STRATEGIC INFRASTRUCTURE DEVELOPMENT APPLICATION TO AN BORD PLEANÁLA (REG NO. PL04.PA0045)

RINGASKIDDY RESOURCE RECOVERY CENTRE, RINGASKIDDY, COUNTY CORK

RESPONSE TO SUBMISSIONS

AIR QUALITY RESPONSE – ATTACHMENT 2

1. Qualifications and Experience

My name is Edward Porter. I hold a Bachelor of Science degree (1st Class (Hons)) in Chemistry (1991) from the University of Sussex and a Ph.D. in Chemistry (Air Quality) from University College Dublin (1997). I am a Chartered Chemist and a full member of the Institute of Air Quality Management (MIAQM) and the Royal Society of Chemistry (C Chem MRSC), a requirement of membership being that I am active in the field of professional chemistry and satisfy the Society's requirements with regard to level of qualifications and experience.

I have been active in the field of air quality and climate for 24 years, the last 20 years as an Environmental Consultant. I have considerable experience in the areas of planning of proposed developments with regard to air quality and climate, assessment of air quality for compliance purposes and air quality mitigation measures in relation to both construction sites and operational developments. I am currently Director of Air Quality and Climate with AWN Consulting. My experience includes:

- Dublin Waste To Energy Facility (2008)
- Ringaskiddy Waste Management Facility (2009)
- M11 Gorey to Enniscorthy (2009)
- College Proteins Meat & Bone Meal CHP (2009)
- Carranstown Waste Management Facility Expansion (2012)
- Drehid MBT Facility (2012)
- N5 Castlebar to Westport (2014)
- National Children's Hospital (2015)
- Dun Laoghaire Cruise Berth (2015).

2. Issues Raised In The Submissions

The Department of Defence, in their letter of the 12 July 2017, confirmed that should the extent of the plume be contained within 150m then it will not impact on Air Corps operations. As outlined below, this report confirms that the extent of plume in terms of risk levels of oxygen, vertical velocity and temperature is limited to a region much lower than 150m and thus this report confirms that there will be no impact on Air Corps operations.

In the report prepared in May 2017 entitled "*Plume Modelling Assessment*", the maximum extent of the risk zone of the plume was confirmed to be significantly below the physical restriction zone of 150m. Since then, An Bord Pleanála [the Board] has received several submissions referring to this report and thus the Board has requested that the applicant respond to various matters raised in the submissions. The submissions raised the following matters:

- The plume modelling was undertaken using ADMS whereas AERMOD was used in the EIS,
- The modelling ignored the vertical extent of the plume,
- The vertical extent of the vertical velocity, temperature and oxygen has been underestimated,
- The meteorological data used in the model (Cork Airport) is not appropriate,
- The effect of plume dispersion due to the wind turbine has not been assessed,
- The effect of the velocity deficit of the wind turbine and associated eddy currents (turbulence) has not been assessed.

These issues, in so far as they relate to air quality, have been addressed below.

2.1 ADMS vs AERMOD Air Dispersion Models

Both ADMS and AERMOD are given equal weighting by the EPA in the guidance document "*Air Dispersion Modelling From Industrial Installations Guidance Note*" (EPA, 2010). However, ADMS has several advantages over AERMOD in terms of determining the parameters of interest (vertical velocity, temperature and oxygen):

Vertical Velocity

- AERMOD does not produce the parameters required to determine the vertical velocity (change in vertical height of plume with time) and thus cannot be used to determine vertical velocity. ADMS does have this capability and thus was selected to undertake the study of the change in vertical velocity with height.

Temperature

- AERMOD cannot track the path of the plume with distance from the stack for the parameters of interest for each hour of the year. ADMS produces a .cen file for every hour of the year which outputs the parameters (temperature, concentration, change of plume height with distance). Thus, actual direct changes in temperature of the plume could be tracked for every hour of the day downwind of the release.

- A requirement of the temperature assessment is the need to know the ambient temperature for every hour of the year. A submission has suggested that an ambient level of 30°C would be appropriate for every hour of the year. However, this would be a gross over-estimation of reality (i.e. the highest temperature ever recorded at Roches Point is 28°C with an average temperature of 10.5°C). Unfortunately, AERMOD is not formulated to extract, even indirectly, the change in temperature of the plume with distance from the stack on an hourly basis.

- The report entitled "*Plume Modelling Assessment*" (May 2017) assessed the temperature of the plume as a function of downwind distance from the stack. Shown in Section 2.4 is the temperature of the plume as a function of vertical distance from stack top (i.e. distance directly above stack top). Results indicate the vertical distance where the temperature is greater than 50°C is limited to 6.8m in the worst-case year (Year 2014) which is slightly greater than the x-y plane results of 3.5m. However, both results should be compared to the physical restriction zone of 150m for context.

Oxygen

- Again, for ADMS, the oxygen concentration can be tracked as a function of distance downstream of the plume which then allows one to determine the change in oxygen % of the plume as a function of distance for each hour.

- AERMOD can be used to indirectly calculate the oxygen concentration for a 3-dimensional grid of receptors as the ambient oxygen level is fixed at 20.95%. In order to address concerns raised, the oxygen concentration using AERMOD has been derived below in Section 2.2 based on a high resolution 3-D grid (2m resolution in horizontal, 1m resolution in the vertical, grid from 65m – 95m above local ground level, 40m x 40m, 13,230 receptors).

2.2 Oxygen / Plume Interaction Using AERMOD

As outlined in the report entitled "*Plume Modelling Assessment*" (May 2017), CERC, the developers of the EPA approved ADMS-5 model, were contacted to determine whether the oxygen concentration in the plume could be derived indirectly from the reduction in the emission concentration of the plume with distance from the stack. CERC developed the following equation which can be used to model the % of oxygen in the plume with distance from the stack top.

For a given emission concentration of any pollutant *e* (in μg/m^3), the oxygen content *O* (%), is related to the plume concentration *c* (in μg/m^3) by the following relationship (6.0 is the worst-case plume oxygen percentage at release):

$$c / e = (20.95-O) / (20.95-6.0)$$

Thus, the calculation can be re-arranged to determine the oxygen content (%) of the plume as a function of distance from the stack top. The re-arranged equation is:

$$O\ (\%) = 20.95 - [(c/e) * (14.95)]$$

AERMOD has now been used in this report to calculate the pollutant concentration and identify the distance, represented as a dense 3-D grid of receptors, where the 12% oxygen level was exceeded. Modelling was undertaken using Cork Airport data over the period 2010 – 2014 with the worst-case year selected. Shown in Figure 2 is the result for the worst-case year (Year 2014).

