Harmattan (Pty) Ltd
12 Athol Oaklands Road
Abbotsford
Sandton
Gauteng 2193
South Africa

Jasper Dick
WKN Windcurrent SA (Pty) Ltd
301 Sunclare Building
21 Dreyer Street
Claremont, 7708
South Africa

18 January 2023

Dear Jasper,

RE: 395.R01 WKN Wake Effects v1

Harmattan understand that WKN Windcurrent SA (Pty) Ltd (the "Client") is developing a cluster of five wind energy facilities (each a "WEF", together "the Cluster") near Soutrivier, Northern Cape, South Africa and wishes to understand the potential wake effects on nearby projects. Harmattan understands that the Cluster comprises the following:

- Soutrivier North WEF: 31 turbines up to 240m rotor diameter and up to 200m hub height;
- Soutrivier Central WEF: 32 turbines up to 240m rotor diameter and up to 200m hub height;
- Soutrivier South WEF: 35 turbines up to 240m rotor diameter and up to 200m hub height;
- Taaibos North WEF: 40 turbines up to 240m rotor diameter and up to 200m hub height;
- Taaibos South WEF: 36 turbines up to 240m rotor diameter and up to 200m hub height.

The location of the Cluster within South Africa is shown in Figure 1 with the detailed layouts in and Figure 2.

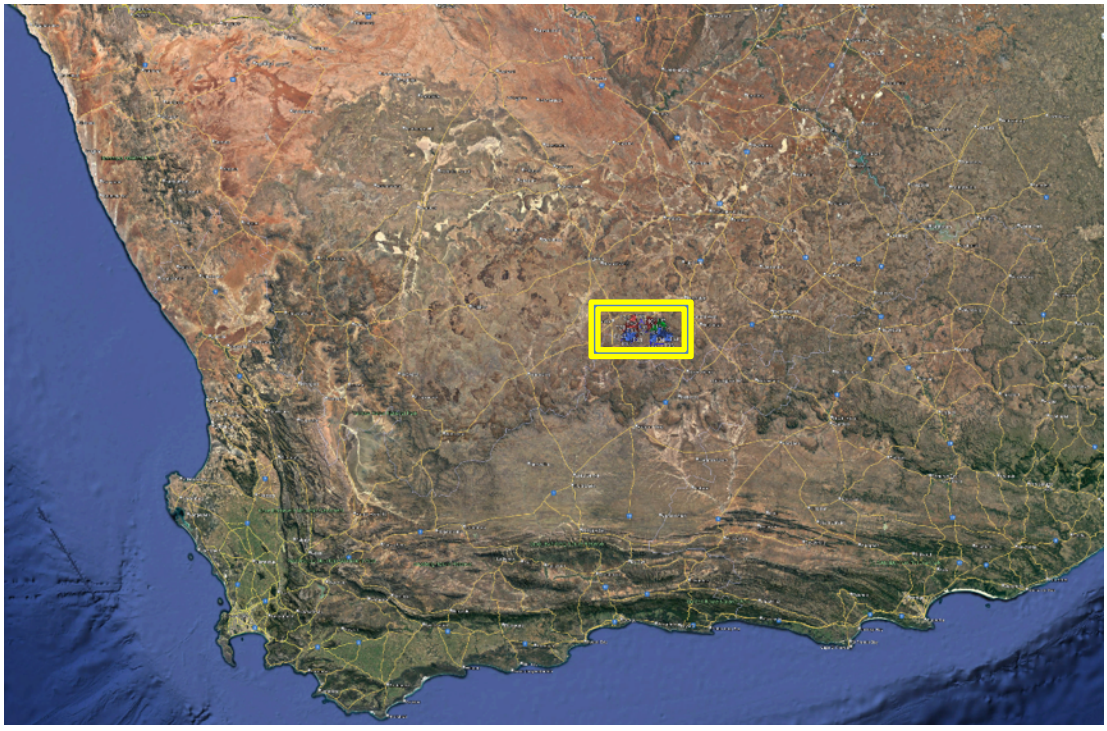

Figure 1: WEF location within South Africa (Image from Google Earth)

