BIALA WIND FARM

Blade Throw Risk

Environmental Resources Management Australia Pty Ltd

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Task and objective:
Consider blade throw risk in the vicinity of the proposed Biala Wind Farm.

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1 EXECUTIVE SUMMARY

DNV GL has been commissioned by Environmental Resources Management Australia Pty Ltd ("the Client" or "ERM") to consider blade throw risks in the vicinity of the proposed Biala Wind Farm, on behalf of Newtricity who is developing the wind farm. The results of the work are reported here. This document has been prepared pursuant to DNV GL proposal 170223/PP/01 Issue A, dated 22 August 2013, and is subject to the terms and conditions contained therein.

Blade throw describes the rare phenomenon of a structural failure in a turbine blade during operation resulting in the ejection of projectiles into the surrounding area.

The Secretary's Environmental Assessment Requirements (SEARs) [3] and the Draft NSW Planning Guidelines for wind farms published by NSW Government Planning and Infrastructure [4] require that the risk of blade throw at a wind farm be considered and appropriately mitigated.

The risk of blade throw and the mitigation measures relevant to the Biala Wind Farm are discussed in this technical note. The risk of damage to life or property through a blade throw event at the Biala Wind Farm can be considered to be negligible.

2 DESCRIPTION OF THE PROPOSED WIND FARM SITE

2.1 The Project

ERM has been commissioned by Newtricity to prepare the Environmental Impact Statement for the proposed Biala Wind Farm, to be developed approximately 8.5 km northeast of the town of Biala and 14.5 km southwest of the town of Crookwell, New South Wales. The terrain at the proposed Biala wind farm can be described as undulating, with elevations varying between approximately 750 m and 930 m above sea level. The site and surrounds can generally be described as open farmland interspersed with areas of denser vegetation and tall trees, particularly in the northeast section of the site.

The general location of the site can be seen in Figure 1, while a map showing turbines, houses and the site boundary can be seen in Figure 2.

2.2 Proposed Wind Farm Layout

The proposed turbine layout for the Biala Wind Farm is comprised of 31 wind turbine generators. The turbines are proposed to be located on top of low lying hills present across the site with base elevations ranging from approximately 813 m to 903 m above sea level.

A list of coordinates of the proposed turbine locations are given in UTM Zone 55 (WGS84 datum) in Table 2. This table also shows distances between turbines and houses.

2.3 House Locations

A list of houses neighbouring the wind farm was supplied to DNV GL by Newtricity [1]. Two houses, which were identified by DNV GL during a site visit on 6 April 2014, are also included in the list of houses assessed in this report.

The supplied list of houses also includes unbuilt house locations for which development approval has been granted. An unbuilt house location with development approval lying within the wind farm boundary (designated 'DA16' in this assessment) has been included in the assessment. A second stakeholder location has been identified but has not been included in the assessments at the request of Newtricity. This involved landholder has an agreement with Newtricity confirming that they will not act on this DA if the Project is approved [2].

The coordinates of dwellings in the vicinity of the wind farm are presented in Table 1. This table also shows distances between houses and turbine locations.

DNV GL has assumed that all listed houses are potential inhabited residential locations. It should be noted that DNV GL has not carried out a detailed and comprehensive survey of house locations in the area and is relying on information provided by the Client.

3 PLANNING GUIDELINES

The Secretary's Environmental Assessment Requirements for the Biala Wind Farm (SEARs) [3] state the following with regard to blade throw:

> *"Hazards/Risks - the EIS must include assessment of the following: … Blade throw: assess blade throw risks."*

In addition, the Draft NSW Planning Guidelines for Wind Farms (Draft NSW Guidelines) [4] currently state:

> *"The risk of 'blade throw' – involving a wind turbine's blades breaking or being ejected during operation – should be considered. Relevant considerations may include (but are not limited to):*
>
> - *whether the proposed turbines are certified against relevant standards such as* IEC 61400-23 Wind turbine generator systems – Part 23: Full-scale structural testing of rotor blades *or other equivalent standards - evidence of any such certification should be provided;*
> - *overspeed protection mechanisms including 'fail safe' mechanisms (e.g. back up (battery) power in the event of a power failure);*
> - *operational management and maintenance procedures including any regular maintenance inspections;*
> - *provisions for blade replacement in the event a blade fault is identified (e.g. during a periodic inspection);*
> - *the separation distance between turbines, neighbouring dwellings and property boundaries;*
> - *the probability of blade throw occurring."*