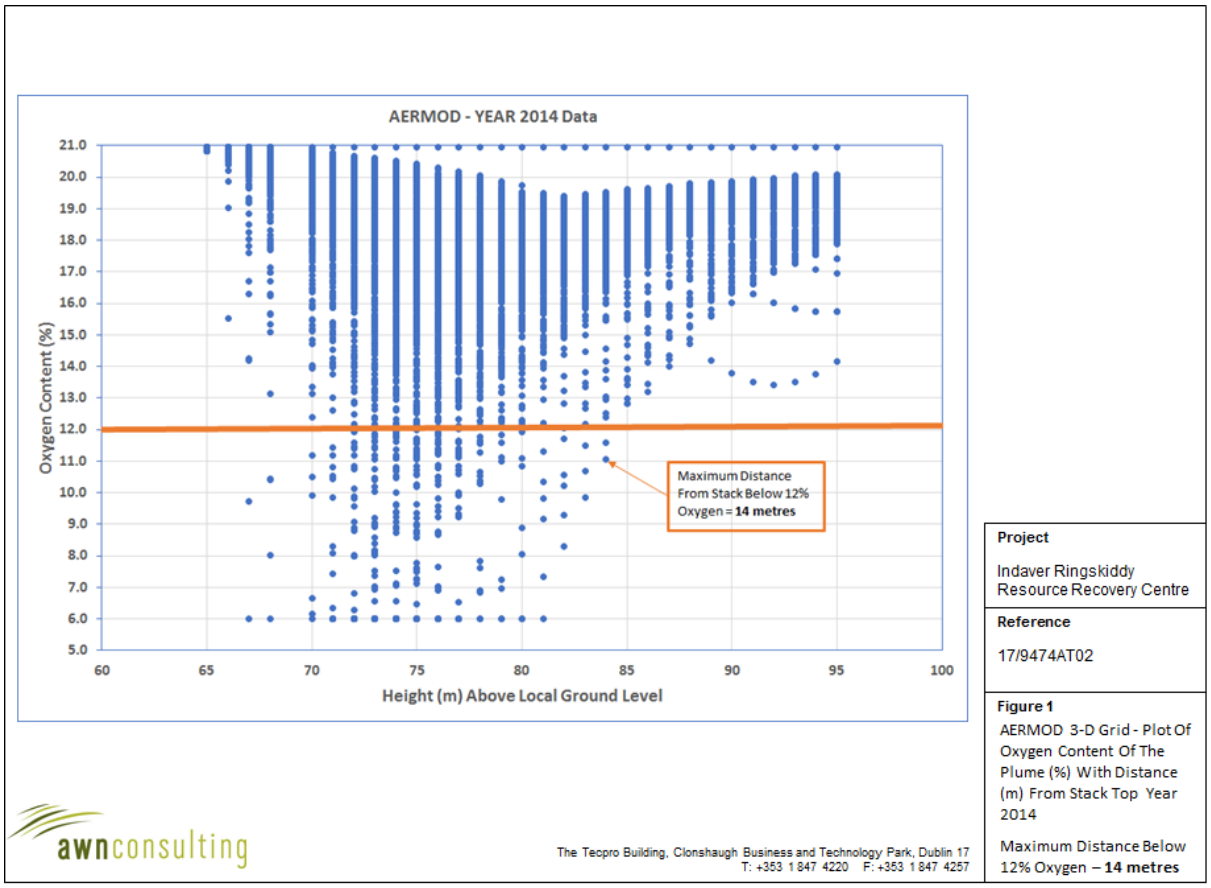


Figure 1 Oxygen Content Of The Plume (%) With Distance From Stack Top - AERMOD

The modelling results determined a maximum vertical and horizontal distance of 14 metres from the stack top where the oxygen content of the plume will be 12% or greater. This analysis is based on every hour of the year for each year over a five-year period (Cork Airport 2010 – 2014) and includes all meteorological conditions including pressure / temperature inversions. The values for the other four years ranged from 9m – 13m (as outlined in Appendix 1, Figure A1 - A8). As shown in Figure 2, the isosurface plot shows that the maximum extent of the plume is similar in both the vertical direction and horizontal direction.

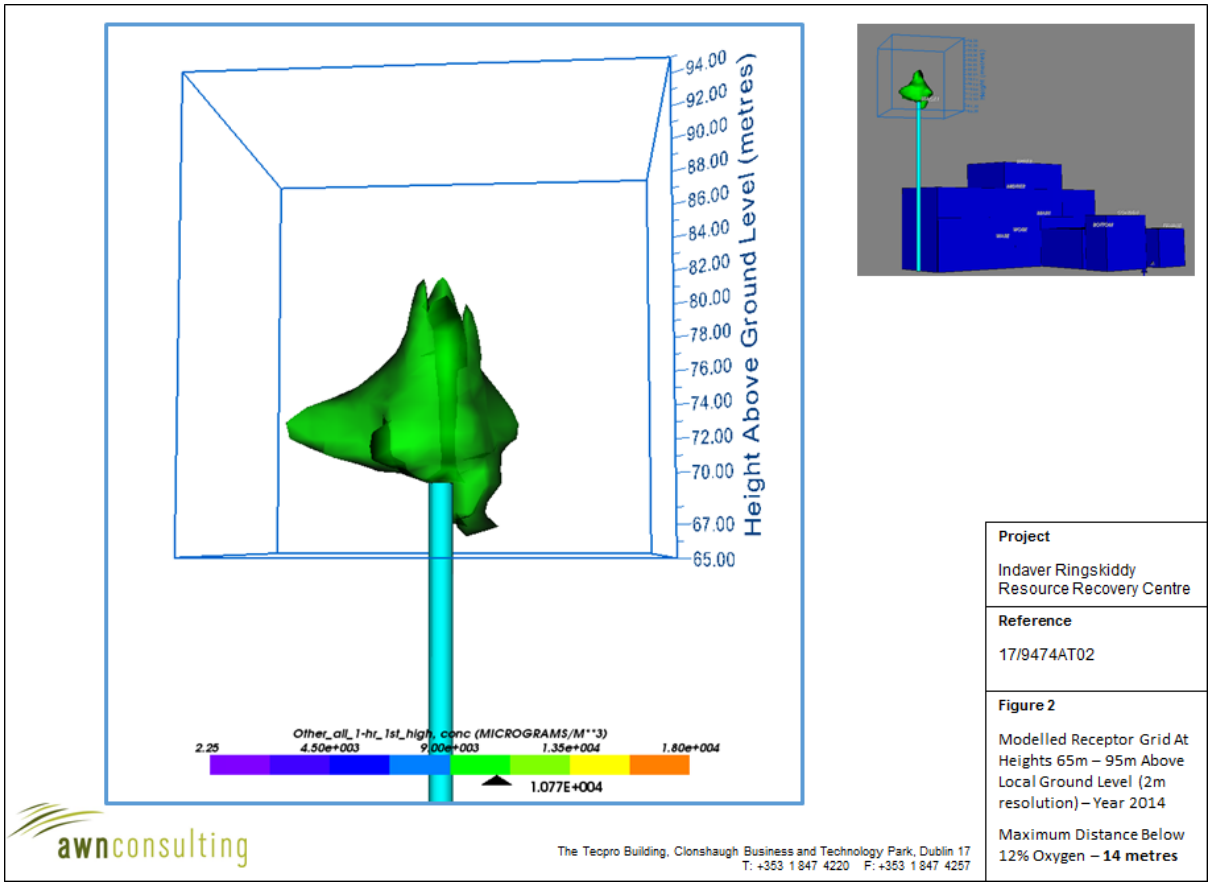


Figure 2 Oxygen Content Of The Plume (%) With Distance From Stack Top - AERMOD

Some differences in the results between ADMS and AERMOD are to be expected for several reasons:

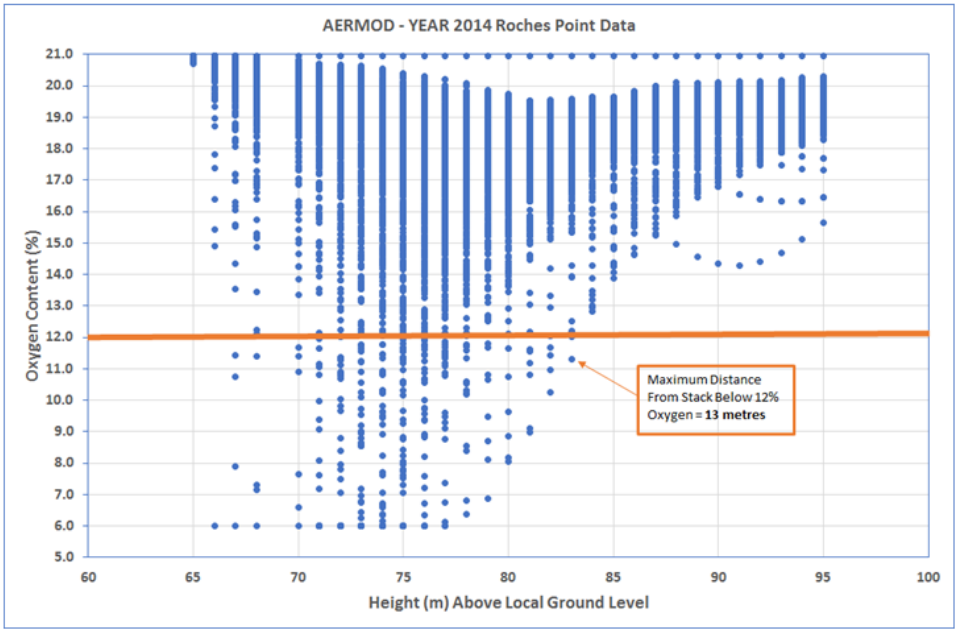
- The models work best at 50m – 100m from stack and thus very close to the stack exit minor differences in formulations will be exaggerated.
- If all input parameters are consistent, models are expected to agree within a factor of two.
- The ADMS modelling and the AERMOD modelling differ in that ADMS is tracking the plume downstream of its release whilst AERMOD is using a fixed grid at which the model concentrations are determined.

