues are more likely at higher latitudes where the sun is lower in the sky and therefore shadows are longer, which extends the radius where potentially significant shadow flicker impact will be experienced.
- If it is not possible to locate the wind turbines where neighboring receptors experience no shadow flicker effects, it is recommended that the predicted duration of shadow flicker effects experienced at a sensitive receptor should not exceed 30 hours per year and 30 minutes per day on the worst affected days, based on a worst-case scenario.
- Recommended prevention and control measures to avoid significant shadow flicker impacts include siting wind turbines appropriately to avoid shadow flicker being experienced or to meet limits placed on the duration of shadow flicker occurrence, as set out in the paragraph above, or programming turbines to shut down at times when shadow flicker limits are exceeded.

Globally, several countries have identified national guidelines to evaluate and assess the potential impacts related to shadow flickering. As the shadow flickering is affected by the angle of the sun at the horizon, it is considered to be more relevant at higher latitudes, leading northern and southern countries to publish specific technical guidelines. In the relatively few cases where the real case impact is regulated, the limit value for dwellings is 8 or 10 hours per year.

Table 8.39 outlines the most relevant guidelines currently in place worldwide and that are able to inform and influence international best practice and standards.

Table 8.39: Relevant National Standards

Country	Reference	Relevant Notes
England	■ Planning for Renewable Energy - A companion guide to PPS22 (Planning policy statement 22) – Office of the Deputy Prime Minister 2004 ■ Onshore Wind Energy Planning Conditions Guidance notes – Renewables Advisory Board and BERR (Business Enterprise and Regulatory Reform) 2007 ■ UK Government Department for Communities and Local Government (March 2012)	■ Shadow flicker has been proven to occur only within a distance of 10 rotor diameters from the turbines. ■ Shadow flicker only occurs inside buildings where the flicker appears through a narrow window opening.

Country	Reference	Relevant Notes
	■ National Planning Policy Framework ■ UK Government Department for Communities and Local Government (July 2013) Planning practice guidance for renewable and low carbon energy	
Northern Ireland	■ Best Practice Guidance to Planning Policy Statement 18 'Renewable Energy' – Northern Ireland Department of the Environment 2009	■ Shadow flicker only occurs inside buildings through narrow window openings. ■ The potential for shadow flicker at distances greater than 10 rotor diameters is very low. ■ It is recommended that shadow flicker at neighboring residential buildings and offices should not exceed 30 hours per year.
Ireland	■ Ireland Government Department of Environment (2013) Wind Energy Development ■ Guidelines	■ Shadow flicker only occurs inside buildings through narrow window openings. ■ The potential for shadow flicker at distances greater than 10 rotor diameters is very low. ■ It is recommended that shadow flicker at neighboring residential buildings and offices should not exceed 30 hours per year.
Germany	■ Länderausschuss für Immissionsschutz (2002) Hinweise zur Ermittlung und Beurteilung der optischen Immissionen von Windenergieanlagen (WEA-Schattenwurf-Hinweise) (Guideline for Identification and Evaluation of the Optical Emissions of Wind Turbines)	■ Worst case scenario limited to a maximum of 30 hours per year and 30 minutes per day. ■ Real case limited to 8 hours per day (a limitation driven by sensor equipment and if worst case limit would be exceeded). ■
Australia	■ Environment Protection and Heritage Council (EPHC) (2010) National Wind Farm Development Guidelines	■ Worst case: 30 hours/year. ■ No daily limit. ■ Real case: 10 hours/year (only required if worst case exceeds 30 hours/year).
Canada	■ Natural Forces Wind Inc (June 2013) Gaetz Brook Wind Farm Shadow Flicker Assessment Report	■ Worst case: 30 hours/year and 30 min/day.
USA	■ National Association of Regulatory Utility Commissioners (NARUC) Grants & Research Department (January 2012) Wind Energy & Wind Park Siting and Zoning Best Practices and Guidance for States	■ Worst case: 30 hours/year and 30 min/day.
Denmark	■ Danish Government – Miljøministeriet Naturstyrelsen (2015) Vejledning om planlægning for og tilladelse til opstilling af vindmøller, 19-20	■ Real case: 10 hours/year
Netherlands	■ Nederlandse overheid – Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer (2017) Regeling algemene regels voor inrichtingen milieubeheer, Art. 3.12	■ Wind turbines shall be equipped with an automatic shadow flicker control system, which stalls the turbine if shadow flicker occurs at sensitive receptors and the distance between the turbine and the sensitive

Country	Reference	Relevant Notes
		receptor is less than 12 times the rotor diameter and if on average the shadow flicker occurs more than 17 days per year for more than 20 minutes per day. ■ Receptors like office buildings are not mapped as sensitive receptors.

Currently, **Laos has not defined national legislation or guidelines to assess shadow flickering** and there are no international guidelines on standards to be followed for the real case scenario. Among the above mentioned national standards, there are a few differences in the exact implementation of the shadow flicker regulation. Some countries and jurisdictions only consider the worst case scenario, relatively few countries also consider the real case impact.

The table shows that not all countries have guidelines or regulations for assessing and limiting shadow flicker impacts. In countries lacking regulations for shadow flicker, the German guideline is often applied as best practice.

As per this consideration, this study considered the IFC guidelines as a reference, integrating the results with a real case scenario modeling in order to assess the effect raised by the inclusion of more local conditions. Based on the analysis of the different national standards, it is proposed to take into consideration the most conservative ones that place the annual limits at 8 or 10 hours (Germany, Australia, and Denmark).

Receptors

Some internationally adopted reference standards (A.D. Clarke 1991)[96] exclude the occurrence of flickering shadows beyond a distance of 10 times the rotor size (in this case 1,550-1,650m).

This approach has been criticized recently in 2017 by ClimateXChange (Scotland's centre of expertise connecting climate change research and policy) and LUC (landuse.co.uk), and suggested that the Scottish guidance should not include a reference to 10 times the rotor diameter.

Considering the receptor distribution and the characteristics of the local landscape, in order to apply a more conservative approach, it was assumed to consider a 2 km study area to map the receptors, beyond the more standard approach suggested by A.D. Clarke.

A total of 2,675 potential shadow flicker receptors (***Figure 8.37***) were identified in a desktop study using topographical maps, aerial photographs, and on site field visits. The project is located in a forested area (***Figure 8.38***).

There are sparsely populated settlements or small communities, where the land is mainly dedicated to agricultural activities. The largest residential area is Dak Chueng in the North East area.

[96] Clarke A.D. 1991: A case of shadow flicker / flashing: assessment and solution. Techno Policy Group, Open University. Milton Keynes, UK

Figure 8.37: Location of Receptors

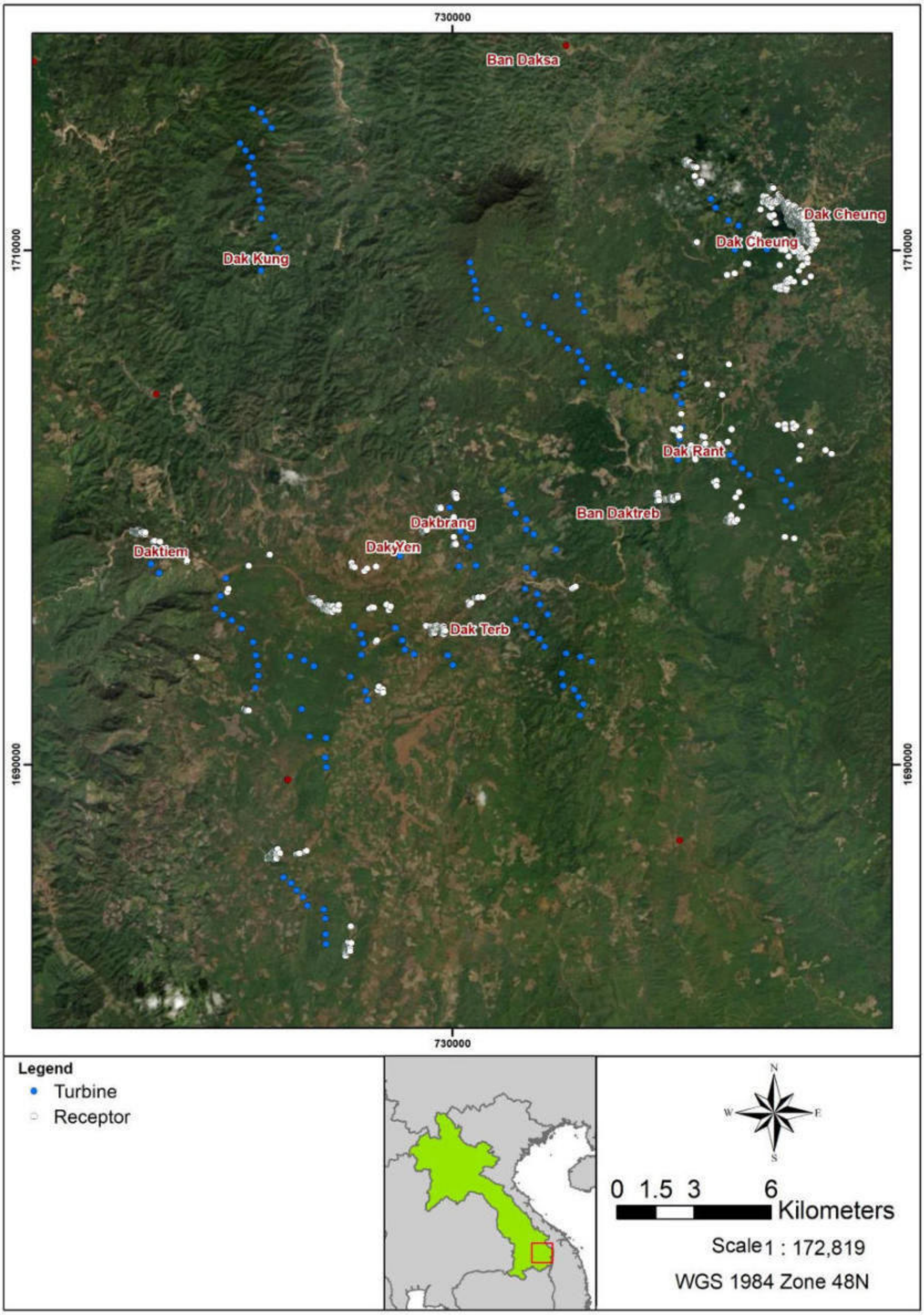


Figure 8.38: Photos of Forests Surrounding Receptors

Shadow Flicker Analysis and Results

WindPro Model: Scenarios and Input Criteria

This assessment has been undertaken using the WindPro 3.4©; a computer package widely used in the wind industry. The software package includes a Shadow Flicker Module (SHADOW) that calculates how often and the intervals in which a specific neighbor or area will be affected by one or more wind turbines.

As reported in the introduction, two main scenarios have been modelled: Worst Case Scenario and Real Case Scenario.

Within the Worst Case Scenario, the calculations are based on conditions that would provide the maximum amount of shadow flicker with no parameters characterizing the local settings and conditions, as well as project specific characteristics, such as:

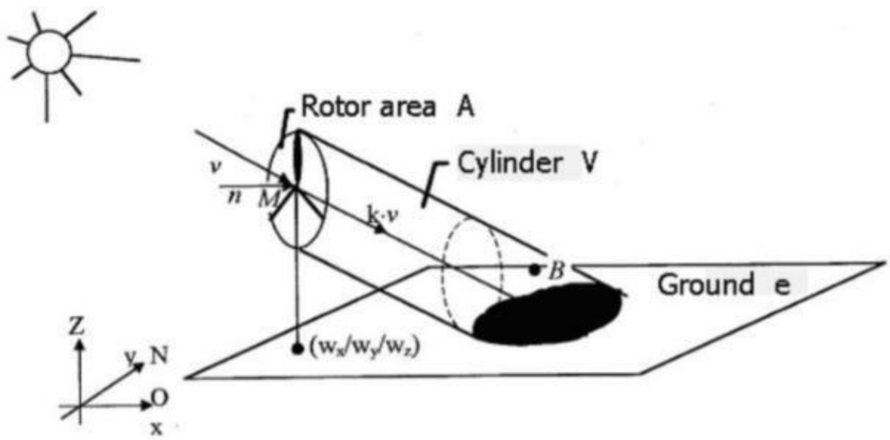
- The presence of physical barriers is not considered;
- Natural vegetation screening is not included;
- Cloud cover, and humidity is not included;
- The sun is shining all the day, from sunrise to sunset;
- Rotor is not turned off for low winds or high winds; and
- Shadow receptors are modelled using the greenhouse mode, meaning that each receptor will face all directions (360 degree visibility).

Within the Real Case Scenario, calculations are based on a more realistic situation where the sun shining probability is based on real datasets. However, it should be stated that such modelling assumptions are not taking into consideration other parameters characterizing the local settings (e.g., wind speed or monsoons) and in any case may lead to an overestimation of the shadow flickering occurrence.