4 BLADE THROW RISK

Although occurrences of blade throw are considered rare, the consequences of a blade throw event may be serious and it is important to gain a full understanding of the risks associated with the phenomenon. Understanding the behaviour of blade throw may help to inform policies regarding safe separation distances between wind turbines and dwellings, as well as safe operational procedures within a wind farm. Much research has been performed within the wind industry to establish the likelihood of a blade throw event occurring and the subsequent risk of damage to property or life.

In order to quantify the likelihood of a blade throw event, researchers have examined historical data sets of accidents and incidents on wind farms. Comprehensive and detailed data sets are not typically available [5,6], however researchers developing wind farm planning guidelines for the Dutch government examined databases in Germany, Denmark and the Netherlands and were able to establish incident rates based on the equivalent of 43,000 turbine years of operation [7]. The risk of loss of an entire blade was found to be $8.4 * 10^{-4}$ incidents per turbine per year and the risk of loss of a blade tip was found to be $1.2 * 10^{-4}$ incidents per turbine per year. Another study calculated the risk of blade failure based on historical records to be in the order of 10^{-3} to 10^{-4} failures per turbine per year [6].

To examine the likely distribution of projectiles in a blade throw event, researchers typically perform aerodynamic modelling considering the projectile motion of a range of blade fragment sizes for various turbine models and wind speed conditions. Rogers et al. [8] performed a Monte Carlo analysis based on blade throw dynamic modelling for different fragment sizes and environmental conditions, using 0.66 MW, 1.5 MW and 3.0 MW turbine models. A theoretical maximum throw distance of 590 m was found to occur for a 20% blade fragment for the 1.5 MW turbine model. This study also demonstrated that turbine throw distance is related mostly to the release velocity of a fragment, rather than the turbine height or blade radius. A similar maximum throw distance of 400 m was modelled by Braam & Rademakers [7] considering overspeed conditions (defined as two times the rated rotor speed) and a 2 MW turbine. Cotton [5] used a simplified point-mass projectile model for a worst-case scenario of a 1 in 50 year extreme wind speed event and low air-drag conditions. Maximum throw distances of 198 m and 1462 m were predicted for a full blade and 10% fragment respectively. However, this seems to represent an extreme and possibly unrealistic scenario. Based on information from the Caithness Windfarm Information Forum which included 37 reported instances of blade throw, Cotton [5] established that most blade throw events resulted in fragments being propelled to within 600 m of the turbine location, with only one reported incident of a blade fragment reaching 1000 m.

With an understanding of the likelihood of occurrence and dynamics of a blade throw incident, it is possible to define the associated risks to life and property. Braam & Rademakers [7] calculated risk contours around a turbine representing the risk of an individual being hit by a turbine fragment. For a 2 MW turbine, a risk contour of 10^{-6} incidents/turbine/year was established at a distance of 144 m from the turbine. Another study calculated the overall risk of direct impact from a blade throw event at a distance of 160 m from turbine locations as being smaller than 10^{-9} incidents/turbine/year [6]. These risks are significantly smaller than many of the risks inherent in everyday activities in society such as road travel or working in the agricultural industry (both approximately 10^{-4} incidents/year) [6].

Although the predictions for blade throw distances and risk levels vary, there is general agreement throughout the literature that the overall risk of damage to human life or property from a blade throw incident is extremely small and well within risk levels typically deemed acceptable by society. It should also be noted that many of the calculated risks are based on historical data which does not necessarily represent modern wind turbine technology and state-of-the-art wind farm operation. As such, it may be that numbers of blade throw incidents will reduce further over time. Given the large number of wind turbines in successful and safe operation throughout the world, wind turbine technology can be generally considered to be safe, robust and reliable.

5 MITIGATION

Modern wind turbines are typically certified to international standards to ensure structural integrity and safe operation over the lifetime of the turbine. A modern turbine integrates sophisticated lightning protection systems and is designed to shut down during high wind speed conditions and in response to a range of faults. Additionally, high quality operation and maintenance programs at wind farms ensure that turbine faults are prevented or detected and rectified quickly, minimising the risk of occurrence of a serious or dangerous problem.