Although the ADMS and AERMOD results differ, the use of both models confirms that the region of risk due to reduced oxygen levels is significantly below the physical restriction zone of 150m.

2.3 The meteorological data used in the model (Cork Airport) is not appropriate.

A submission has suggested that Cork Airport data is inappropriate and that Roches Point data should be used for assessing dispersion in the vicinity of the facility. Roches Point station is unmanned and thus does not have all relevant meteorological parameters such as cloud cover. However, wind speed, wind direction, temperature and relative humidity are available and have been used for Year 2014 with the missing parameters such as cloud cover supplemented by Cork Airport 2014 data.

As shown in Figures 3 and 4, the maximum distance is 13 metres from the stack top where the oxygen content of the plume will be 12% or greater. Thus, for Year 2014, Roches Point indicates a slightly lower distance where oxygen is below 12% compared to Cork Airport.



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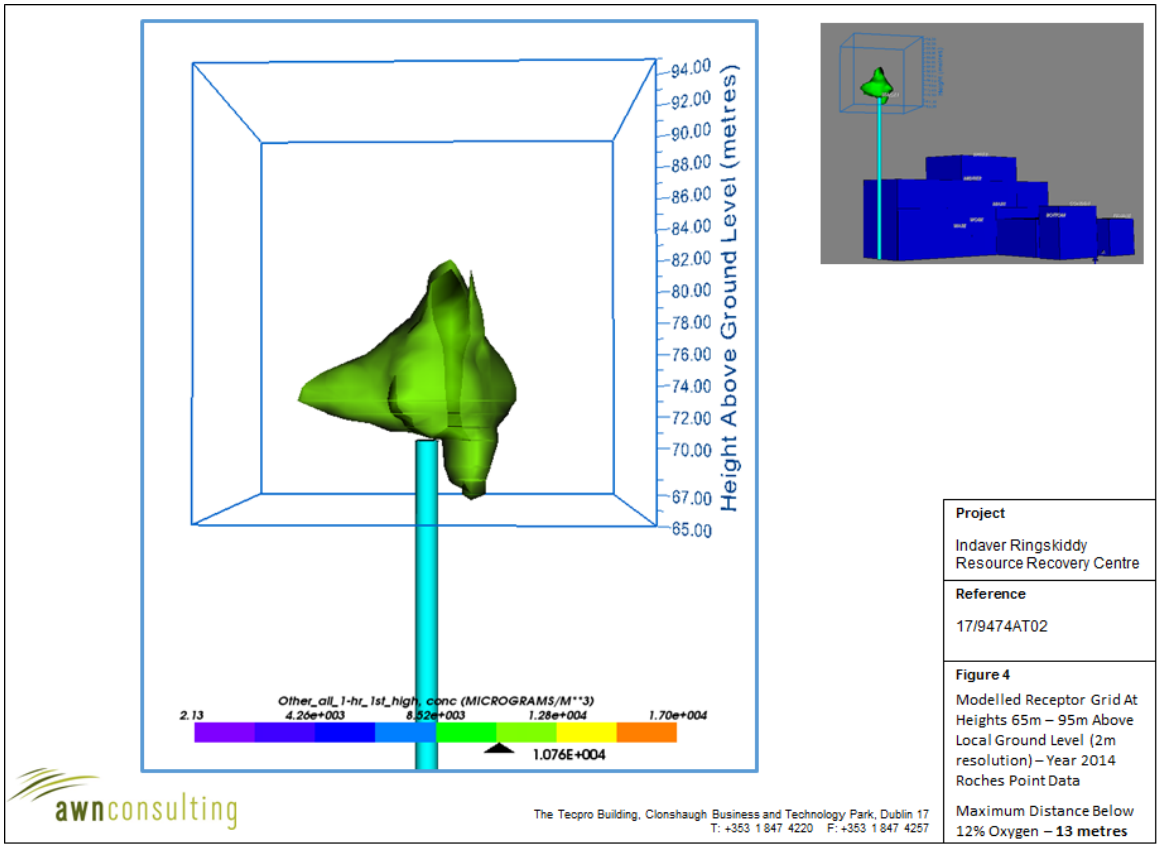
The Tecpro Building, Clonshaugh Business and Technology Park, Dublin 17
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Project
Indaver Ringskiddy Resource Recovery Centre

Reference
17/9474AT02

Figure 3
AERMOD 3-D Grid - Plot Of Oxygen Content Of The Plume (%) With Distance (m) From Stack Top Year 2014 –Roches Point Data

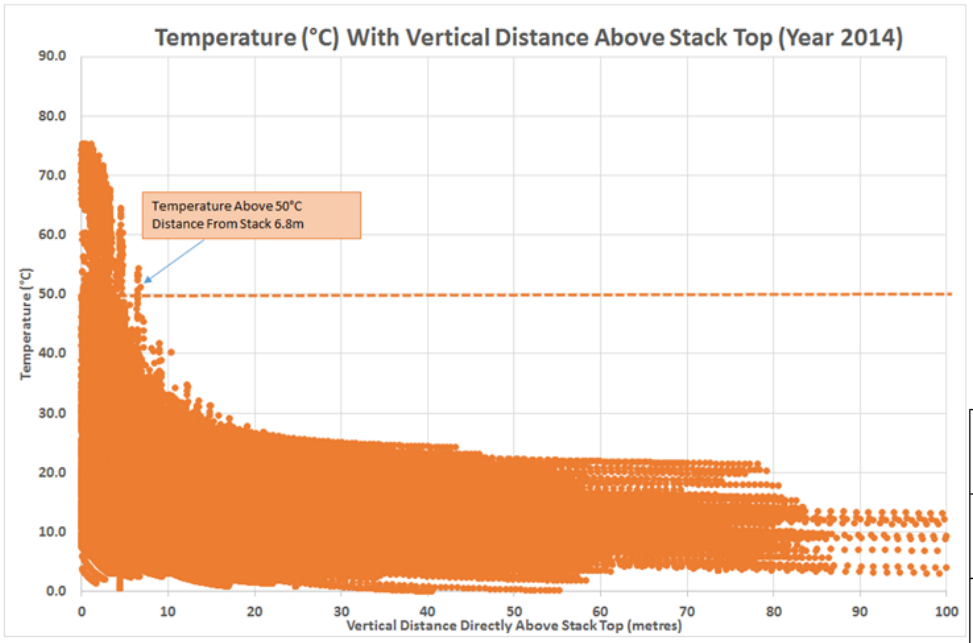
Maximum Distance Below 12% Oxygen – **13 metres**



2.4 Vertical Temperature / Plume Interaction

As outlined in the "*Plume Modelling Assessment*" (May 2017), temperatures in excess of 50°C are potentially hazardous to helicopters and thus the decrease in the initial temperature of the plume (145°C) with distance from the stack was investigated. Modelling of the temperature of the plume with distance from the stack was been undertaken using the CERC ADMS-5 model for every hour of the year based on Cork Airport 2010 - 2014 meteorological data. The model found that the plume would be below 50°C within 3.5 metres downwind of the stack tip for every hour over a five-year period covering all meteorological conditions including pressure / temperature inversions.

This modelling has been supplemented in this section in order to determine the vertical zone, directly above the stack, where the temperatures is in excess of 50°C. Modelling of the temperature of the plume with vertical distance above the stack was been undertaken using the CERC ADMS-5 model for every hour of the year based on Cork Airport 2010 - 2014 meteorological data. The model found that the plume will be below 50°C within 6.8 metres directly above the stack tip for every hour over a five-year period and covers all meteorological conditions including pressure / temperature inversions as shown in Figure 5 for the worst-case year (Year 2014).