All scenarios have been carried out with a temporal resolution of 1 minute, meaning if shadow flicker is predicted to occur in any 1-minute period, the model records this as 1 minute of shadow flicker.

Independent of the selected scenario, the model calculates outputs according to the principles presented in ***Figure 8.39***.

Figure 8.39: Shadow flickering theory



Source: WindPro user manual

All dwellings/group of dwellings on site have been modelled taking into consideration the following:

- Single story buildings, and so shadow flicker has been calculated at a height of 1 m (equivalent to the first floor windows);
- Slope of the window has been set to 90°; and
- The identified receptors are simulated as fixed points with the possibility to view 360°C, representing an unrealistic scenario, as real windows would be facing only a particular direction.

Worst Case Scenario

The following assumptions have been considered in the modelling setting for Worst Case Scenario:

- Rotors are always turning;
- Sun is always shining, all the day, from sunrise to sunset;
- Local topography has been obtained from digital terrain model (DTM)
- No cloud cover or any other meteorological conditions that could potentially reduce visibility and sunlight;
- Receptors modelled using greenhouse mode (the receptor is not facing one particular direction, but instead is facing all directions); and
- No physical barriers are considered.

Real Case by Statistics Scenario

The following assumptions have been considered in the modelling setting for Real Case Scenario:

- Data about the average daily sunshine hours presented in below (derived statistically for the site from ERA5 cloud cover data):

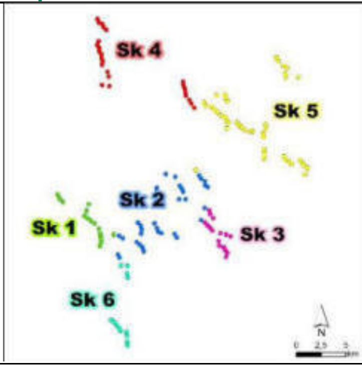
Sunshine probability S (Average daily sunshine hours) []

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4,98	7,98	6,98	2,79	2,56	1,24	2,13	0,53	1,41	0,47	3,63	2,78

- Local topography has been obtained from SRTM DTM;
- Estimation of indicative annual cloud coverage, no other meteorological conditions that could potentially reduce visibility and the sunlight have been assumed;
- Receptors modelled using greenhouse mode;
- No existing physical barriers have been considered such as forests; and
- Rotors are always turning; the site was divided into six areas and the operational hours for each sector depends on the area of the site in which the turbine is located (***Table 8.40***).

Table 8.40: Operational hours by sector for every site areas

Map	Area	Operational time												
		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	Sum
	Sk 1	147	262	3.015	686	200	281	424	957	1.937	439	221	191	8.760
	Sk 2	136	314	3.584	417	135	270	742	858	781	686	508	329	8.760
	Sk 3	159	164	3.182	1.175	146	201	359	495	1.157	1.043	363	314	8.758
	Sk 4	223	367	2.810	686	230	286	519	914	1.363	710	416	236	8.760
	Sk 5	142	2.813	688	94	81	96	432	1.408	2.111	590	184	121	8.760

Map	Area	Operational time																
		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	Sum				
	Sk 6	159	1.110	2.432	258	166	416	1.314	1.190	614	437	403	260	8.759				

It should be noted that for the Real Case Scenario the shadow flickering assessment performed with such assumptions is still likely an over estimation in terms of the annual number of hours of flickering experienced at a specific location due to the following reasons:

- The occurrence of cloud cover has the potential to significantly reduce the number of hours during which the observer is experiencing the flickering;
- The presence of fog and high humidity can reduce the visibility and consequently reduce the effects of flickering on the observer;
- The presence of aerosols in the atmosphere have the ability to influence the flickering duration, as the length of the shadow cast by a wind turbine is dependent on the degree that direct sunlight is diffused, which is strictly dependent on the amount of dispersant in between the observer and the rotor; and
- The analysis has not considered the presence of vegetation or other physical barriers around a receptor that are able to shield the view (at least partially) of the turbine.

Table 8.41 outlines the modeling settings adopted for each scenario.

Table 8.41: WindPro shadow module inputs (the key differences between the scenarios are in bold)

Inputs	Worst Case Scenario	Real Case Scenario
Rotor diameter and hub height	155-165m / 110m	155-165m / 110m
Wind turbine operation	Rotors are always turning	Rotors are always turning
Wind turbine visibility	A WTG will be visible if it is visible from any part of the receiver window (greenhouse mode)	A WTG will be visible if it is visible from any part of the receiver window (greenhouse mode)
Window stories dimensions	1m height / 1 m large / 1 m from the first floor	1 m height / 1 m large / 1 m from the first floor
Cloud cover	Not considered	ERA5 cloud cover data
Physical barriers (i.e., vegetation)	Not considered	Not considered
Minimum sun height over horizon for influence	3°	3°
Day step for calculation	1 day	1 day
Time step for calculation	1 minute	1 minute
Shining period	**The sun is always shining all day, from sunrise to sunset**	**The sun is shining as per local sunshine data provided**

Height contour	SRTM DTM	SRTM DTM
Eye height	1.5 m	1.5 m

Model Results

As presented above, two scenarios have been modelled using Shadow Flickering WindPro Module to identify the receptors potentially affected by the flickering. The project area is characterized by the presence of different dwellings/group of dwellings, mainly in the Dak Cheung Village.

The following sections outline the number of potentially affected receptors for each scenario.

1. Worst Case Scenario – Results

As reported above, the modelling package calculates the predicted shadow flickering durations at receptors. The Worst Case Scenario has considered a fully worst case scenario with unrealistic conditions leading to a potential of 484 impacted receptors (both for hours/year and minutes/day) among the 2,675 mapped receptors. For these, IFC thresholds have been exceeded for both parameters: hours/year and minutes/day.

The following maps present the distribution of areas where flickering is calculated according to the Worst Case Scenario (***Figure 8.40*** and ***Figure 8.41***). For further detailed modeling results, refer to ***Appendix E.***

Figure 8.40: Map of predicted shadow flicker (hours/year) – Worst Case Scenario

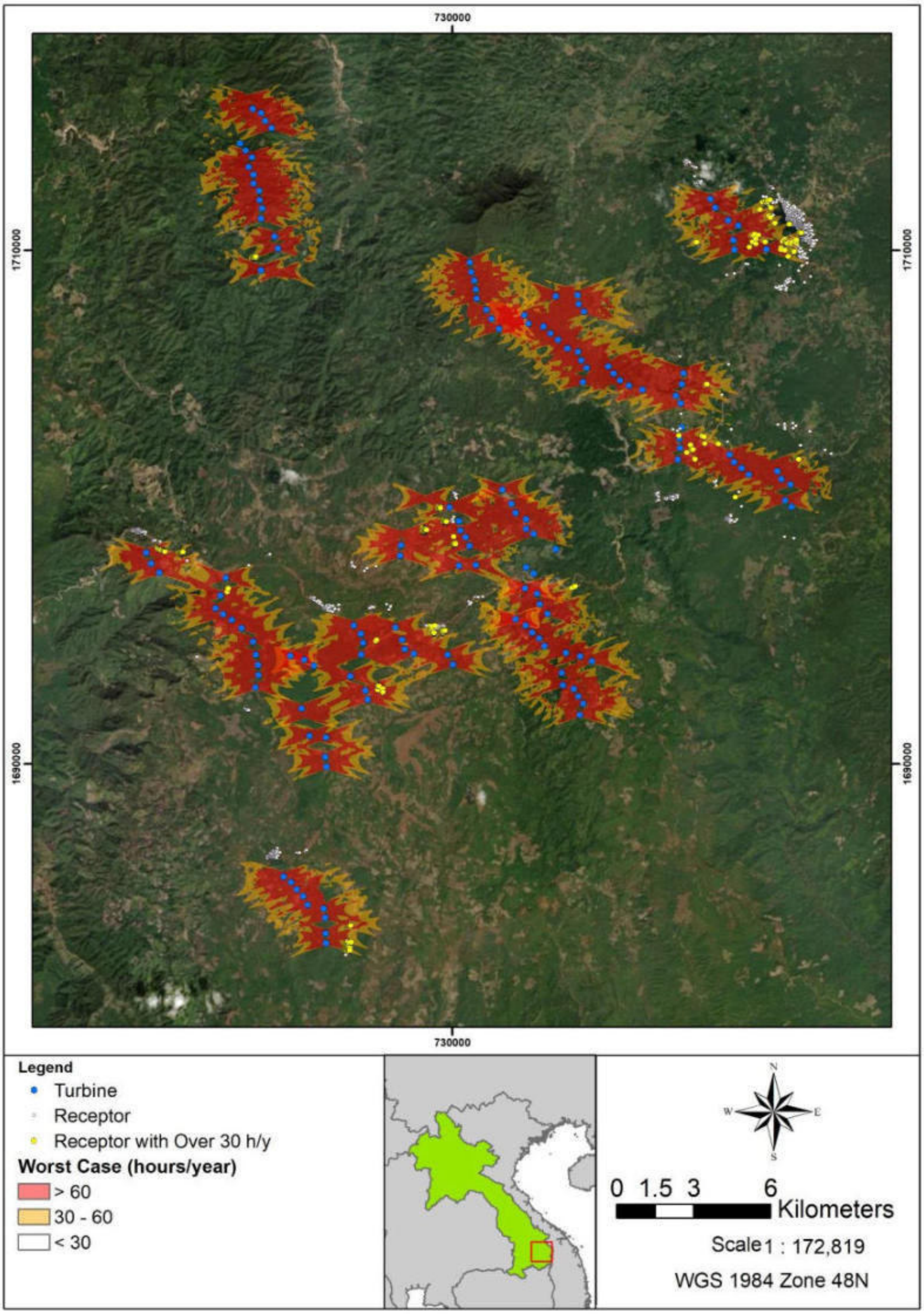
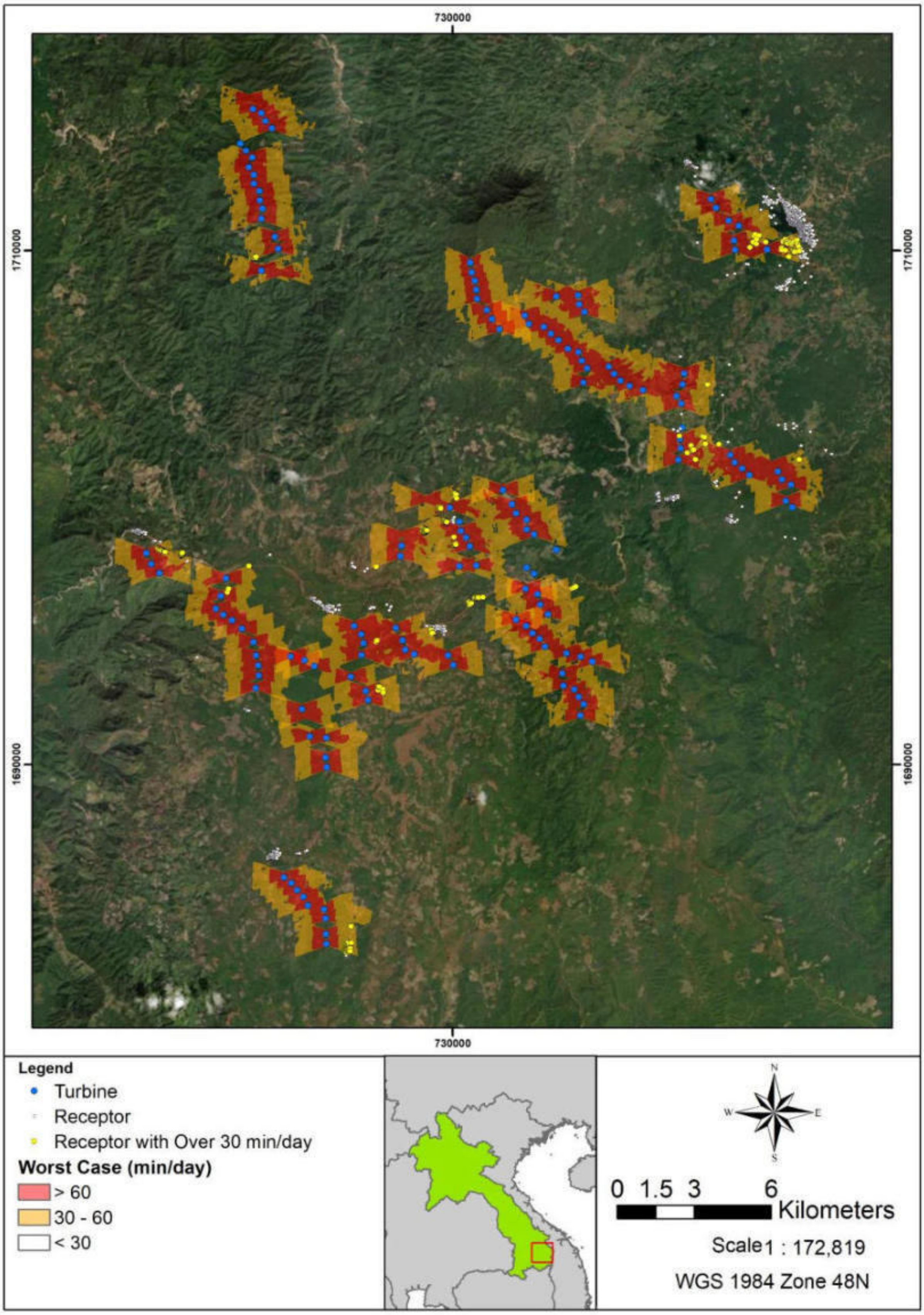


Figure 8.41: Map of predicted shadow flicker (min/day) – Worst Case Scenario



2. Real Case by Statistics Results – Real Case Scenario

Following the results of the Worst Case Scenario presented in the previous section, a second scenario was calculated in order to assess the effect raised by the inclusion of more local conditions (the average daily sunshine hours and wind direction) on the 484 receptors that exceeded the threshold defined by the World Bank EHS for shadow flicker issues.