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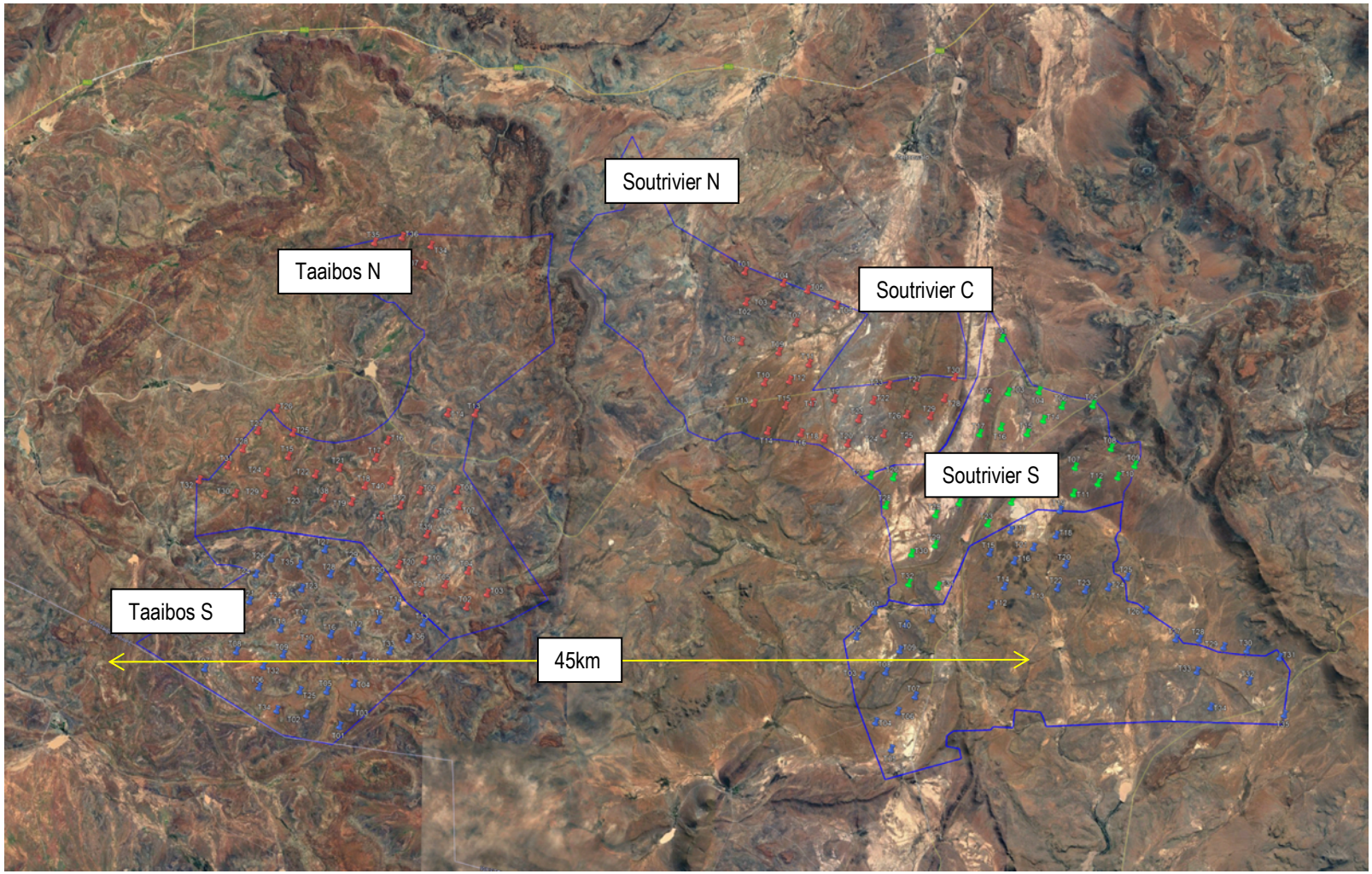

Figure 2: WEF Layouts

Two met masts have been installed by the Client as follows:

- Taaibos – 140m;
- Soutrivier – 140m.