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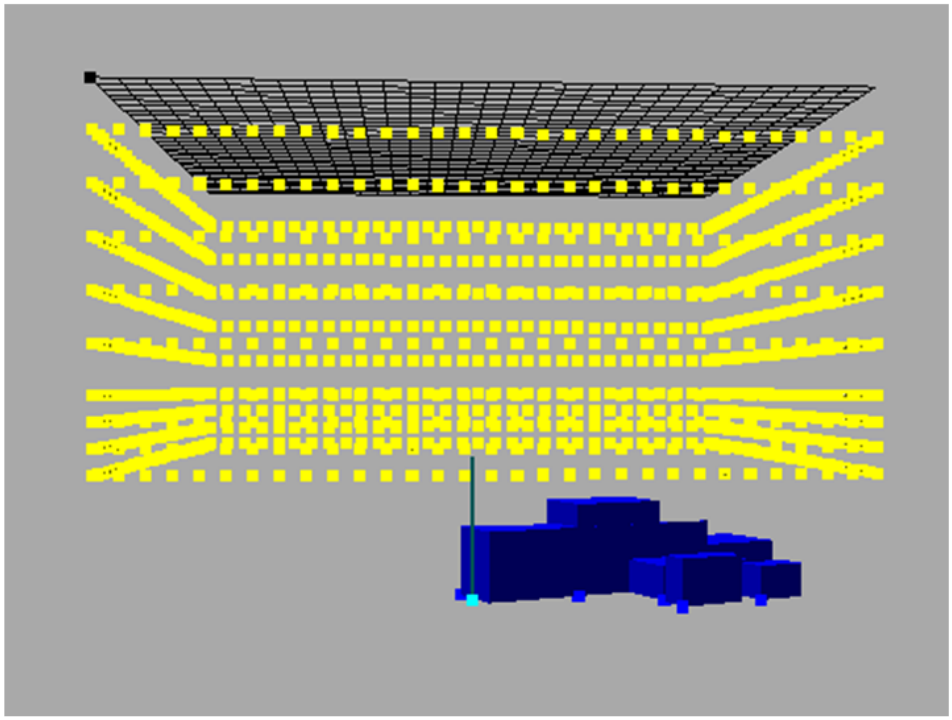
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Figure 5
Plot Of Plume Temperature (°C) With Vertical Distance (m) Above Stack Top (Year 2014)

2.5 Oxygen / Plume Using AERMOD At 150m From Stack

The AERMOD model has been run with a receptor grid placed at a distance of 150m from the stack top, both horizontally and vertically as shown in Figure 6 using Roches Point data for 2014. 150m has been selected as this is the physical restriction zone to which the Air Corps operate. The receptor spacing is 5m in the horizontal with the grid spacing in the vertical increasing from 5m to 20m with altitude.

The results indicate that at a distance of 150m from the stack top, the minimum 1-hour oxygen concentration, over the course of a full year is **20.78% oxygen** compared to an ambient level of 20.95% oxygen. For this particular hour (23:00, 02/09/2014), the predicted temperature is 15.1°C compared to an ambient level of 13.6°C. The results should also be compared to the risk level of 12% oxygen and a temperature risk level of 50°C. Thus, should a helicopter approach the facility at a distance of 150m from the stack top the minimum oxygen level experienced is predicted to be 20.78% oxygen.



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Figure 6
Modelled Receptor Grid Based On 150m From Stack –Year 2014 Roches Point Data

Maximum % Oxygen At 150m – **20.78% Oxygen**

2.6 Wind Turbine Effect Due To Depuy Wind Turbine On Ringaskiddy RRC Plume

A submission has raised the issue of the interaction of the plume with the De Puy wind turbine located approximately 390 metres south-east (at an angle of approximately 325°) of the proposed facility.

Studies have found that the cross-wind radius of the wake of the wind turbine extents approximately 1.2 x diameter (i.e. radius of 120m in this case) at a distance 6.9 x diameter (690m) downwind[1]. Thus, at a distance of 400m downwind, the wake will laterally extend to a radius of 70m (diameter of 140m).

Due to the limited lateral spread in the wake, the effect of the wind turbine is likely to occur during specific, rather narrow, wind directions i.e. when the wind is blowing from a north-west direction (between 310° - 340°) the plume may interact with the wind turbine leading to possible changes in dispersion and turbulence of the plume (Scenario1, Fig. 1 below in Figure 7).

Another possible effect is when the wind is blowing from 130° - 160° the wind turbine will cause a velocity deficient in the wake of the turbine and thus the wind speed at the stack will be reduced leading to possible changes to dispersion and turbulence of the plume (Scenario 2, Fig. 2 below in Figure 7).

[1] Porte-Agel et al, A Numerical Study of the Effects of Wind Direction on Turbine Wakes and Power Losses in a Large Wind Farm (2013) Energies 6 5297-5313

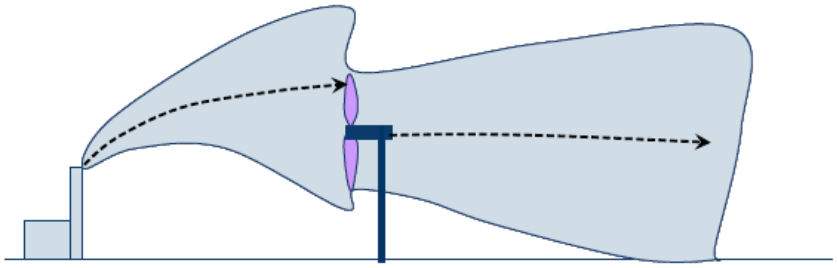


Fig. 1 Upwind plume trapped into the wake of a wind mill

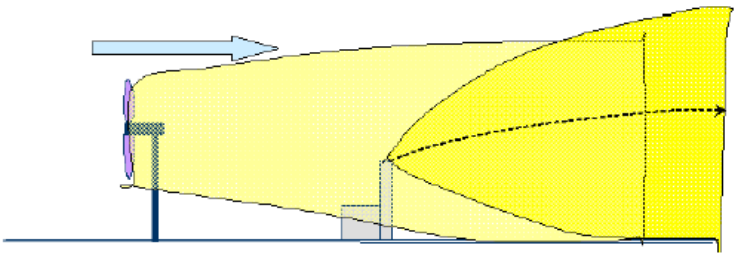


Fig. 2 Downwind plume is emitted into the wake of a wind will

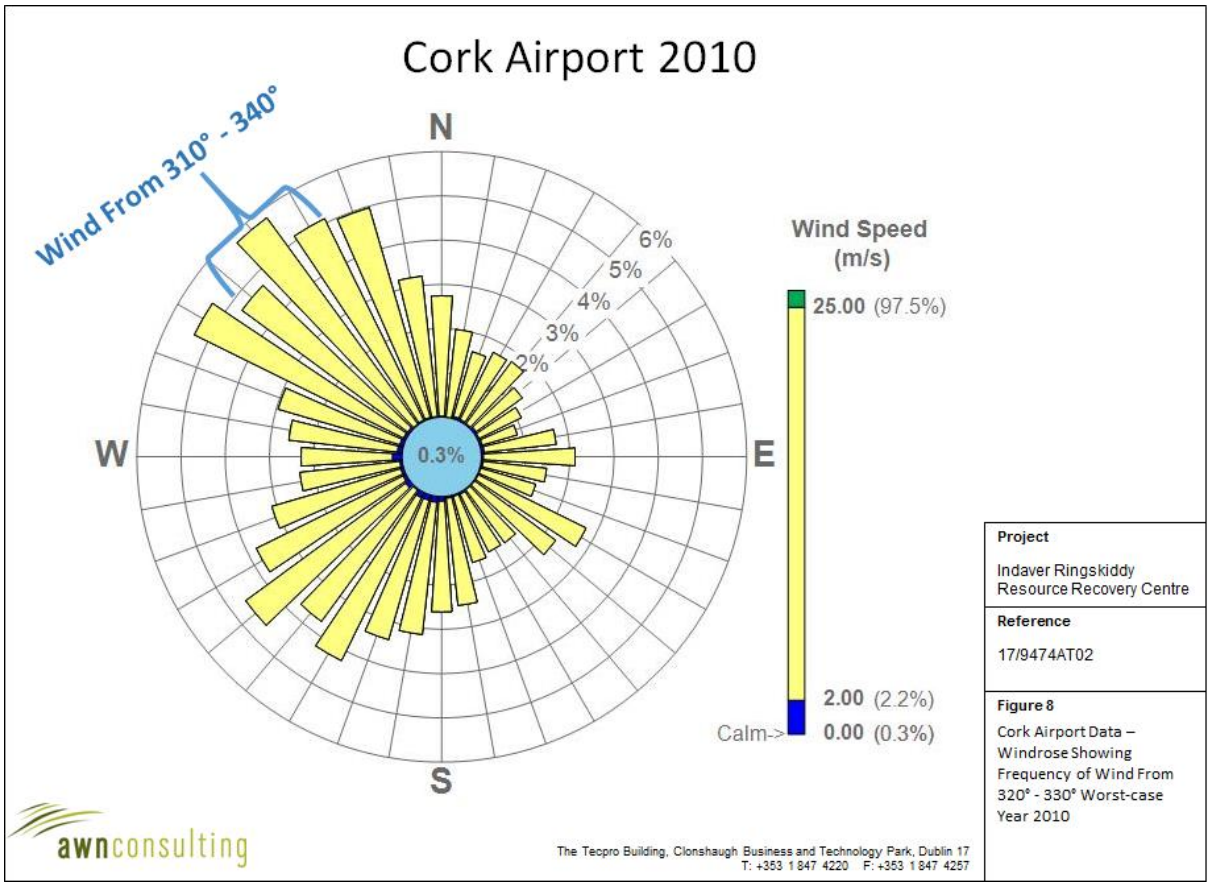
Taken from "Erbrink & Verhees "Enhanced Dispersion From Tall Stacks Near Modern Wind Mills", Poster Presentation International Technical Meeting on Air Pollution Modelling and its Applications, Utrecht (2012)