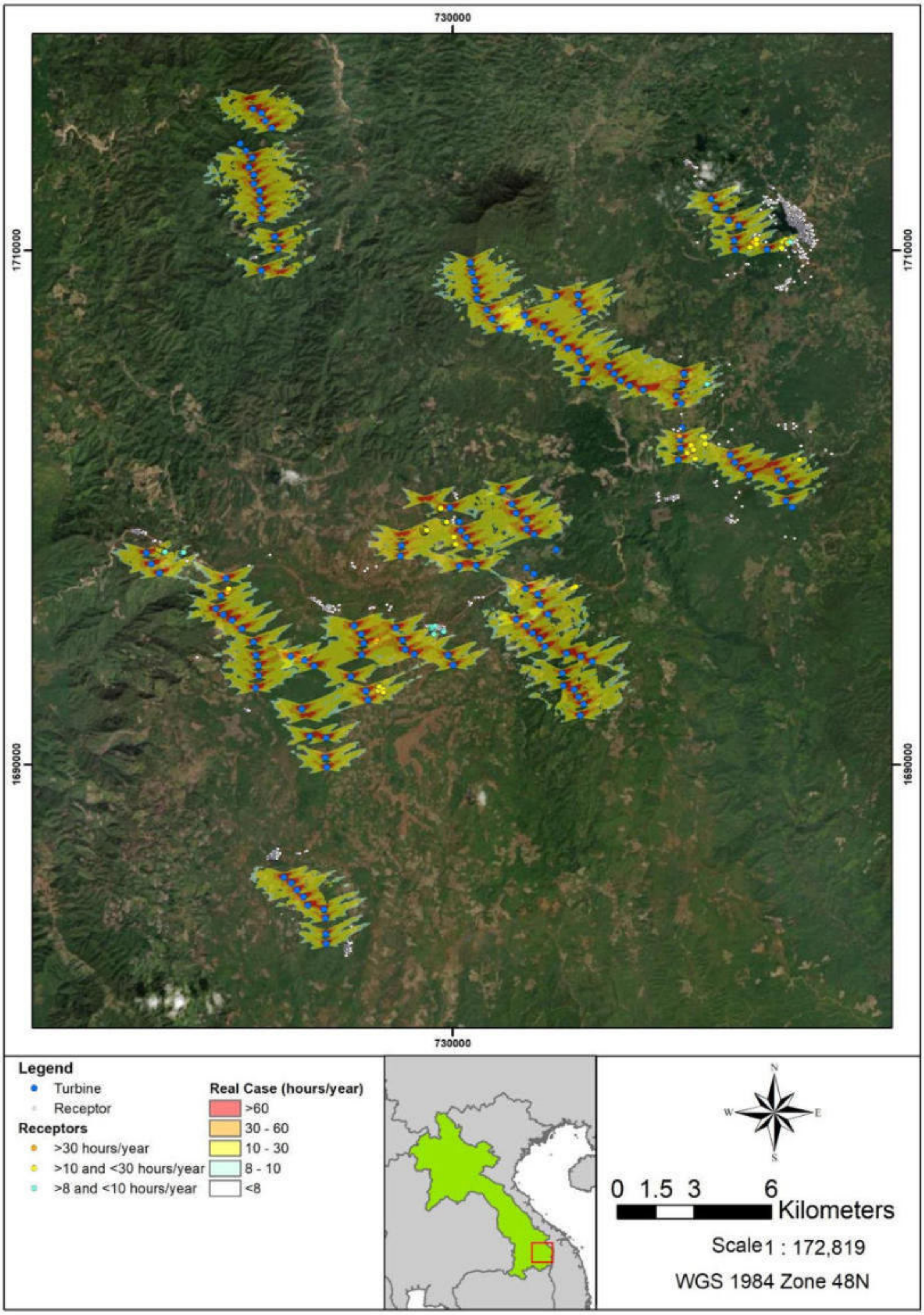
There are no international guidelines on standards to be followed internationally for the Real Case Scenario, and we decided to take into consideration the most conservative standards that place the annual limits at 8 or 10 hours.

Based on the annual limit of 8 or 10 hours the Real Case Scenario leads to a potential of 279 impacted receptors (see ***Appendix E*** for more detailed results), with:

- 37 impacted receptors experiencing between 8-10 hours/year;
- 218 impacted receptors experiencing between 10-30 hours/year; and
- 24 impacted receptors more than 30 hours/year.

The predicted shadow flicker durations at receptors are presented in ***Figure 8.42.***

Figure 8.42: Map of predicted shadow flicker (hours/year) – Real Case Scenario



8.3.8.2 Potential Impacts

The association between shadow flicker caused by wind turbines and the effect on human health is highly debated.

Some studies suggest that flicker from turbines pose a potential risk of inducing photosensitive seizures (Harding et al, 2008; Smedley et al., 2010).

However, in 2011, the UK Department of Energy and Climate Change concluded in their Update Shadow Flicker Evidence Base report that "*On health effects and nuisance of the shadow flicker effect, it is considered that the frequency of the flickering caused by the wind turbine rotation is such that it should not cause a significant risk to health."*

Despite such conclusions, other reports state that although shadow flicker from wind turbines is unlikely to lead to a risk of photo-induced epilepsy, the potential for annoyance and disturbance are still present, leading to stress (Cope et al., 2009; Minnesota Department of Health, 2009; National Research Council, 2007).

8.3.8.3 Existing Controls

There are no existing controls.

8.3.8.4 Significance of Impacts

Methodology for Assessment of Impact Significance

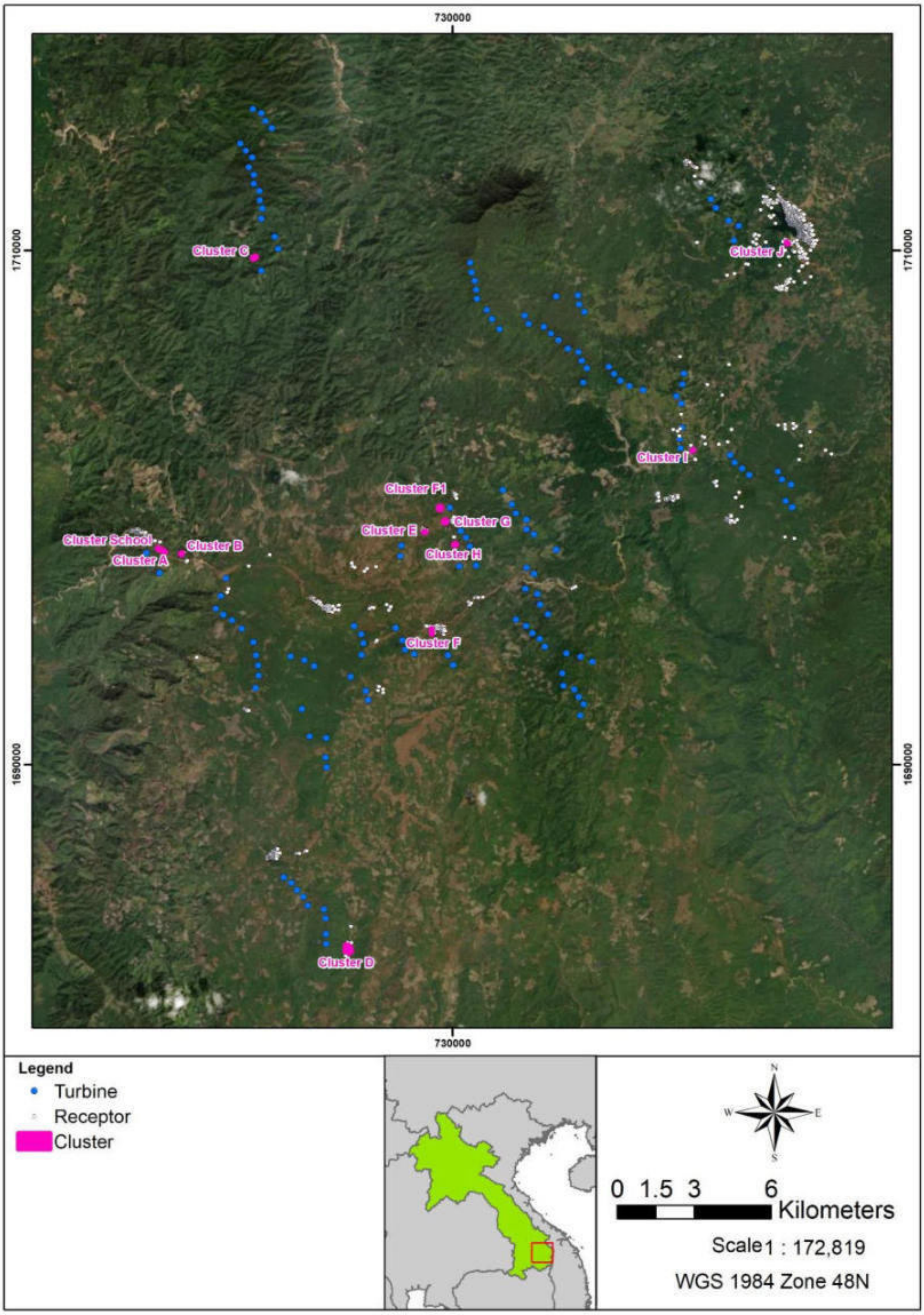
The Impact Assessment Methodology is a quantitative methodology, generated through a spreadsheet provided by a model, and backed up by professional judgement in the application of the criteria.

The shadow flickering assessment has taken into consideration two scenarios: a worst case scenario and a more realistic one embedding local meteorological conditions. In both scenarios, many receptors are considered to be potentially impacted by shadow flickering above international guidance levels.

Shadow flicker impacts are negative, direct and long-term during the operation phase of the Project. The impact scale is within 1,300 m of the WTGs on the receptors in the north-northwest of the WTGs. Impact magnitude varies based on the distance of receptors from the WTGs and their orientation.

Based on the modelling results, it should be noted that the shadow flickering occurrence is limited to 12 clusters of potentially affected receptors (***Figure 8.43***).

Figure 8.43: Cluster locations



Some general considerations are provided, based on the outcomes of the field photo survey, that can prevent/reduce shadow flickering once the Project is in operation:

- A majority of receptors were observed to have no windows facing the shadow direction of the turbines.
- Most of the typical houses are equipped with awnings.
- There are existing natural barriers (i.e., forest, vegetation patches) surrounding the receptors.

As outlined above, the real case is still affected by conservative results. Specific considerations were made within each cluster, and the results can be viewed in the graphic sheets presented below.

The graphic sheets are organized as presented in ***Figure 8.44***:

1. Cluster location;
2. Cluster name;
3. Distance and positioning of the turbine with respect to the cluster on which it impacts;
4. Turbine calendar telling when (hours, days and months) the flickering problems may occur (worst case);
5. Worst case cluster map;
6. Real case cluster map;
7. Assumptions;
8. Considerations;
9. Photos of some receptors of the cluster.

Figure 8.44: Legend of Cluster Graphic Sheets

Figure 8.45: Shadow Flicker Results – Cluster: School

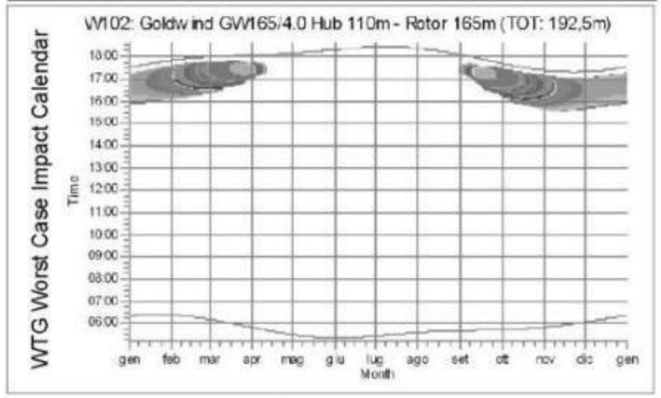
Worst Case - receptors
- Over 30 hours/year and minutes/day
- Over 30 hours/year
- Over 30 minutes/day
- Below 30 hours/year and minutes/day

Worst Case (hours/year)
- > 60
- 30 - 60
- < 30

Real case - receptor
- >30 hours/year
- >10 and <30 hours/year
- >8 and <10 hours/year
- >30 hours/year and 30 min/day in Worst Case
- <8 hours/year

Real Case (hours/year)
- >30
- 10 - 30
- 8 - 10
- <8

Cluster School



<u>Assumptions:</u>

⇒ Shadow receptors are modelled using the greenhouse mode *(each receptor will face all directions)*

⇒ Natural vegetation screening or presence of physical barriers is not considered *(e.g. the nearby building)*

⇒ Rotor is not turning off for low winds or high winds *(e.g. Monsoon period)*

so the results value are very conservative and can be seen as a worst-case scenario.