These are shown in Figure 3 along with the following nearby wind energy projects:

- Noblesfontein Wind Farm – operational – 41 Vestas V100 turbines installed at 80m hub height;
- Nuweveld East, West and North – development – 280MW each, EA for 8MW WTGs, up to 150m hub height, 190m rotor diameters, total of 105 WTGs (35 per project);
- Hoogland WEF 1, 2, 3 and 4 – development – 420MW each for 3 and 4.

The operational turbines are shown by location while the development projects are shown as site boundaries.

We note that the list of nearby projects may not be exhaustive as wind development is confidential at early stage.

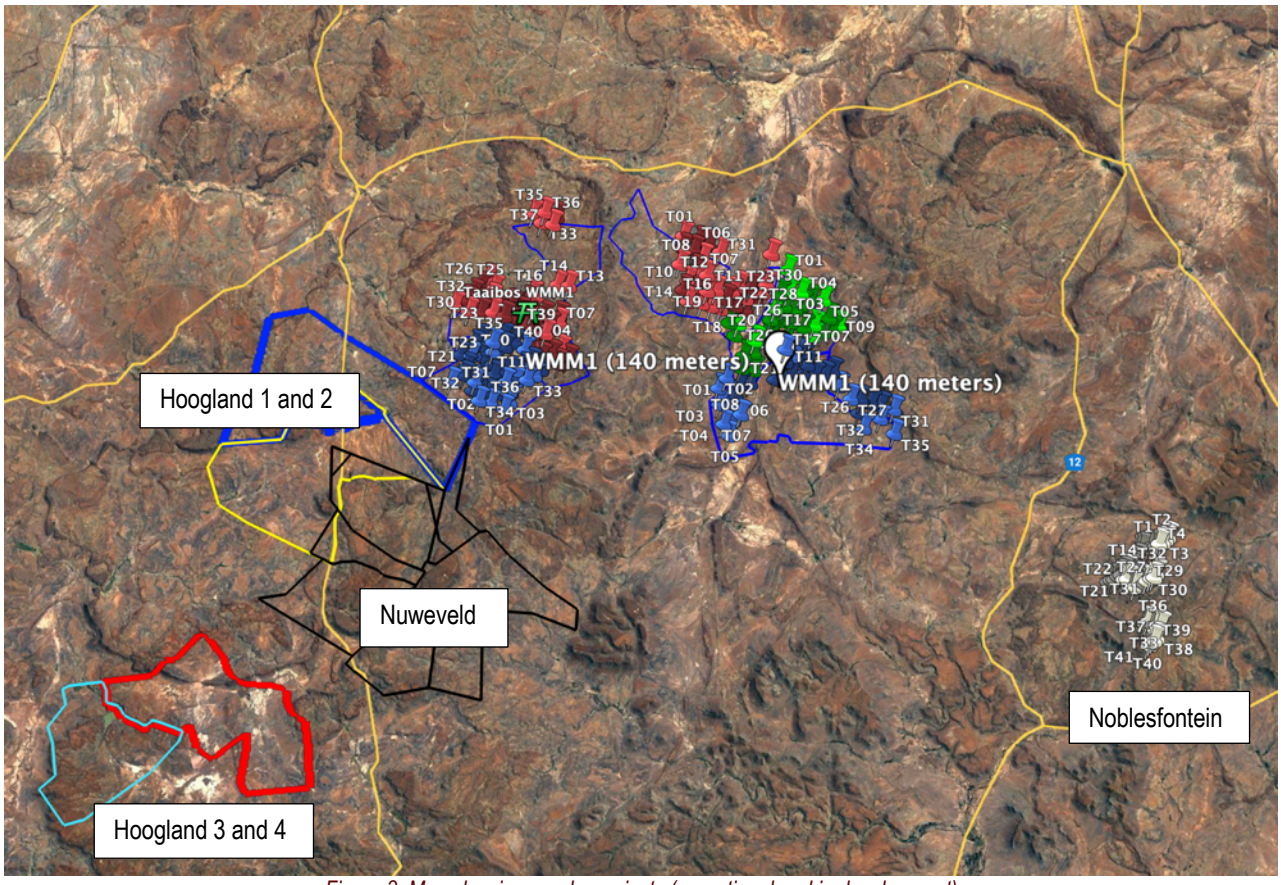

Figure 3: Map showing nearby projects (operational and in development)

When considering any potential wake impact, the wind speed and direction is critical. The wind direction shown by the met mast at Taaibos is strongly bi-directional with WNW and ESE being the dominant sectors (Figure 4) while Soutrivier is similar with NNW and SSE dominant (Figure 5).

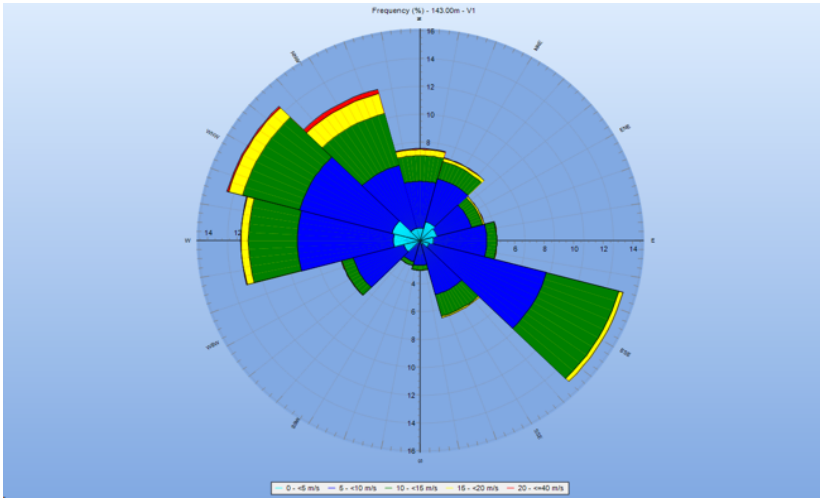

Figure 4: Taaibos mast wind rose

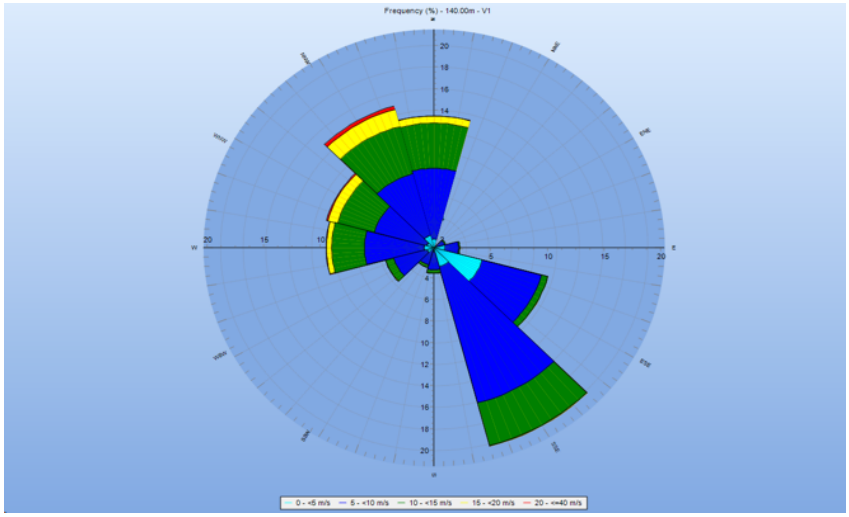

Figure 5: Soutrivier mast wind rose

Propagation of wake effects with distance.