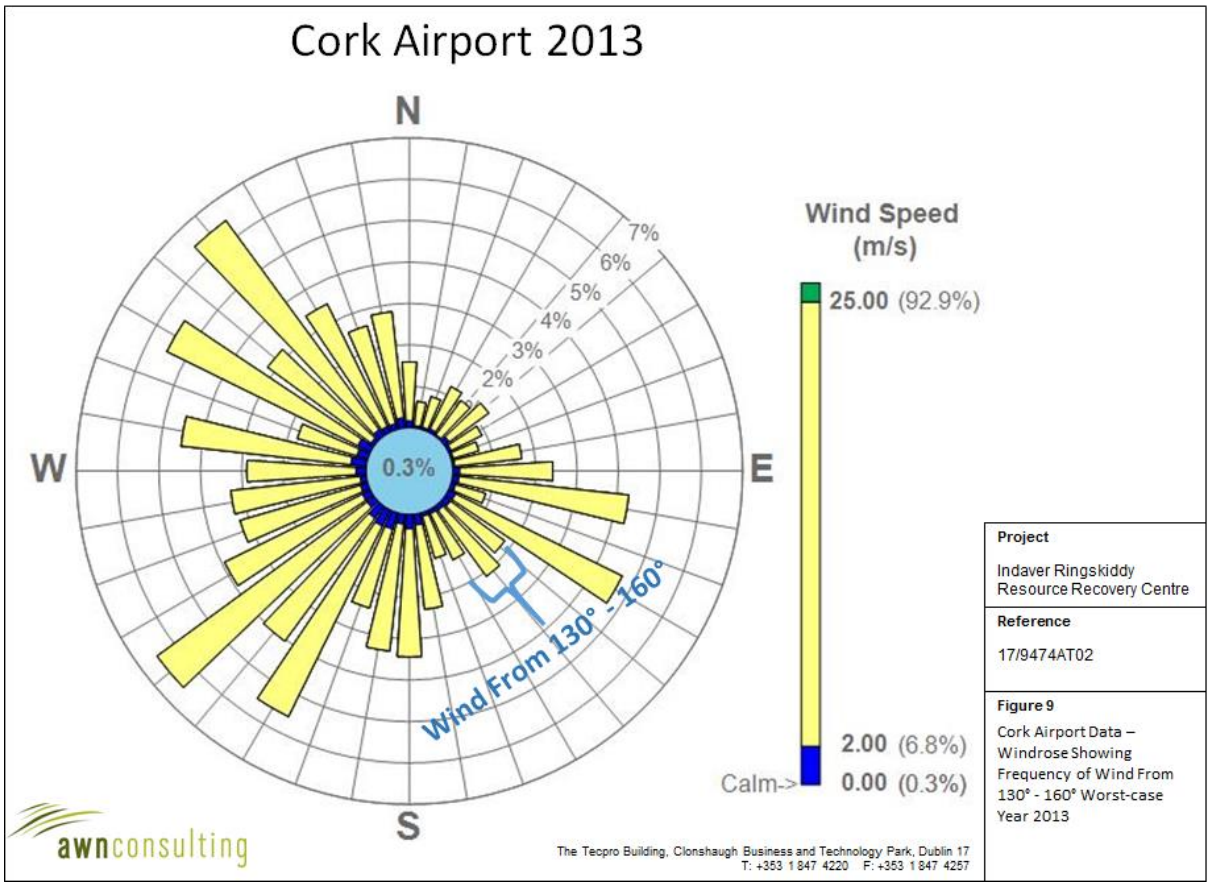
Figure 7 Upwind And Downwind Plume Interaction With A Nearby Wind Turbine

As shown in Table 1 and Figure 8, the frequency of Scenario 1 is relatively small with a five-year average of 11.9% and a maximum year (Year 2010) average over this period of 15.7%. Again, as shown in Figure 9, the frequency of Scenario 2 is minor with a five-year average of 5.6% and a maximum year (Year 2013) average over this period of 6.9%. Periods when the turbine will not be in operation (i.e. when wind speeds are below 2 m/s or above 25 m/s) have been excluded from the totals. Thus, for 82.5% of the time, based on a five-year average, no interaction between the plume and the turbine is likely to occur. Appendix 1 (Figures A9 – A12) show the frequency for the other years considered (Cork Airport 2011, 2012, 1014, Roches Point 2014).

Met Station / Year	Frequency of Wind Blowing From 310° – 340° (Scenario 1)	Frequency of Wind Blowing From 130° – 160° (Scenario 2)
Cork Airport / 2010	15.7%	5.2%
Cork Airport / 2011	8.8%	4.6%
Cork Airport / 2012	11.1%	5.8%
Cork Airport / 2013	12.7%	6.9%
Cork Airport / 2014	10.8%	4.5%
Roches Point / 2014	12.3%	6.6%
Average	11.9%	5.6%

Table 1 Frequency of Wind Direction For Scenarios 1 and 2





2.7 Impact of Wind Turbines on Dispersion Due To The Velocity Deficit

The impact of Du Puy wind turbine located within 400 m of the proposed main stack of the Ringaskiddy RRC has been assessed using the ADMS model.

ADMS has the ability to model the wake from the wind turbine in the region where the flow field is affected by the turbine. The flow wind will be influenced by the wind turbine leading to changes in the wind speed (velocity deficient) and turbulence (eddy currents) i.e. the wind speed downstream of a wind turbine will be reduced whilst there will be an additional shear-induced turbulence in the wake and a lack of large-scale wind direction meandering. These changes to the flow field affect the calculations of the location of the stack plume centreline and the plume spread parameters[2]. ADMS has been validated using real wind turbines as part of the EU funded TOPFARM project with the report concluding that the model predicts wake-affected wind fields which agree well with observations[3].

The model first calculates the existing flow field and any associated changes to the wind / turbulence flow field due to the presence of the wind turbine for every hour of the year. ADMS then models the dispersion of the plume from the stack and determines whether the stack plume will interaction with the turbine wake either via scenario 1 (the plume encounters the wake of the wind turbine) or scenario 2 (the turbine affects the wind speed and turbulence which encounters the plume leading to changes to plume dispersion) as described in Section 2.5.

The impact of the wind turbine on ambient air concentrations due to emissions from the Ringaskiddy RCC stack was assessed by modelling the NO_2 emissions from the

[2] CERC (2016) ADMS User Manual Section 9.23
[3] CERC (2011) CERC Activities Under The TOPFARM Project: Wind Turbine Wake Modelling using ADMS

facility both with and without the wind turbines in place and comparing the results. Data for the wind turbines was taken from manufacture datasheets.