<u>Considerations:</u>

The potential impact will occur in a limited time frame from 4:00 pm to 6:00 pm from September through mid-April

The receptors were observed to have windows facing the shadow direction of the turbines, but there were also existing natural barriers observed in the form of trees covering the receptor group area, which may reduce the impact.

Rec. 117

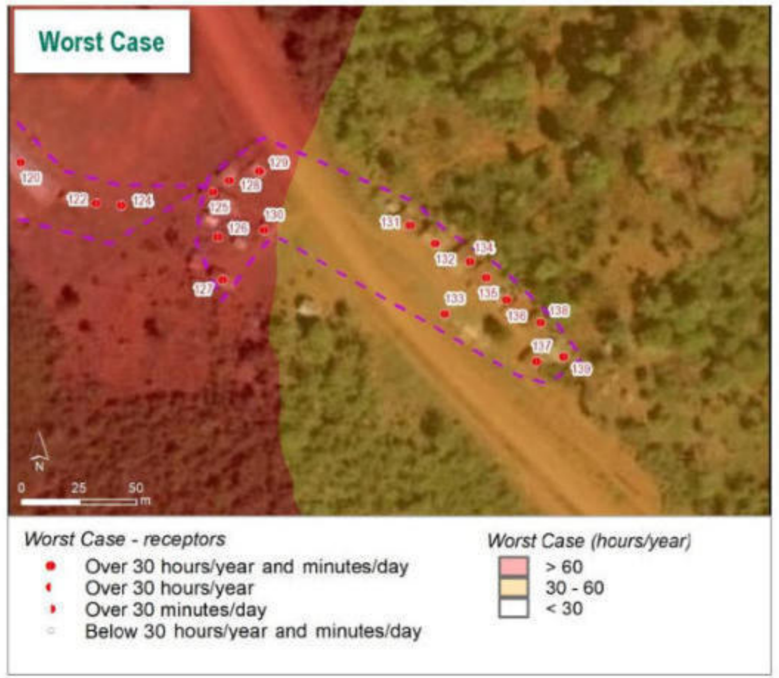
Rec. 118

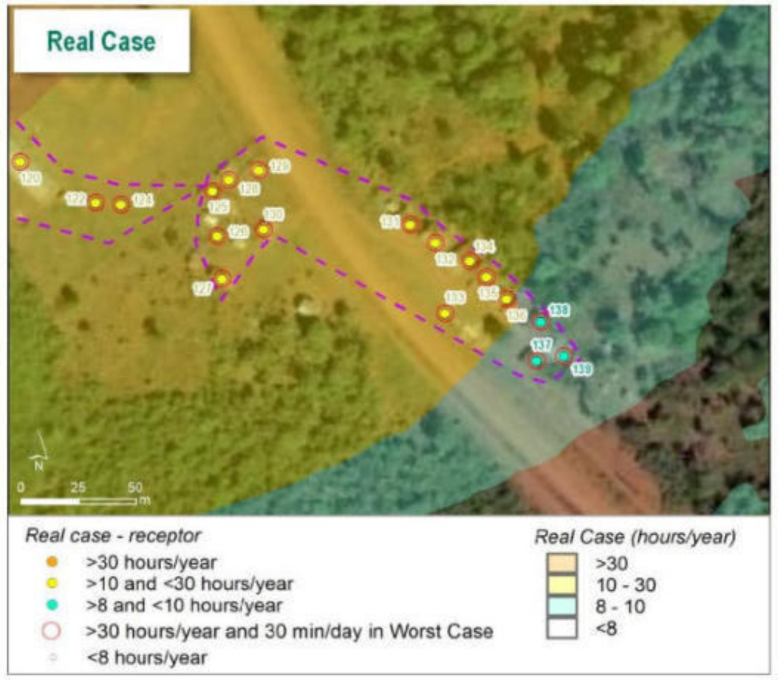
Rec. 119

Rec. 120

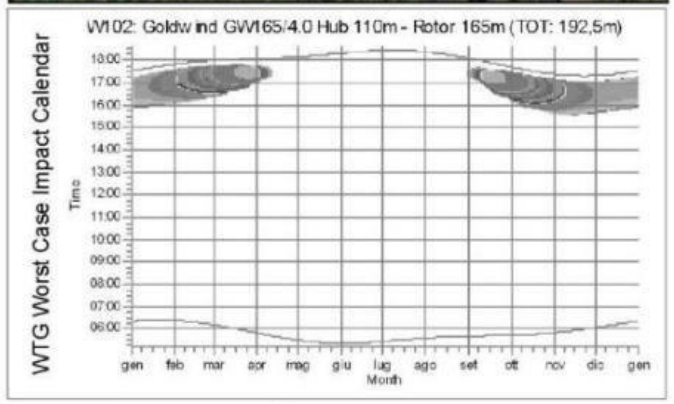
Environmental and Social Impact Assessment – Shadow Flicker Component ERM

Figure 8.46: Shadow Flicker Results – Cluster: A





Cluster A



Assumptions:

⇒ Shadow receptors are modelled using the greenhouse mode (*each receptor will face all directions)*

⇒ Natural vegetation screening or presence of physical barriers is not considered *(e.g. the nearby building)*

⇒ Rotor is not turning off for low winds or high winds *(e.g. Monsoon period)*

so the results value are very conservative and can be seen as a worst-case scenario.

Considerations:

The potential impact will occur in a limited time frame from 4:00 pm to 6:00 pm from September through mid-April

Some of the receptors observed not to have windows facing the shadow direction of the turbines (e.g. photo 3).

Even if the houses is observed to have windows, the shadow flicker impact should not be a concern for the house is equipped with awning or a sloping roof sheltering (e.g. rec 127)

ddd

Environmental and Social Impact Assessment – Shadow Flicker Component

Figure 8.47: Shadow Flicker Results – Cluster: B

Worst Case - receptors
- Over 30 hours/year and minutes/day
- Over 30 hours/year
- Over 30 minutes/day
- Below 30 hours/year and minutes/day

Worst Case (hours/year)
- > 60
- 30 - 60
- < 30

Real case - receptor
- >30 hours/year
- >10 and <30 hours/year
- >8 and <10 hours/year
- >30 hours/year and 30 min/day in Worst Case
- <8 hours/year

Real Case (hours/year)
- >30
- 10 - 30
- 8 - 10
- <8

Cluster B

Assumptions:

⇒ Shadow receptors are modelled using the greenhouse mode (*each receptor will face all directions*)
⇒ Natural vegetation screening or presence of physical barriers is not considered *(e.g. the nearby building)*
⇒ Rotor is not turning off for low winds or high winds *(e.g. Monsoon period)*

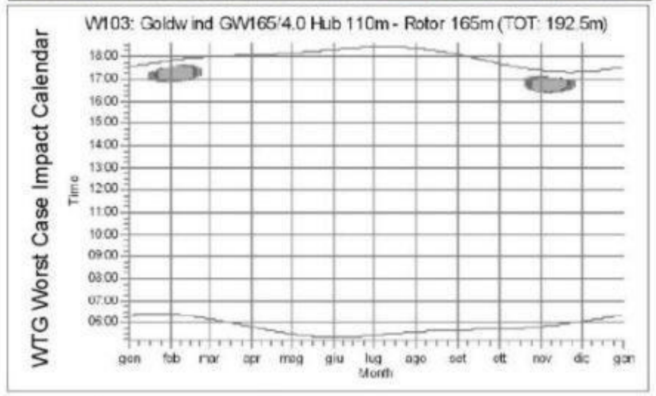
so the results value are very conservative and can be seen as a worst-case scenario.

Considerations:

The potential impact will occur in a limited time frame from 4:30 pm to 6:30 pm in January, February, October and November

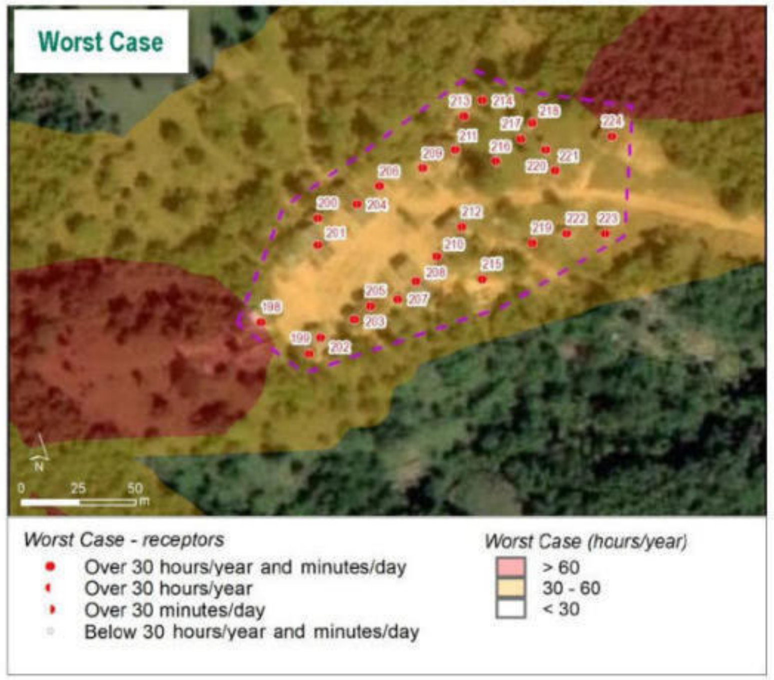
There were many natural barriers in the form of trees covering the receptors group area which is considered to be able to reduce the impact.

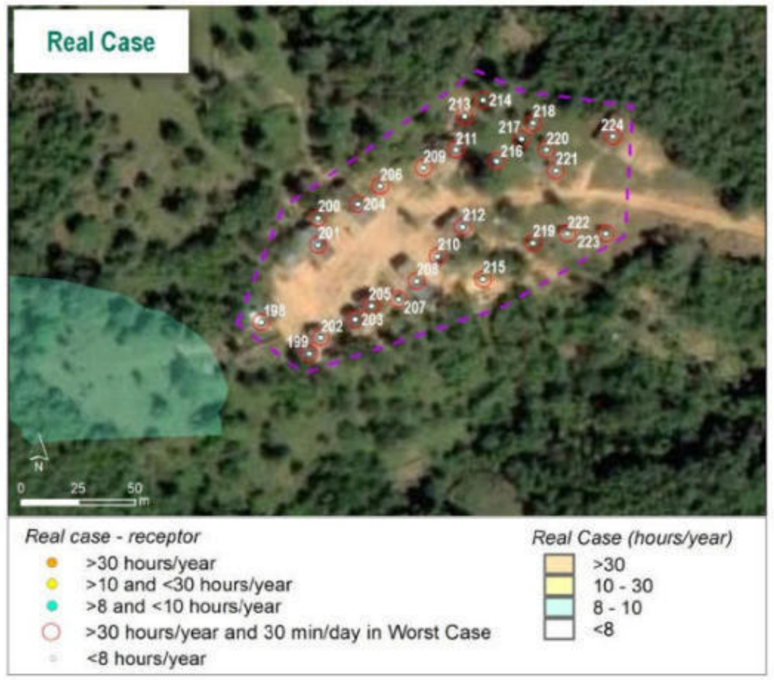
Even if the houses is observed to have windows, the shadow flicker impact should not be a concern for the house is equipped with awning or a sloping roof sheltering