The turbine model to be selected for use at the Biala Wind Farm is unknown at this time. However, the selected turbine model is likely to have been certified to the appropriate standards. These standards *include IEC 61400-23 Wind turbine generator systems – Part 23: Full-scale structural testing of rotor blades* and *IEC 62305-1/3/4 Protection against lightning*.

Distances between turbines and dwellings are presented in Table 1 and Table 2. It can be noted that the minimum distance between a turbine and a non-stakeholder dwelling is 2.0 km, while the minimum distance between a turbine and a stakeholder dwelling is 0.9 km. As described in the preceding discussion, the likelihood of a blade throw event damaging life or property at this distance is extremely small.

In addition, access to the wind farm area is expected to be restricted and wind farm personnel would be required to maintain safe distances from the turbines during high wind speed conditions.

Given these factors, the risk of damage to life or property through a blade throw event at the Biala Wind Farm can be considered negligible.

6 CONCLUSIONS

The SEARs for the Biala Wind Farm and Draft NSW Planning Guidelines require that the risk of a blade throw event is considered and appropriately mitigated. An understanding of the dynamics and risks associated with blade throw has been achieved within the wind industry through a broad range of research and investigation of blade throw incidents. From this, it is generally accepted that the risk of death or damage to property by blade throw is extremely small, and well within risk levels typically deemed acceptable by society.

The risks of blade throw at the Biala Wind Farm will be mitigated through use of a turbine designed and built to appropriate certification standards, an operation and maintenance program designed to ensure asset integrity and large separation distances between turbines and residential dwellings.

7 REFERENCES

1. Emails from A. Lavery of Newtricity to D. Price of DNV GL, 3, 4, 7, 18 March, 5 April 2014.
2. Email from E. Dethridge of ERM to T. Gilbert of DNV GL, 25 February 2015.
3. "Secretary's Environmental Assessment Requirements (SSD 13_6039), NSW Planning and Infrastructure, 19 May 2015.
4. "Draft NSW Planning Guidelines Wind Farms", NSW Planning and Infrastructure, December 2011.
5. "Numerical Modelling of Wind Turbine Blade Throw ", Cotton, R., 2007, Health & Safety Laboratory, Bristol.
6. "Study and development of a methodology for the estimation of the risk and harm to persons from wind turbines ", Health and Safety Executive UK, MMI Engineering Ltd Warrington UK, 2013.
7. "Guidelines on the environmental risk of wind turbines in the Netherlands", Braam, H., Rademakers, L.W.M.M., 2002, presentation Global Wind Energy Conference, Paris, France.
8. "A method for defining wind turbine setback standards", Rogers, J., Slegers, N., Costello, M., *Wind Energy*, John Wiley & Sons, Ltd., 2011.

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House ID	Easting[1] (m)	Northing[1] (m)	Type	Status	Distance to nearest turbine (m)
HS01[2]	716458	6172607	House	Stakeholder	911
HS02[2]	716378	6172571	House	Stakeholder	912
HN03	714805	6174684	House	Non-Stakeholder	2409
HN04	713279	6174207	House	Non-Stakeholder	2598
HN05	716899	6174610	House	Non-Stakeholder	2243
HN06	718838	6173981	House	Non-Stakeholder	2004
HN07	719217	6173652	House	Non-Stakeholder	2062
HS08[2]	718825	6171869	House	Stakeholder	962
HN09	717729	6169285	House	Non-Stakeholder	2005
HS10[2]	713039	6171444	House	Stakeholder	1002
HN11	717228	6168754	House	Non-Stakeholder	2001
HN12	716395	6167298	House	Non-Stakeholder	2035
HN13	711857	6166539	House	Non-Stakeholder	2377
HN14	711969	6166279	House	Non-Stakeholder	2382
HN15	711963	6169014	House	Non-Stakeholder	2442
DA16[2, 3]	717303	6170119	DA house	Stakeholder	1093
HN17	718838	6169071	House	Non-Stakeholder	2920

Notes:
1. Coordinate system is WGS84 Zone 55H
2. Project stakeholders are highlighted in the above table.
3. Location with development approval for a house.