The modelling results are detailed in Table 2 for the 1-hour concentration (measured as a 99.8th%ile) and Table 3 for the annual mean result for Years 2010 – 2014 for Cork Airport and 2014 for Roches Point. The results indicate that the difference in the maximum concentrations at the worst-case receptor at ground level for the years modelled are not significantly impacted by the wind turbine. The maximum difference in the "With" and "Without" scenarios for the 1-hour results (measured as a 99.8th%ile) was a difference of 4.3% of the 1-hour limit value.

The results for the annual mean scenario also demonstrate that the difference in the maximum concentrations at the worst-case receptor for the years modelled are not significantly impacted by the wind turbine. The maximum difference in the "With" and "Without" scenario for the annual average results was a difference of 1.1% of the limit value.

Based on the small magnitude of changes in concentrations between the "With" and "Without" wind turbine scenarios modelled, the wind turbine is not deemed to have a significant impact on dispersion of pollutants from proposed Ringaskiddy RRC as all pollutants will remain well within the ambient air quality standards when adjusted by 1% - 4.3% of the ambient air quality standards. As outlined in Chapter 8 of the EIS (Air Quality Chapter), the modelling found that:

"The spatial impact of the facility is limited with concentrations falling off rapidly away from the maximum peak. For example, the short-term concentrations due to process emissions at the nearest residential receptor will be less than 17% of the short-term ambient air quality limit values. The annual average concentration has an even more dramatic decrease in maximum concentration away from the facility with concentrations from emissions at the proposed facility accounting for less than 1% of the limit value (not including background concentrations) at worst case sensitive receptors near the facility."

Thus, adjusting the results by 1% - 4% of the ambient limit values to account for wind turbine effects will have only a minor influence on results and all ambient levels of regulated pollutants will remain well below the ambient air quality standards.

Pollutant / Year	**Averaging Period**	**Process Contribution "Without" Wind Turbine ($\mu g/m^3$)**	**Process Contribution "With" Wind Turbine ($\mu g/m^3$)**	**Difference of "With" and "Without" ($\mu g/m^3$)**	**Difference as a % of the Limit Value**
NO_2 / 2010	99.8th%ile of 1-hr means	37.0	45.6	8.6	4.3
NO_2 / 2011	99.8th%ile of 1-hr means	37.7	46.0	8.4	4.2
NO_2 / 2012	99.8th%ile of 1-hr means	40.1	42.2	2.1	1.0
NO_2 / 2013	99.8th%ile of 1-hr means	33.9	39.0	5.1	2.6
NO_2 / 2014	99.8th%ile of 1-hr means	40.6	43.2	2.6	1.3
NO_2 / 2014 (Roches Point)	99.8th%ile of 1-hr means	37.6	35.3	-2.3	-1.2

Table 2 Difference in Modelled 1-Hour NO_2 Concentrations (expressed as a 99.8th%ile) for "With" and "Without" Wind Turbines Scenario using ADMS ($\mu g/m^3$)

Pollutant / Year	Averaging Period	Process Contribution "Without" Wind Turbine ($\mu g/m^3$)	Process Contribution "With" Wind Turbine ($\mu g/m^3$)	Difference of "With" and "Without" ($\mu g/m^3$)	Difference as a % of the Limit Value
NO_2 / 2010	Annual Mean	1.0	1.0	0.01	0.02
NO_2 / 2011	Annual Mean	0.67	0.92	0.24	0.61
NO_2 / 2012	Annual Mean	0.65	0.72	0.07	0.16
NO_2 / 2013	Annual Mean	0.73	0.75	0.02	0.06
NO_2 / 2014	Annual Mean	0.49	0.91	0.42	1.1
NO_2 / 2014 (Roches Point)	Annual Mean	0.49	0.52	0.03	0.08

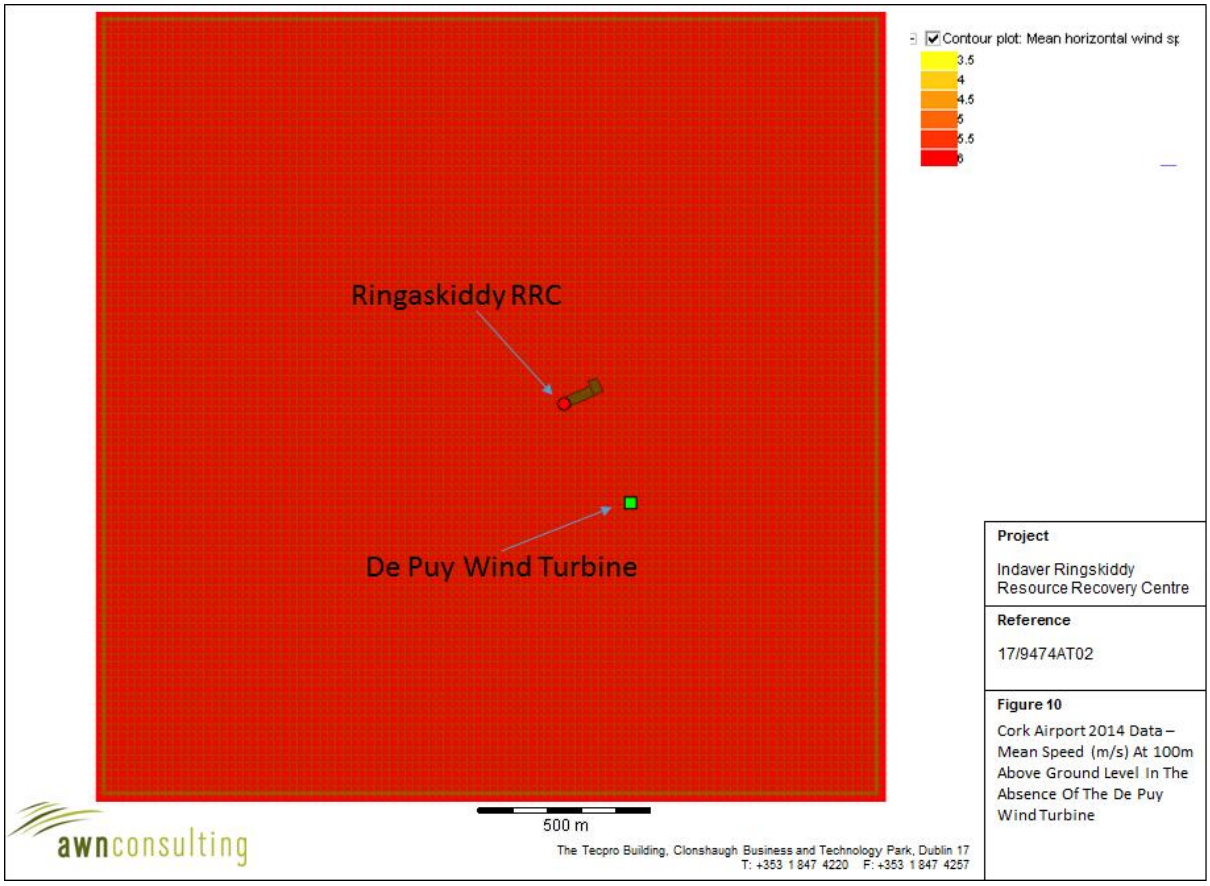
Table 3 Difference in Modelled Annual Mean NO_2 Concentrations for "With" and "Without" Wind Turbine Scenarios using ADMS ($\mu g/m^3$)