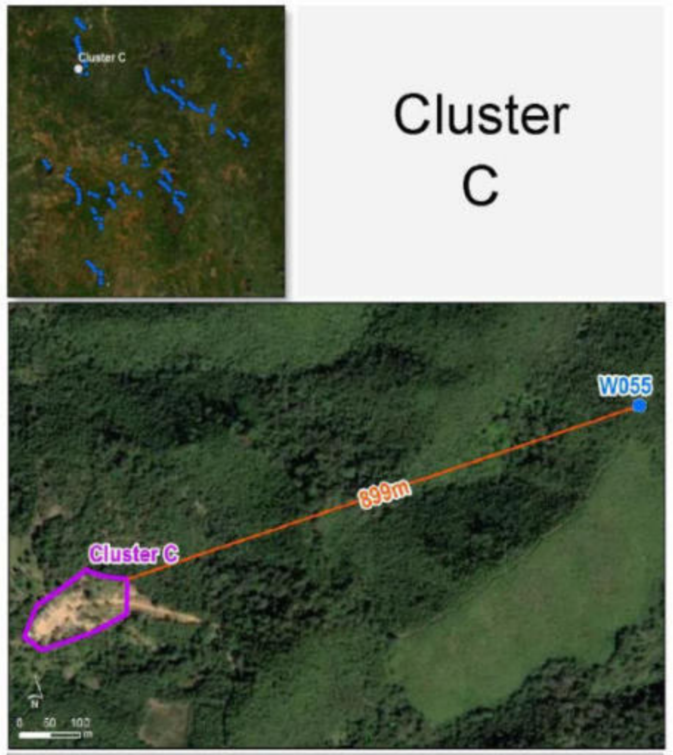


Environmental and Social Impact Assessment – Shadow Flicker Component ERM

Figure 8.48: Shadow Flicker Results – Cluster: C







Assumptions:

⇒ Shadow receptors are modelled using the greenhouse mode *(each receptor will face all directions)*

⇒ Natural vegetation screening or presence of physical barriers is not considered *(e.g. the nearby building)*

⇒ Rotor is not turning off for low winds or high winds *(e.g. Monsoon period)*

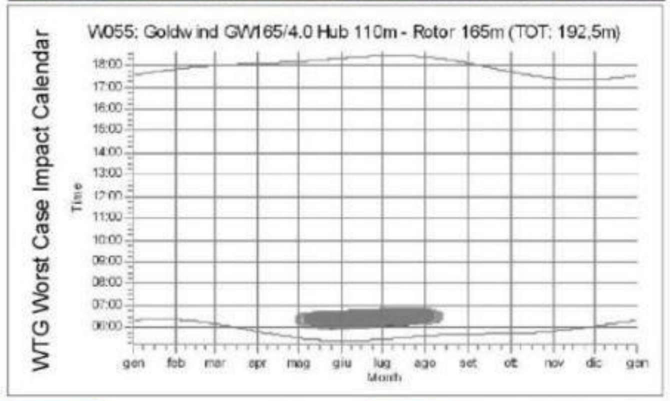
so the results value are very conservative and can be seen as a worst-case scenario.

Considerations:

The potential impact will occur in a limited time frame from 6:00 am to 7:00 am from May through mid-August

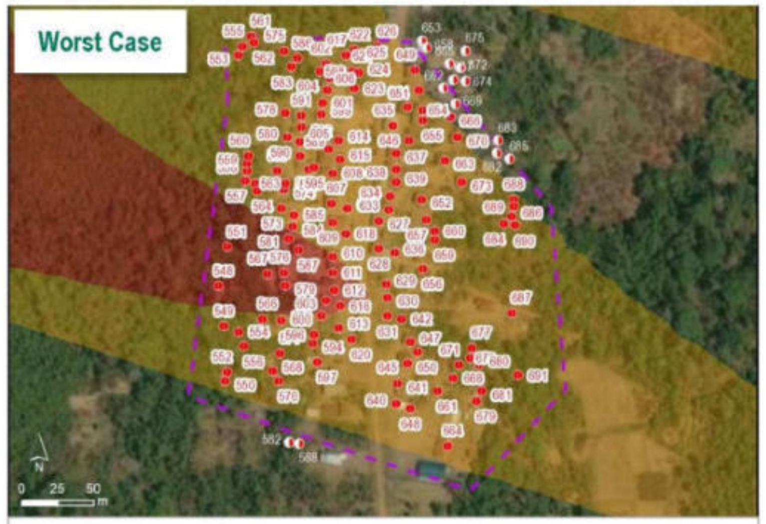
There were many natural barriers in the form of trees covering the receptors group area which is considered to be able to reduce the impact.

Even if the houses is observed to have windows, the shadow flicker impact should not be a concern for the house is equipped with awning or a sloping roof sheltering



Environmental and Social Impact Assessment – Shadow Flicker Component ERM

Figure 8.49: Shadow Flicker Results – Cluster: D

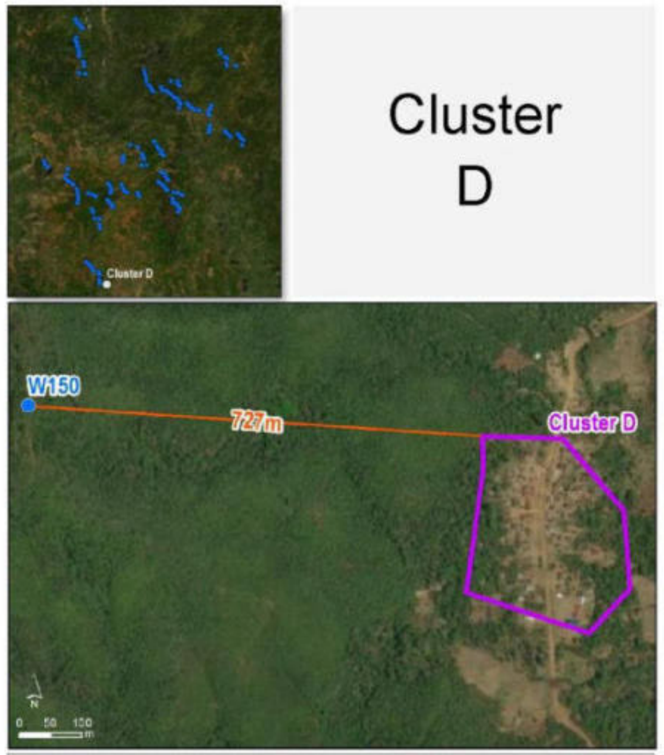


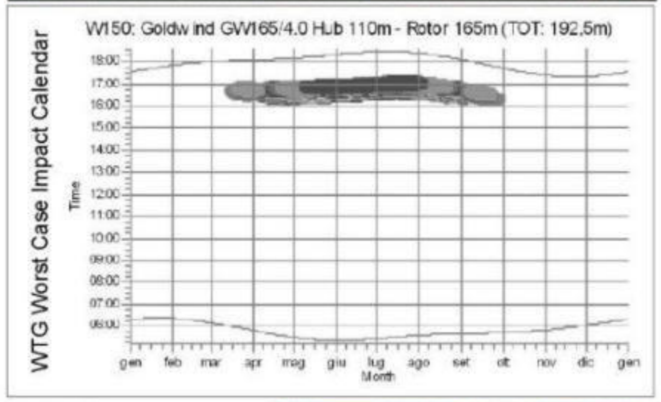
Worst Case - receptors
- Over 30 hours/year and minutes/day
- Over 30 hours/year
- Over 30 minutes/day
- Below 30 hours/year and minutes/day

Worst Case (hours/year)
- > 60
- 30 - 60
- < 30

Real case - receptor
- >30 hours/year
- >10 and <30 hours/year
- >8 and <10 hours/year
- >30 hours/year and 30 min/day in Worst Case
- <8 hours/year

Real Case (hours/year)
- >30
- 10 - 30
- 8 - 10
- <8





__Assumptions:__

⇒ Shadow receptors are modelled using the greenhouse mode *(each receptor will face all directions)*

⇒ Natural vegetation screening or presence of physical barriers is not considered *(e.g. the nearby building)*

⇒ Rotor is not turning off for low winds or high winds *(e.g. Monsoon period)*

so the results value are very conservative and can be seen as a worst-case scenario.

__Considerations:__

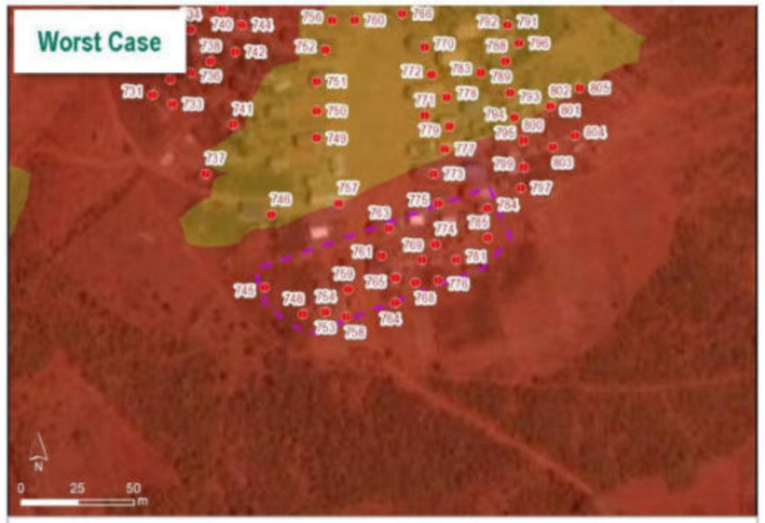
The potential impact will occur in a limited time frame from 4:00 pm to 5:30 pm from March to the end of September

There were many natural barriers in the form of trees covering the receptors group area which is considered to be able to reduce the impact.

Moreover the houses are close to each other creating barriers that reduce shadows and the houses are equipped with a sloping roof sheltering

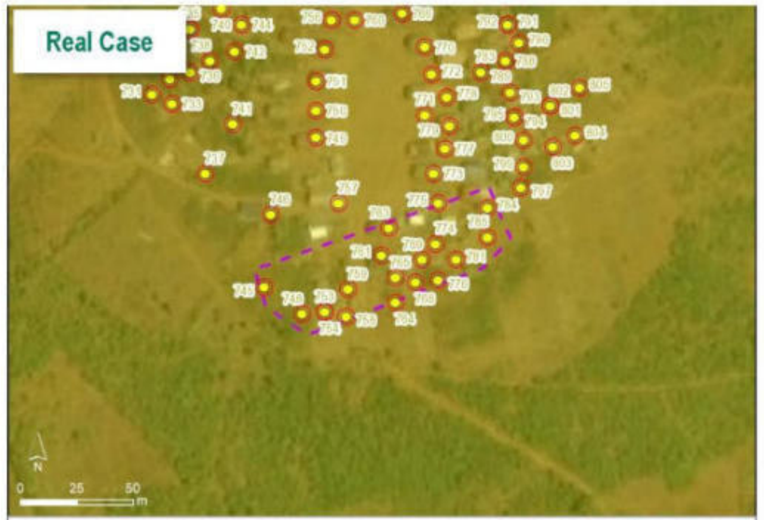
Environmental and Social Impact Assessment – Shadow Flicker Component

Figure 8.50: Shadow Flicker Results – Cluster: E



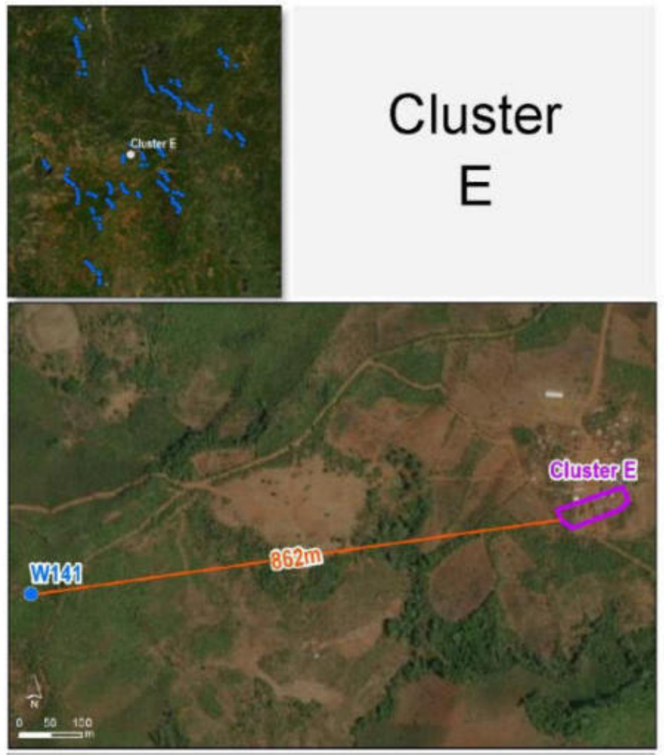
Worst Case - receptors
- Over 30 hours/year and minutes/day
- Over 30 hours/year
- Over 30 minutes/day
- Below 30 hours/year and minutes/day

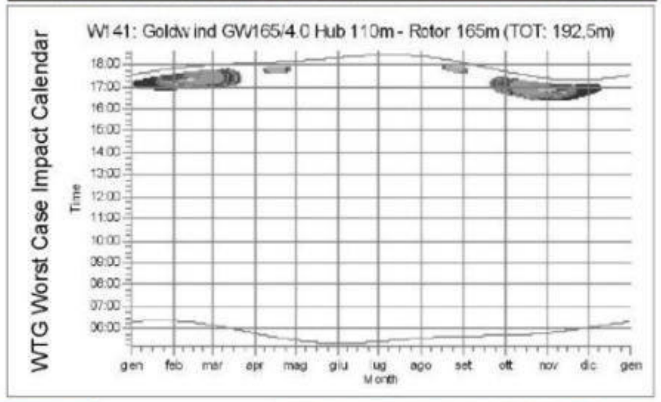
Worst Case (hours/year)
- > 60
- 30 - 60
- < 30



Real case - receptor
- >30 hours/year
- >10 and <30 hours/year
- >8 and <10 hours/year
- >30 hours/year and 30 min/day in Worst Case
- <8 hours/year

Real Case (hours/year)
- >30
- 10 - 30
- 8 - 10
- <8





Assumptions:

⇒ Shadow receptors are modelled using the greenhouse mode *(each receptor will face all directions)*

⇒ Natural vegetation screening or presence of physical barriers is not considered *(e.g. the nearby building)*

⇒ Rotor is not turning off for low winds or high winds *(e.g. Monsoon period)*

so the results value are very conservative and can be seen as a worst-case scenario.