The wake effects from a turbine or wind farm are most acutely felt directly behind the turbines (downwind). When examining the wind roses for each project (Figure 4 and Figure 5), we can see that the WNW and NNW sectors are the most important for energy production meaning an analysis of the Cluster's impacts on the proposed and existing projects is critical to the SSE and ESE sectors. There are no known projects to the North of the Cluster. The WNW and NNW directions can be ignored in this analysis as this would be the other projects affecting the Cluster not *vice versa*.

Despite being closest to the Cluster, the Hoogland 1 and 2 WEFs are unlikely to be affected by the Cluster as the NE sectors make up an insignificant percentage of wind (speed and frequency). Both the Hoogland 3 and 4 WEFs and the Nuweveld WEFs will have the same issue in addition to being screened from any wake effects from the Cluster by Hoogland 1 and 2. These projects are therefore excluded from further study.

This leaves the Noblesfontein operational WEF as the only project in the relevant direction from the Cluster to have the potential for significant wake effects.

There have been numerous studies completed that have investigated the decay of wind turbine wakes over distance. Many of these have been focussed on the offshore environment due to the size of projects involved but also because of the wind conditions. Wake effects propagate most effectively when the wind flow is linear i.e. it is undisturbed by terrain effects and obstacles and hence the seas are the idea environment.

On land, changes in topography (hills, ridges, valleys etc), roughness (surface cover such as crops, scrub or grassland) and obstacles (trees, fences, buildings etc) all disturb the air. There is also a consideration of whether a wind farm is to be treated as an obstacle (likely most useful for neighbouring projects within 100s of metres) or as a change in roughness (more applicable for 10's of kilometres away).

One of the early pioneers of the wind industry, the Risø National Laboratory in Denmark (Risø) conducted a study on the shadowing effect of large wind farms[1]. Whilst their study focussed on offshore projects, their conclusions were that the wind speed typically recovers to 98% of its initial value within 8km of the upwind project.