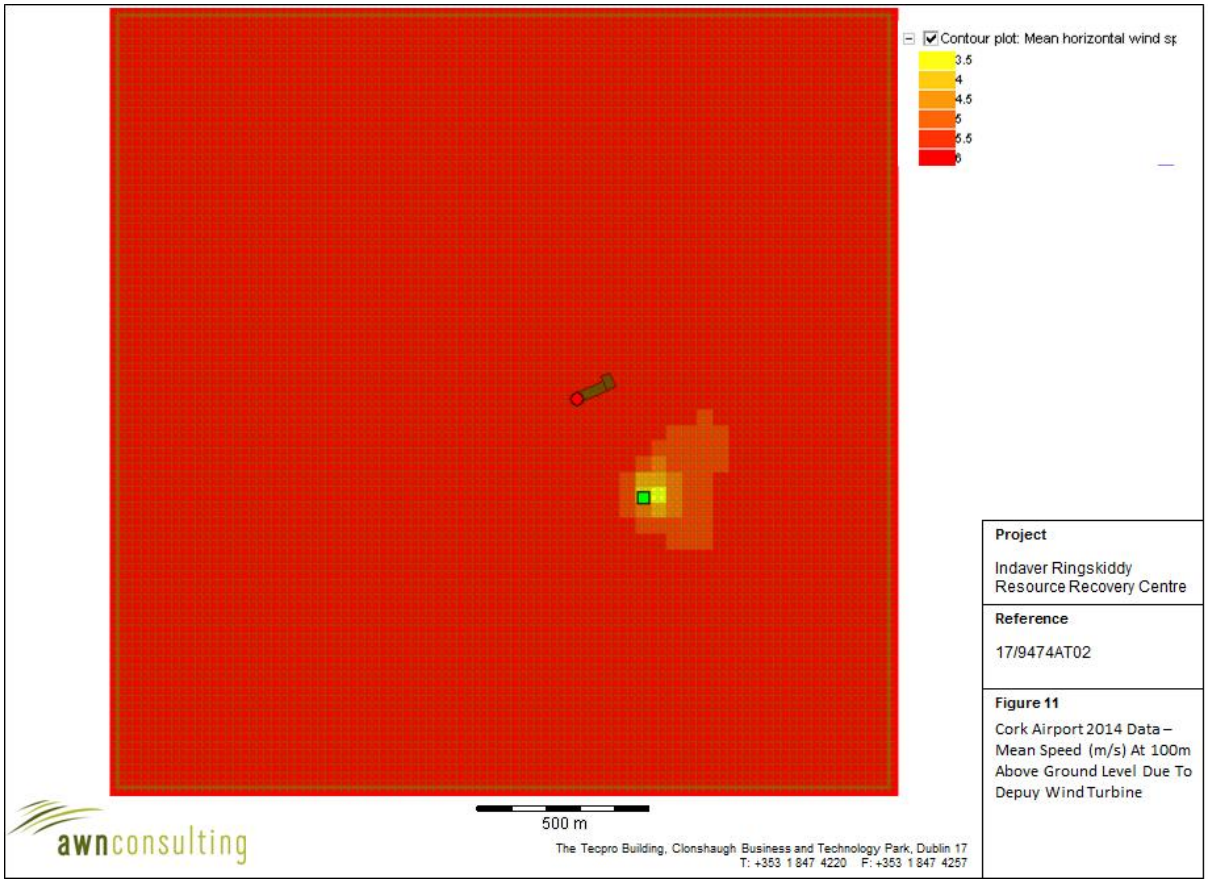
Comparing the results of the ADMS modelling, based on the "no wind turbine" scenario, with the results in the Ringaskiddy RRC EIS using AERMOD, revels that the agreement is good. The maximum process contribution for NO_2 as a 99.8th%ile of 1-hour means is 40.6 $\mu g/m^3$ using ADMS and 36.1 $\mu g/m^3$ using AERMOD. Similarly, the annual mean process contribution for NO_2 is 1.0 $\mu g/m^3$ using ADMS and 1.2 $\mu g/m^3$ using AERMOD.

2.8 Impact of Wind Turbines on Wind Field Parameters

The wind field in the vicinity of the wind turbine has been investigated using ADMS. The mean wind speed (m/s) at a height of 100m has been modelled in ADMS both with and without the wind turbine in order to determine the extent of the region where the wind speed is impacted on an annual mean basis.

As shown in Figure 10, the wind field at a height of 100m above ground in the absence of the wind turbine is essentially uniform with an average wind speed of between 6 – 6.5 m/s. Figure 11 shows the wind field at 100m with the Depuy wind turbine in place. It is evident that there is a reduction in mean wind speed in the region of the wind turbine with mean wind speeds falling to 3.5 m/s within 100m downwind of the prevailing wind near the turbine. However, within 400m the annual mean wind velocity deficit is not apparent and wind speeds return to levels which exist in the absence of the wind turbine.