Considerations:

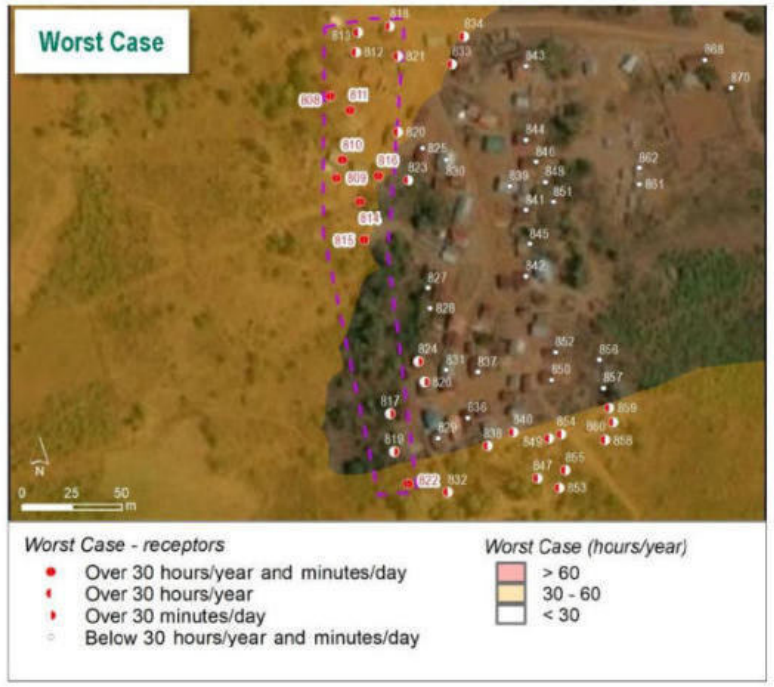
The potential impact will occur in a limited time frame from 4:30 pm to 6:00 pm from mid-September to mid-April

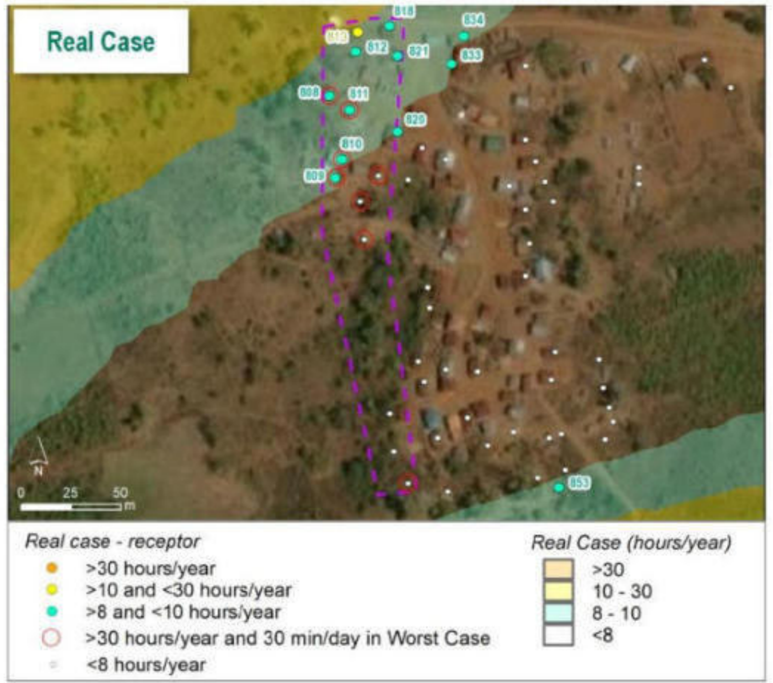
The shadow flicker impact should not be a concern for the house is equipped with awning or a sloping roof sheltering (e.g. Rec. 761)

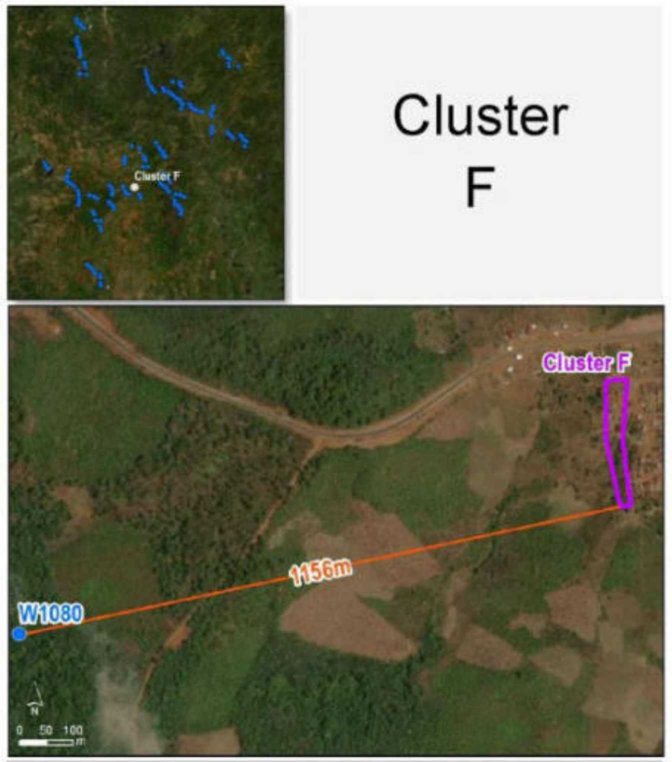
Houses are close to each other, which creates barriers that reduce shadows on hidden receptors

Environmental and Social Impact Assessment – Shadow Flicker Component ERM

Figure 8.51: Shadow Flicker Results – Cluster: F







Assumptions:

⇒ Shadow receptors are modelled using the greenhouse mode (*each receptor will face all directions)*

⇒ Natural vegetation screening or presence of physical barriers is not considered *(e.g. the nearby building)*

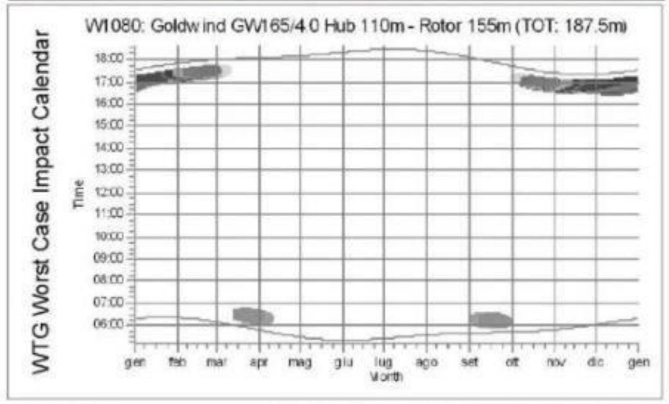
⇒ Rotor is not turning off for low winds or high winds *(e.g. Monsoon period)*

so the results value are very conservative and can be seen as a worst-case scenario.

Considerations:

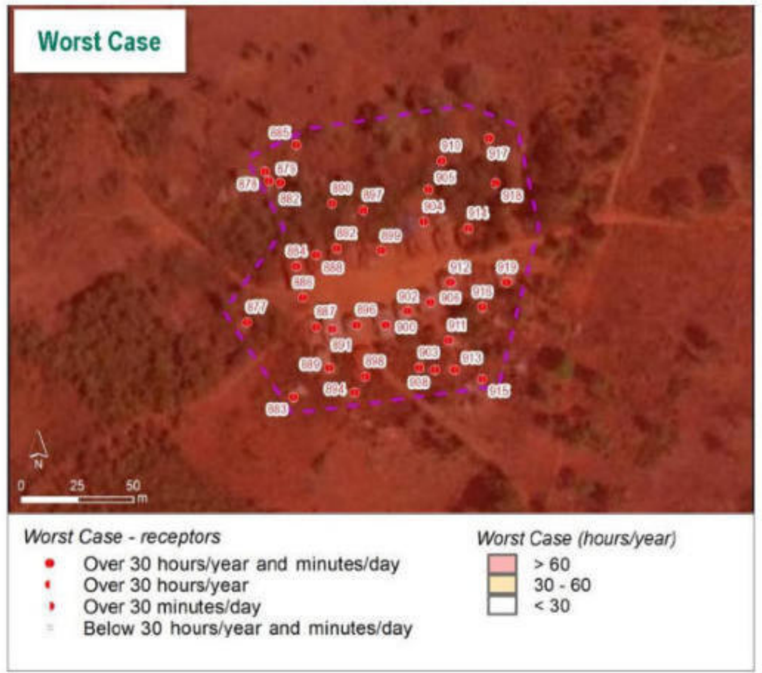
The potential impact will occur from 4:30 pm to 6:00 pm from October to mid-March and from 6:00 am to 7:00 am in March and September

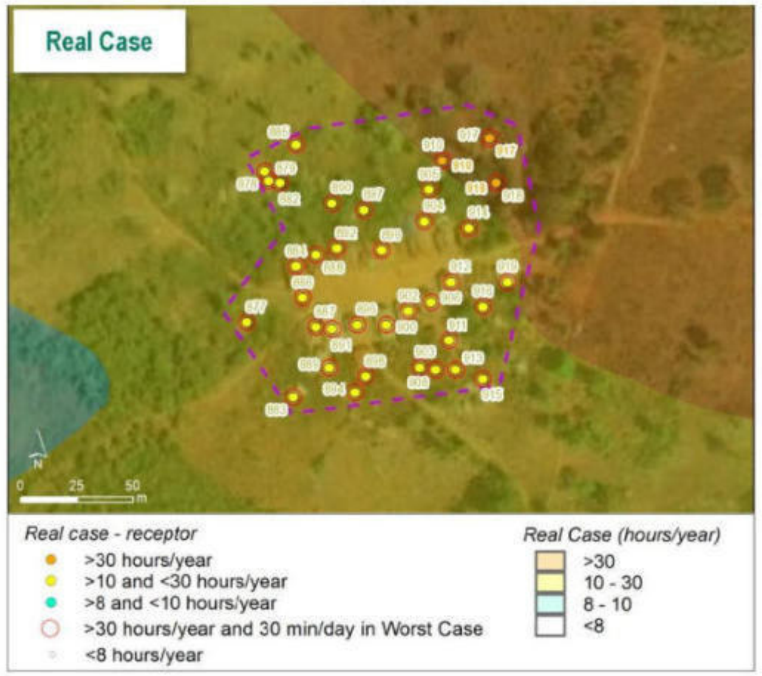
The shadow flicker impact should not be a concern for the house is equipped with awning or a sloping roof sheltering (e.g. Rec. 813)

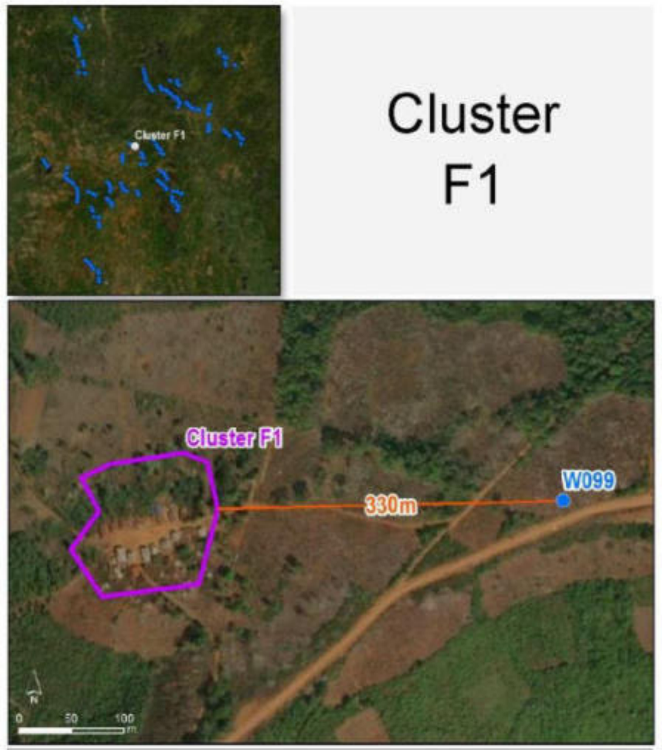


Environmental and Social Impact Assessment – Shadow Flicker Component

Figure 8.52: Shadow Flicker Results – Cluster: F1







Assumptions:

⇒ Shadow receptors are modelled using the greenhouse mode *(each receptor will face all directions)*

⇒ Natural vegetation screening or presence of physical barriers is not considered *(e.g. the nearby building)*

⇒ Rotor is not turning off for low winds or high winds *(e.g. Monsoon period)*

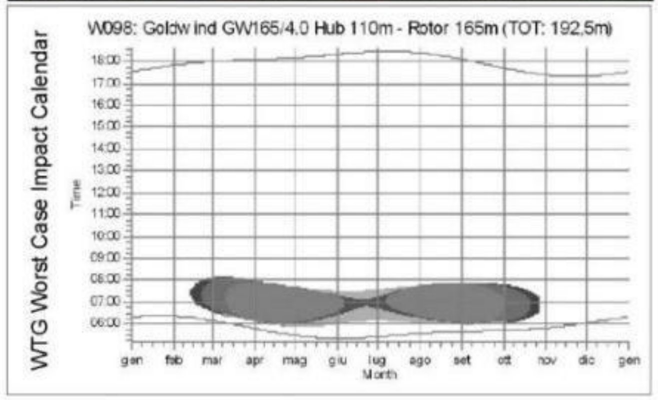
so the results value are very conservative and can be seen as a worst-case scenario.