Table 1: Dwelling locations within 3 km of turbines at the proposed Biala Wind Farm

Turbine ID	Easting[1] [m]	Northing[1] [m]	Base Elevation [m]	Nearest House	Distance to Nearest House [m]
T01	717864	6171824	897	HS08	960
T02	717535	6172459	874	HS01	1085
T03	717211	6172095	893	HS01	910
T04	716535	6170896	902	DA16	1092
T05	716389	6171280	902	HS02	1294
T06	716235	6171670	898	HS02	914
T07	716003	6170542	903	DA16	1364
T08	715899	6170905	882	DA16	1607
T09	715503	6171219	867	HS02	1612
T10	715337	6171583	858	HS02	1435
T11	715269	6171908	845	HS02	1291
T12	715149	6172300	836	HS02	1256
T13	715415	6170615	871	DA16	1948
T14	715165	6170992	900	HS02	1992
T15	714719	6171266	864	HS10	1686
T16	714332	6171832	827	HS10	1347
T17	714042	6171415	823	HS10	1001
T18	715593	6169908	893	DA16	1719
T19	715322	6170274	890	DA16	1982
T20	714763	6170375	870	HS10	2026
T21	714201	6170556	862	HS10	1461
T22	713921	6170969	823	HS10	1000
T23	714064	6170175	862	HS10	1632
T24	715042	6169630	876	DA16	2308
T25	714491	6169769	856	HS10	2217
T26	715169	6169139	859	HN11	2090
T27	714673	6168987	864	HN12	2411
T28	714425	6169376	836	HN15	2483
T29	714657	6168605	850	HN12	2173
T30	714409	6167741	832	HN12	2030
T31	714079	6167384	813	HN12	2312