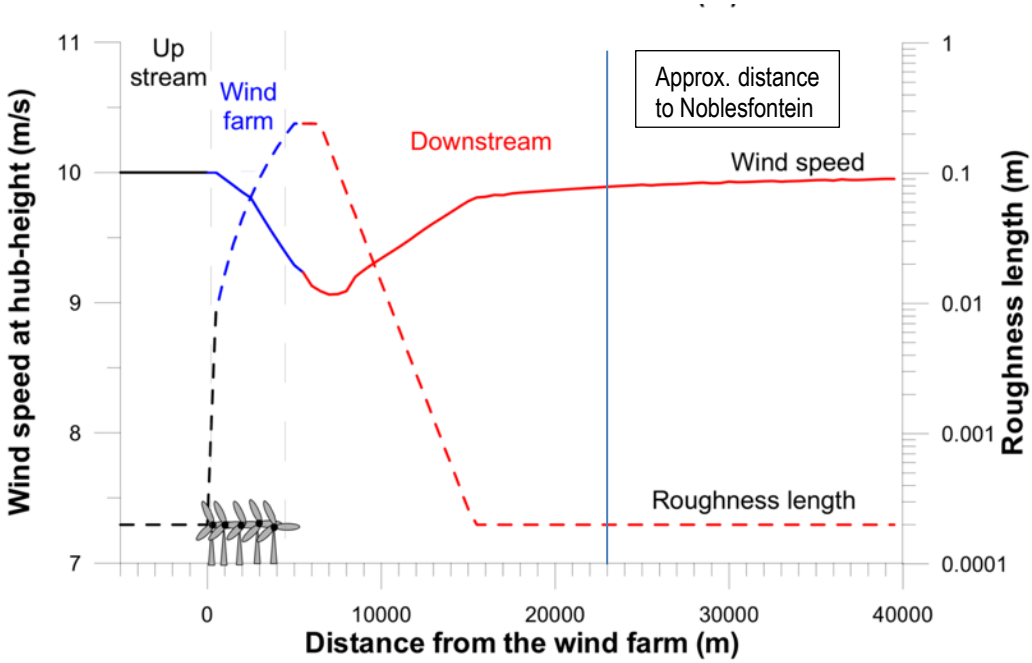

Figure 6: Wind speed recovery with distance

This was shown in both WAsP and utilising CFD. Onshore, Harmattan considers it likely that disturbances to the air flow from other sources (topography, roughness and obstacles) will render this minor reduction indistinguishable from the initial value and as separation distances increase, the effect of a new project will be even less visible. It is also worth noting that in the vicinity of the Cluster, the roughness value of the terrain would be between 0.1 to 0.5m rather than the lower value of 0.0002m modelled by Risø (roughness for water).

It is approximately 23km from the Noblesfontein WEF to the nearest Cluster WTG (T35) which would mean that even in flat terrain, the wind speed would have largely recovered from the effects of the Cluster by the time of reaching Noblesfontein WEF. Helpfully for the Cluster, the ground is not flat as shown in Figure 7.

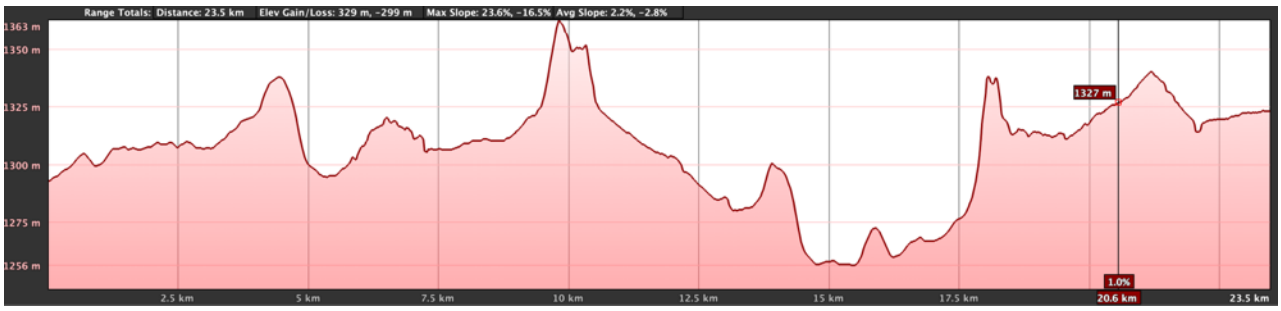

Figure 7: Terrain profile from Cluster T35 (left) to Noblesfontein boundary (right)

[1] Risø R-1616(EN) 2007

The hills and valleys between the Cluster and Noblesfontein WEF make it more likely that the wind will have recovered even closer to its initial values over the distance. Furthermore, the terrain will induce turbulence of its own to the wind reach Noblesfontein WEF as the flow passes over the various valleys and hills likely playing a more significant role in the disruption of wind from the NW.

Conclusion

Harmattan has performed a high-level investigation into the likelihood of the wakes from the proposed Cluster affecting nearby planned and operational projects. While wake effects are a commonly observed factor, none of the development projects lie downwind of the Cluster in any significant wind sectors. The operational Noblesfontein WEF does lie downwind of an important wind sector, but distance and terrain effects are likely to mean no significant impact is experienced at that site.

Further Reading

- DOI: 10.1175/JAMC-D-19-0235.1, Pryor et al
- Costs and consequences of wind turbine wake effects arising from uncoordinated wind energy development, Lundquist et al
- Estimating Long-Range External Wake Losses in Energy Yield and Operational Performance Assessments Using the WRF Wind Farm Parameterization, Stoelinga et al