Considerations:

The potential impact will occur from 6:00 am to 8:00 am from mid-February to the end of October

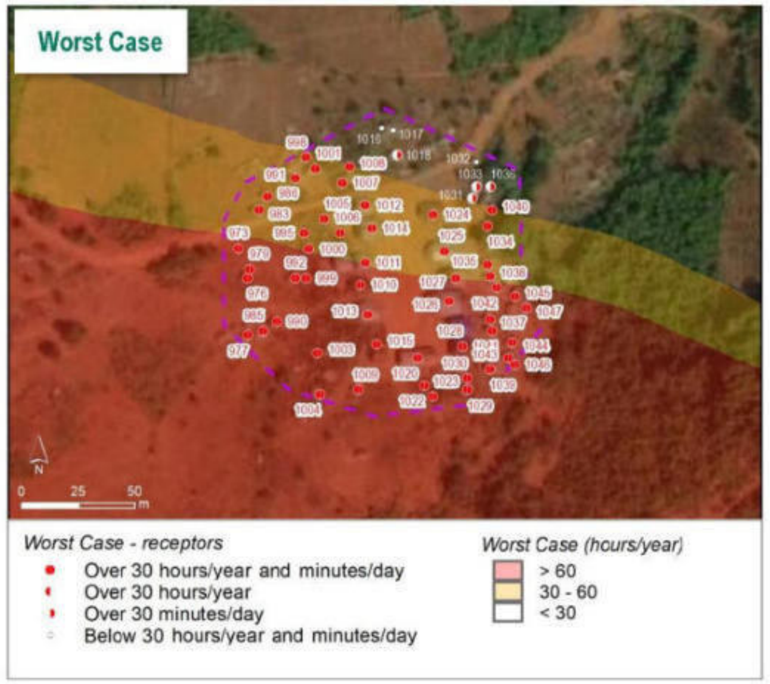
Some of the receptors observed not to have windows facing the shadow direction of the turbines
The shadow flicker impact should not be a concern for the house is equipped with awning or a sloping roof sheltering (e.g. Rec. 884)

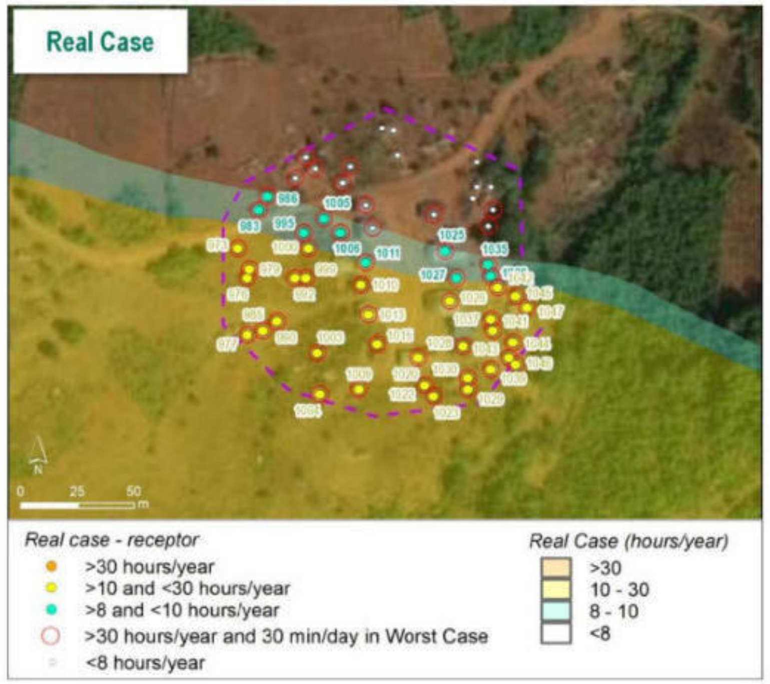
Houses are close to each other creating barriers that reduce shadows on hidden receptors. There were also observed existing natural barriers in the form of trees covering the receptor group area which is considered to be able to reduce the impact

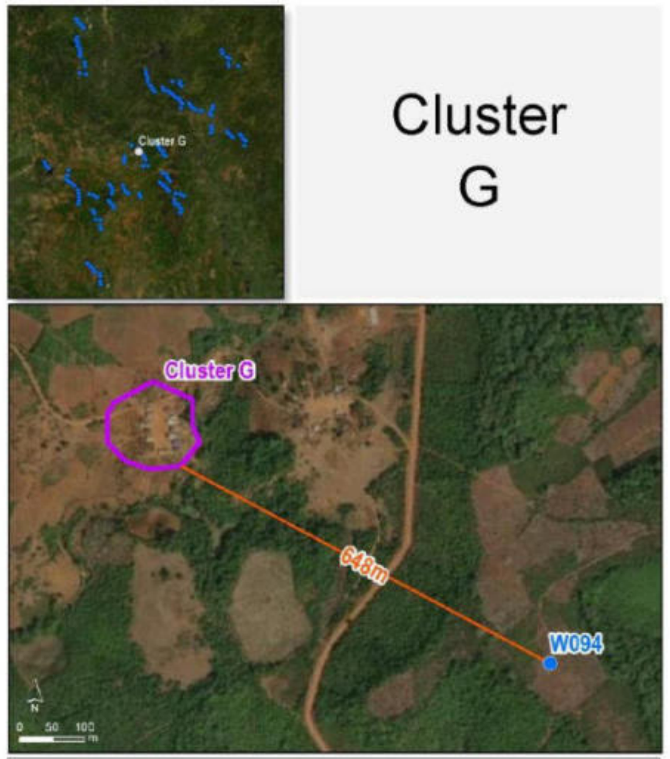


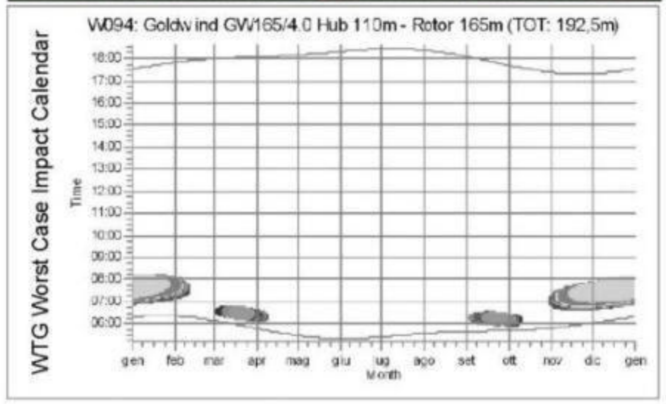
Environmental and Social Impact Assessment – Shadow Flicker Component

Figure 8.53: Shadow Flicker Results – Cluster: G









Assumptions:

⇒ Shadow receptors are modelled using the greenhouse mode *(each receptor will face all directions)*

⇒ Natural vegetation screening or presence of physical barriers is not considered *(e.g. the nearby building)*

⇒ Rotor is not turning off for low winds or high winds *(e.g. Monsoon period)*

so the results value are very conservative and can be seen as a worst-case scenario.

Considerations:

The potential impact will occur from 6:00 am to 8:00 am from September to May

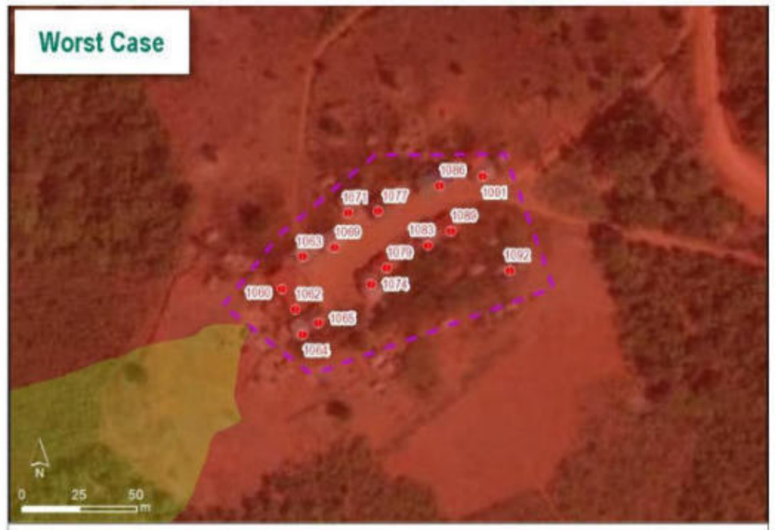
Some of the receptors observed not to have windows facing the shadow direction of the turbines

The shadow flicker impact should not be a concern for the house is equipped with awning or a sloping roof sheltering (e.g. Rec. 1021)

Houses are close to each other creating barriers that reduce shadows on hidden receptors.

Environmental and Social Impact Assessment – Shadow Flicker Component

Figure 8.54: Shadow Flicker Results – Cluster: H



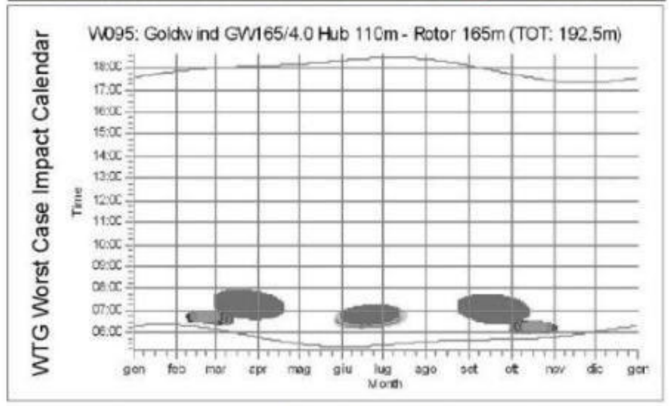
Worst Case - receptors
- Over 30 hours/year and minutes/day
- Over 30 hours/year
- Over 30 minutes/day
- Below 30 hours/year and minutes/day

Worst Case (hours/year)
- > 60
- 30 - 60
- < 30

Real case - receptor
- >30 hours/year
- >10 and <30 hours/year
- >8 and <10 hours/year
- >30 hours/year and 30 min/day in Worst Case
- <8 hours/year

Real Case (hours/year)
- >30
- 10 - 30
- 8 - 10
- <8

Cluster H



Assumptions:

⇒ Shadow receptors are modelled using the greenhouse mode *(each receptor will face all directions)*

⇒ Natural vegetation screening or presence of physical barriers is not considered *(e.g. the nearby building)*

⇒ Rotor is not turning off for low winds or high winds *(e.g. Monsoon period)*

so the results value are very conservative and can be seen as a worst-case scenario.

Considerations:

The potential impact will occur (not continuously) from 6:00 am to 8:00 am from February to November

Some of the receptors observed not to have windows facing the shadow direction of the turbines
The shadow flicker impact should not be a concern for the house is equipped with awning or a sloping roof sheltering (e.g. Rec. 1071)

Houses are close to each other creating barriers that reduce shadows on hidden receptors.