[1] Coordinate system: UTM zone 55, WGS84 datum

Table 2: Proposed turbine layout for the Biala Wind Farm site

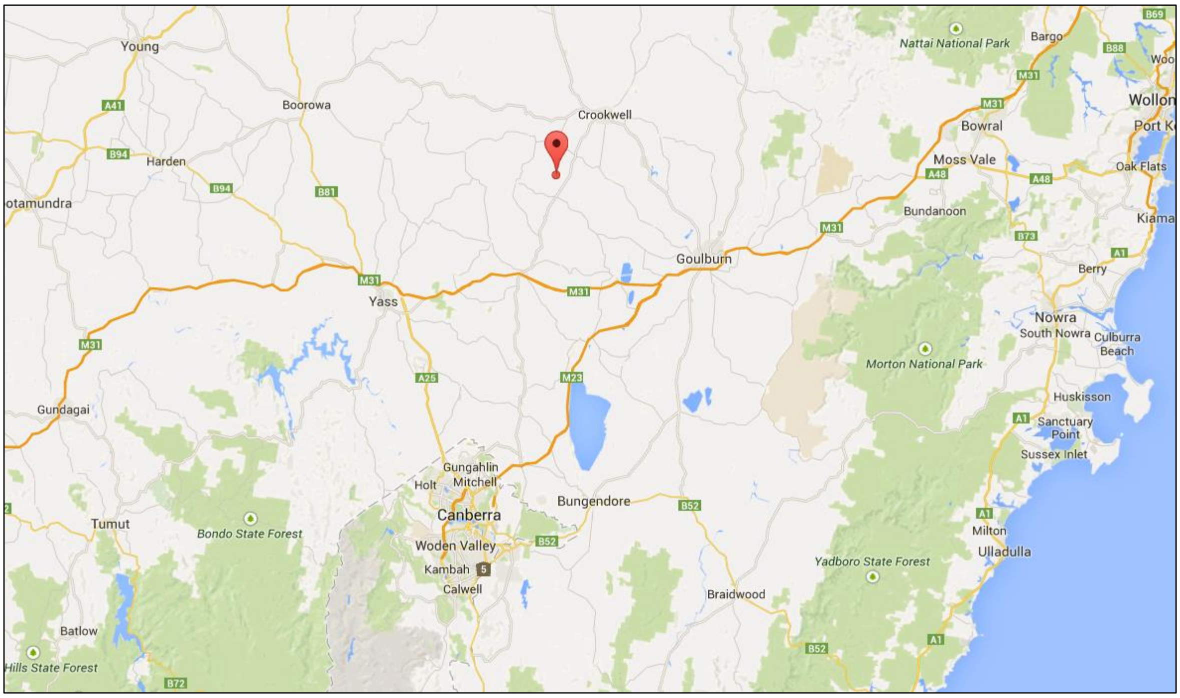

Figure 1: Location of the proposed Biala Wind Farm

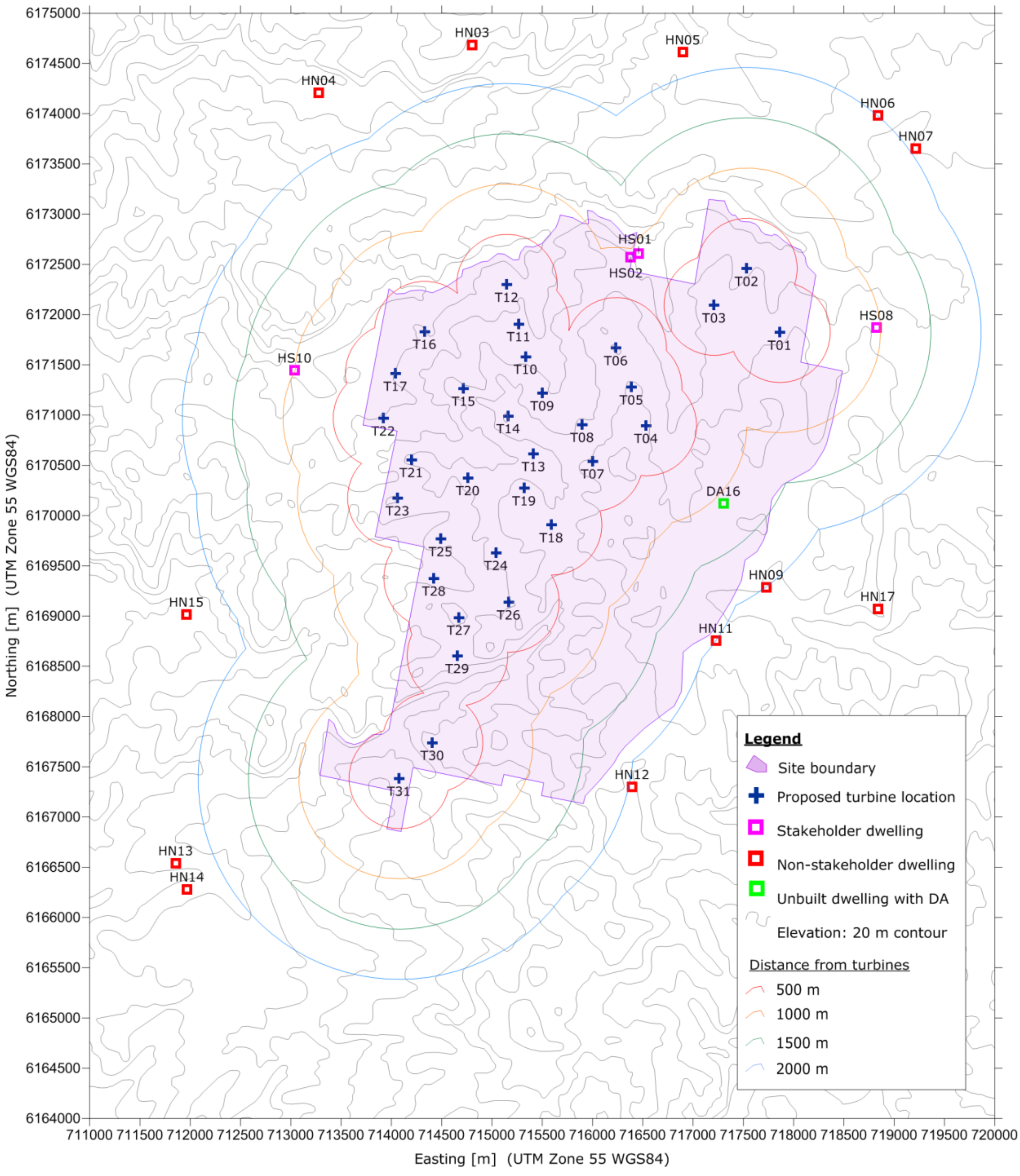

Figure 2: Map of the proposed Biala Wind Farm showing distances from turbines to dwellings and site boundary.

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