Environmental and Social Impact Assessment – Shadow Flicker Component

Figure 8.55: Shadow Flicker Results – Cluster: I

Worst Case - receptors
- Over 30 hours/year and minutes/day
- Over 30 hours/year
- Over 30 minutes/day
- Below 30 hours/year and minutes/day

Worst Case (hours/year)
- > 60
- 30 - 60
- < 30

Real case - receptor
- >30 hours/year
- >10 and <30 hours/year
- >8 and <10 hours/year
- >30 hours/year and 30 min/day in Worst Case
- <8 hours/year

Real Case (hours/year)
- >30
- 10 - 30
- 8 - 10
- <8

Cluster
I

<u>Assumptions:</u>

⇒ Shadow receptors are modelled using the greenhouse mode (*each receptor will face all directions)*

⇒ Natural vegetation screening or presence of physical barriers is not considered *(e.g. the nearby building)*

⇒ Rotor is not turning off for low winds or high winds *(e.g. Monsoon period)*

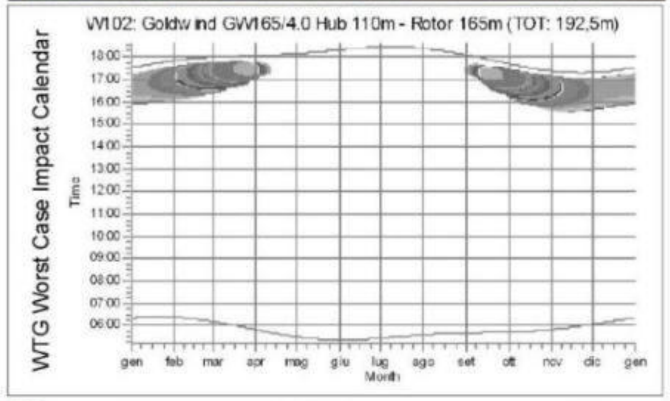
so the results value are very conservative and can be seen as a worst-case scenario.

<u>Considerations:</u>

The potential impact will occur from 3:30 pm to 6:00 pm from September to May

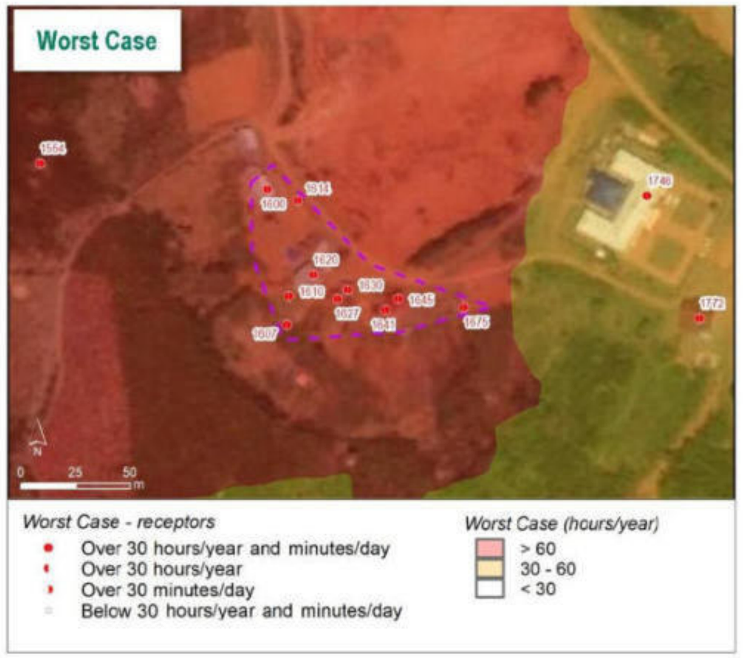
Some of the receptors observed not to have windows facing the shadow direction of the turbines
The shadow flicker impact should not be a concern for the house is equipped with awning or a sloping roof sheltering (e.g. Rec. 1267)

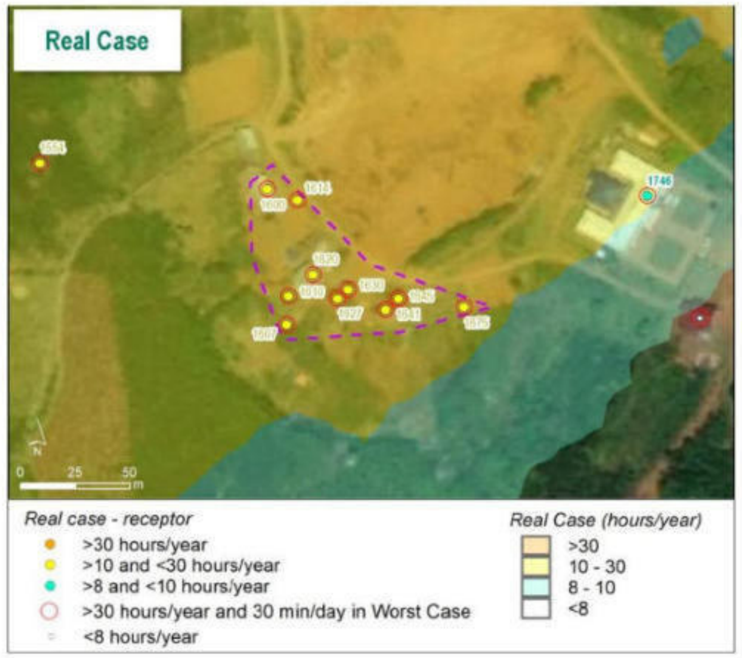
Houses are close to each other creating barriers that reduce shadows on hidden receptors. There were also observed existing natural barriers in the form of trees covering the receptor group area which is considered to be able to reduce the impact

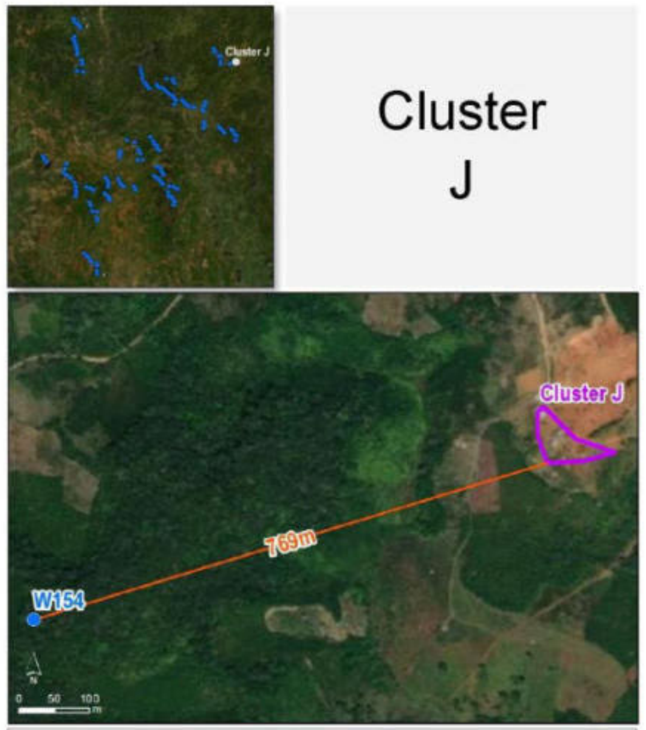


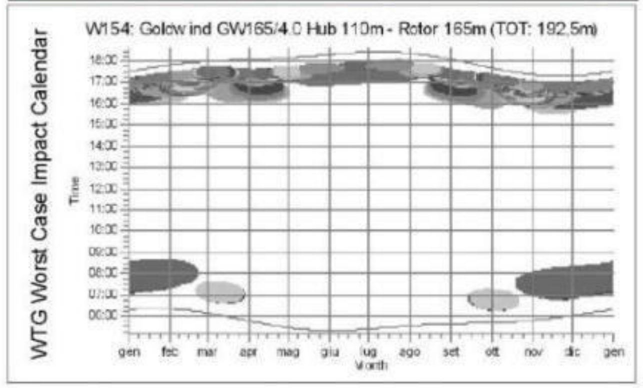
Environmental and Social Impact Assessment – Shadow Flicker Component

Figure 8.56: Shadow Flicker Results – Cluster: J









Assumptions:

⇒ Shadow receptors are modelled using the greenhouse mode *(each receptor will face all directions)*

⇒ Natural vegetation screening or presence of physical barriers is not considered *(e.g. the nearby building)*

⇒ Rotor is not turning off for low winds or high winds *(e.g. Monsoon period)*

so the results value are very conservative and can be seen as a worst-case scenario.

Considerations:

The potential impact will occur from 3:30 pm to 6:00 pm during all the year round and from 6:00 am to 9:00 am from mid-Septembre to April

Some of the receptors observed not to have windows facing the shadow direction of the turbines
The shadow flicker impact should not be a concern for the house is equipped with awning or a sloping roof sheltering (e.g. Rec. 1600)

Environmental and Social Impact Assessment – Shadow Flicker Component

Receptor Sensitivity and Impact Magnitude

Based on the modeling results and the photographic field survey, the sensitivity of the 12 clusters is estimated as shown in ***Table 8.42***. The overall impact significance is negligible to moderate depending on the cluster.

Table 8.42: Cluster Sensitivity and Magnitude

Cluster	Sensitivity	Magnitude	Impact Significance
School	Low - Medium	Small	Minor
A	Medium	Small - Medium	Moderate
B	Medium	Small	Minor
C	Medium	Negligible	Negligible
D	Medium	Negligible	Negligible
E	Medium	Small - Medium	Moderate
F	Medium	Negligible - Small	Minor
F1	Medium	Small - Medium	Moderate
G	Medium	Small	Minor
H	Medium	Small - Medium	Moderate
I	Medium	Small	Minor
J	Medium	Medium	Moderate

8.3.8.5 Additional Mitigation, Management, and Monitoring Measures

It should be understood that shadow flicker is considered an environmental “nuisance”, rather than medical risk, as there is insufficient evidence to indicate that shadow flicker causes health problems. Thus, these mitigation measures are identified to address issues regarding cause and effect of shadow flicker from wind turbines.

- Siting - Wind turbines have been sited according to the World Bank/IFC Guidelines to ensure shadow flicker is below 30 hours per year at all potential sensitive receptors, where possible, while maintaining the economic viability of the Project.
- Grievance Monitoring and Reporting - Close monitoring through engagement with residents during the operational phase, where there are predicted impacts from shadow flickers for locations that have been finalized by the project proponent and earmarked for construction.
- Visual Screening (Natural) – Continuously assess identified and any potentially sensitive receptors, where shadow flicker modelling indicates the amount could exceed 30 hours per year and 30 minutes per day, to ascertain the extent of existing natural visual screening in place. If not existing, the occurrence of shadow flickering during operation could be further investigated, and if confirmed, natural screening could be implemented to minimize the effect.
- Visual Screening (Architectural/Structural) - If grievances will be received or if natural visual screening at potentially sensitive receptors are found to be insufficient, investigations to implement architectural/structural screening, such as the installation of blinds, window shades, window tinting, awnings or fences, at affected receptors could be evaluated to further minimize the effect of shadow flicker.
- Compensation - If shadow flicker mitigation through natural or architectural/structural visual screening methods are found to be insufficient, IEAD will provide compensation to affected receptors based on an assessment of economic impacts of shadow flicker, and taking into

consideration the residual impact of shadow flicker following mitigation through alternative means (outlined above). A socioeconomic census has been undertaken at sensitive receptors prior to construction of the wind farm to support application of any compensation process.

- Relocation - If visual screening, both natural and architectural/structural, and compensation methods fail to mitigate shadow flicker impacts at sensitive receptors, IEAD will facilitate relocation. Any relocation will take into account the standards/principles stipulated in IFC PS-5 regarding resettlement. This includes the undertaking of a socioeconomic census prior to construction of the wind farm. Any replacement of land or residences, including farmland if necessary, will be provided by IEAD. However, the project will not be responsible for any affected settlements constructed after the commencement of wind farm construction. It is not expected that relocation or resettlement will be required to mitigate shadow flicker impacts for the Project.

8.3.8.6 Residual Impact Significance

The mitigation measures above will be implemented for identified receptors that experience shadow flicker. Residual impacts following the implementation of these mitigation measures will reduce to **Minor** (***Table 8.43***).

Table 8.43: Impact of Shadow Flicker (Operation)

Significance of Impact					
Impact	Shadow flicker impacts during construction and operation.				
Impact Nature	**Negative**	Positive	Neutral		
	Potential impacts from shadow flicker would be considered to be negative				
Impact Type	**Direct**	Indirect	Induced		
	Impacts would be direct				
Impact Duration	**Temporary**	Short-term	**Long-term**	**Permanent**	
	Only a certain times under right conditions				
Impact Extent	**Local**	Regional	International		
	The impact will only be localized within the Area of Influence of the Project.				
Impact Scale	Impact scale is considered localized and small.				
Frequency	Impacts could occur during the operation phase.				
Impact Magnitude	Positive	**Negligible**	**Small**	**Medium**	Large
	Based on the characteristic above, the impact is likely to be negligible to medium, depending on the receptor.				
Receptor Sensitivity	**Low**	**Medium**	High		
	The sensitivity is considered to be Low to Medium, depending on the receptor.				
Impact Significance	**Negligible**	**Minor**	**Moderate**	Major	
	The medium sensitivity and magnitude are assessed as negligible to moderate. Cluster A, E, F1, H and J are moderate.				
Residual Impact Magnitude	Positive	Negligible	**Small**	Medium	
Residual Magnitude Significance	Negligible	**Minor**	Moderate	Major	
	Upon considering the mitigation measure, the residual impact is assessed to be Minor.				