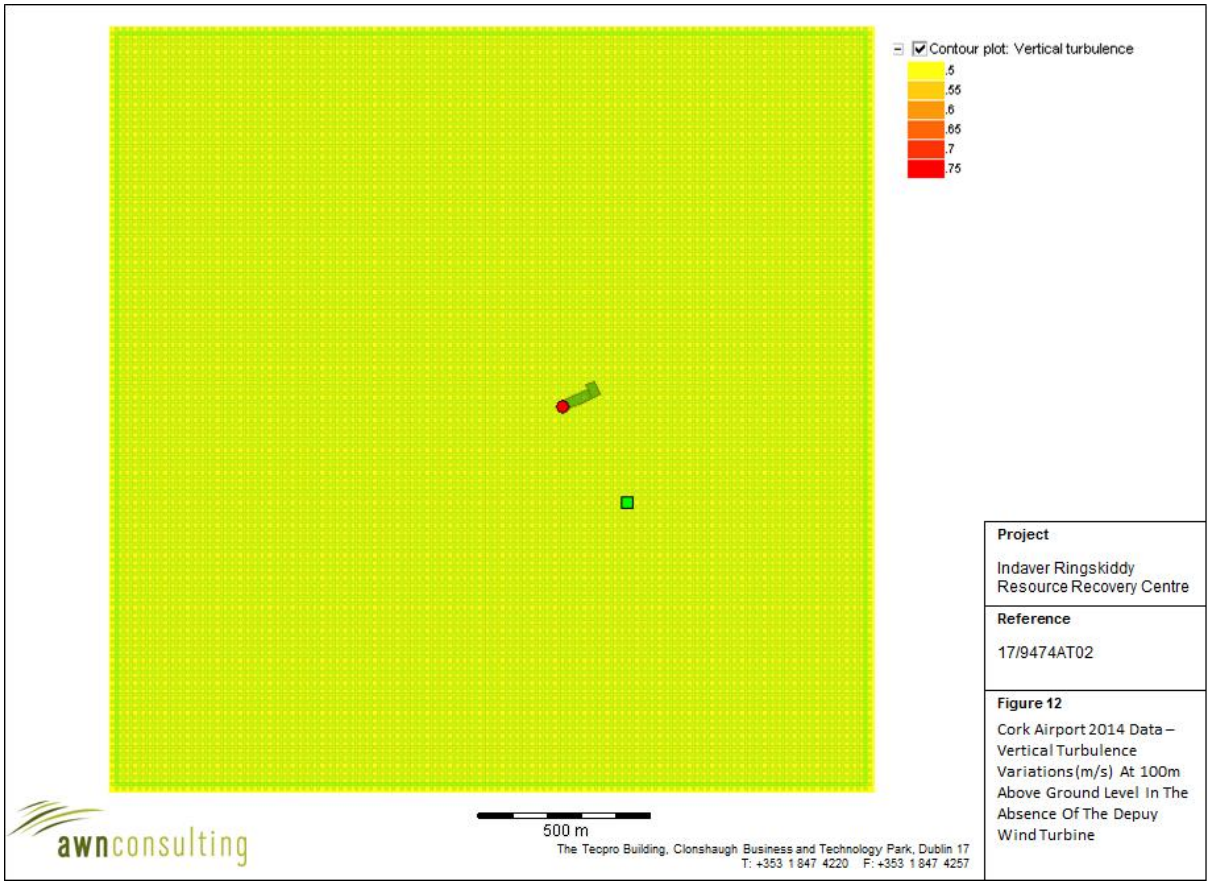


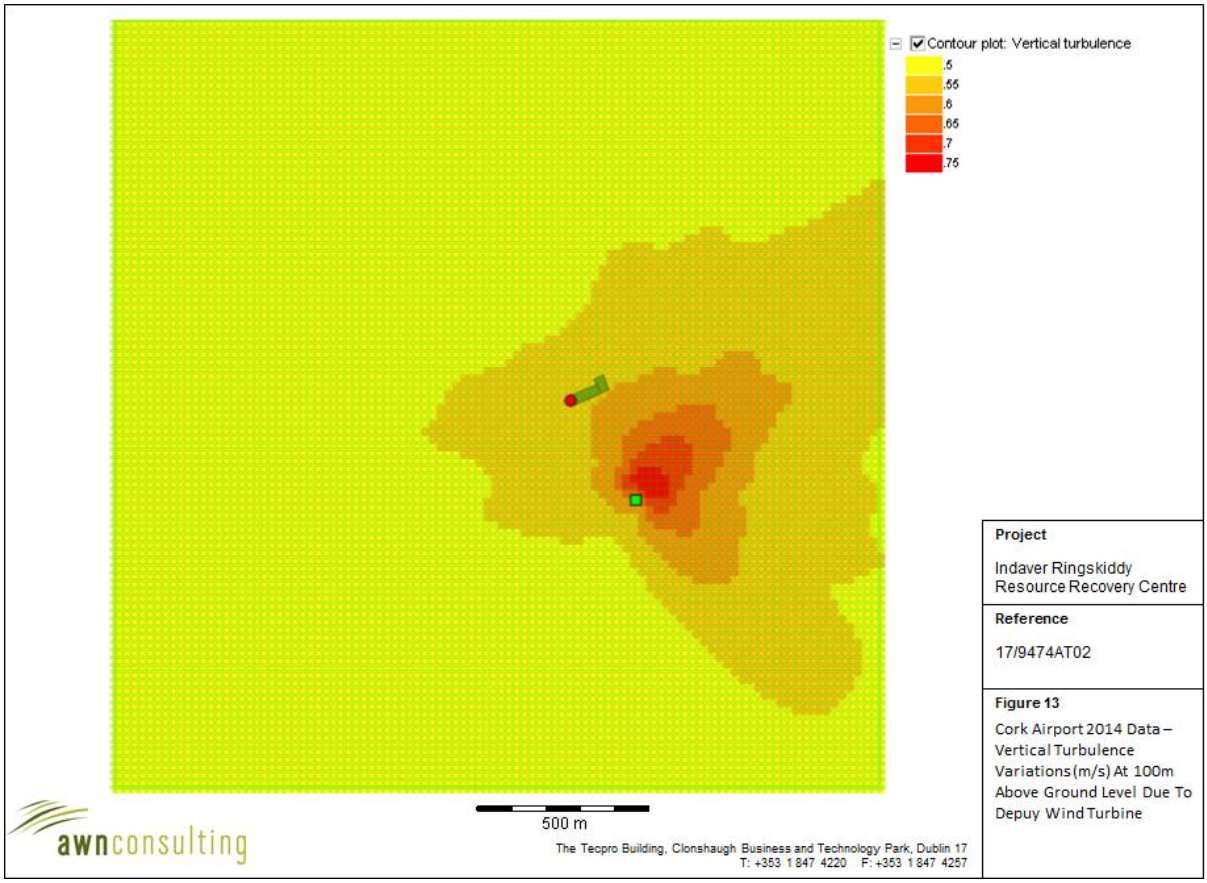


The wind field in the vicinity of the wind turbine can be used by ADMS to determine

the vertical turbulence (m/s) in the region of the wind turbine. The vertical turbulence (m/s) at a height of 100m has been modelled in ADMS both with and without the wind turbine in order to determine the extent of the region where the vertical turbulence is affected on an annual mean basis.

As shown in Figure 12, the vertical turbulence at 100m in the absence of the wind turbine is essentially uniform with an average vertical turbulence of between 0.5 – 0.55 m/s. Figure 13 shows the vertical turbulence at 100m with the De Puy wind turbine in place. It is evident that there is an increase in vertical turbulence in the region of the wind turbine with mean vertical turbulence increasing to 0.75 m/s within 100m downwind of the prevailing wind near the turbine and levels of 0.65 m/s extending to 350m downwind of the prevailing wind. In the region of the proposed Ringaskiddy RCC stack, the annual mean vertical turbulence is predicted to increase, at a height of 100m from 0.5 - 0.55 m/s to 0.55 - 0.6 m/s.





2.9 SUMMARY

Thus, in summary the results of the analysis are as follows:

- **Oxygen Content (ADMS) -** within 3.5 metres of the stack the oxygen concentration will increase above the 12% risk level for oxygen.
- **Oxygen Content (AERMOD) -** 14 metres of the stack the oxygen concentration will increase above the 12% risk level for oxygen.
- **Temperature (ADMS) –** the temperature of the plume will drop to less than 50°C within 3.5 metres in the x-y plane and 6.8 metres directly above stack top.
- **Vertical Velocity (ADMS) –** the critical vertical velocity of 4.3 m/s will not be exceeded beyond 3.4 metres, vertically, above the stack top.

Thus, the maximum extent of the risk zone of the plume for each parameter is shown below based on five years of meteorological data (and Roches Point 2014 data) covering all meteorological conditions including pressure / temperature inversions:

- Risk Zone for Oxygen **– 14 metres**
- Risk Zone for Temperature **– 6.8 metres**
- Risk Zone for Vertical Velocity **– 3.4 metres**
- **COMBINED RISK ZONE USING AERMOD & ADMS – 14 metres**

The assessment has also confirmed the following:

- At 150m from the stack top, the minimum predicted oxygen concentration is 20.78% compared to an ambient level of 20.95% and a risk level of 12% oxygen. For this worst-case hour, the associated temperature of the plume is 15.1°C compared to an ambient level of 13.6°C and a risk level of 50°C.

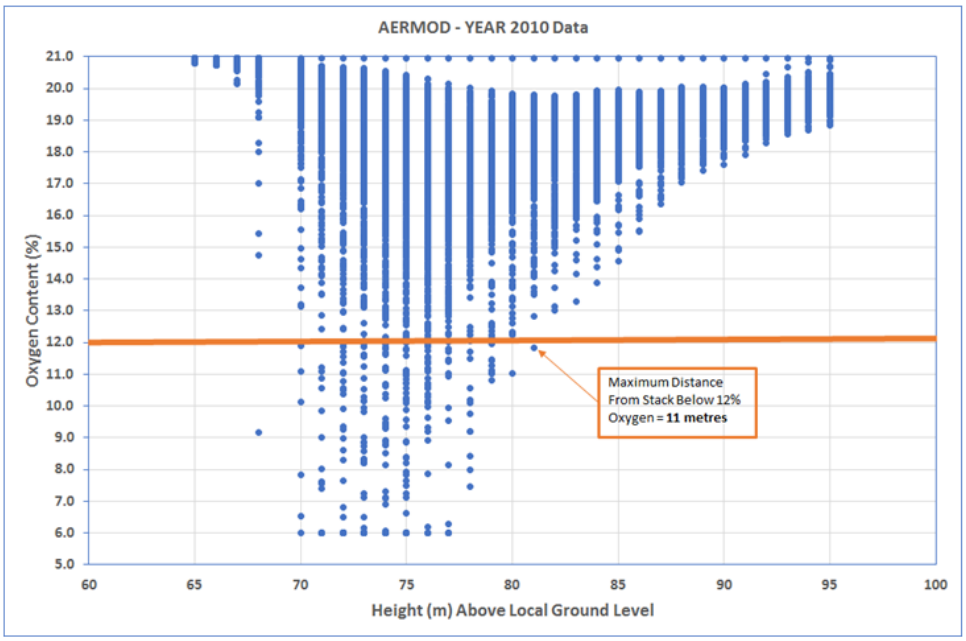
- Modelling of the effect of the wind turbine on dispersion of the plume from the Ringaskiddy RRC stack has found that the impact of the velocity deficit and associated turbulence (eddy diffusion) on ambient levels of pollutants is not significant and all pollutants will remain well below the ambient air quality standards.

- Modelling of the flow field in the region of the wind turbine has found that downwind of the wind turbine there will be some changes to the annual mean velocity, reducing to 3.5 m/s compared to levels of 6 m/s outside of this zone. However, levels in the region of the Ringaskiddy RRC will not be significantly changed on an annual basis.

- Similarly, modelling of the vertical turbulence in the region of the wind turbine has found that downwind of the wind turbine there will be some increase to the annual mean vertical turbulence, increasing to 0.75 m/s compared to levels of 0.5 m/s outside of this zone. Levels in the region of the Ringaskiddy RRC will not be significantly affected on an annual basis increasing slightly to 0.55 m/s.

In summary, any risk from the Ringaskiddy RCC plume will be contained to well within 150m from the stack top and thus will not impact on the Air Corps operations.

Appendix 1



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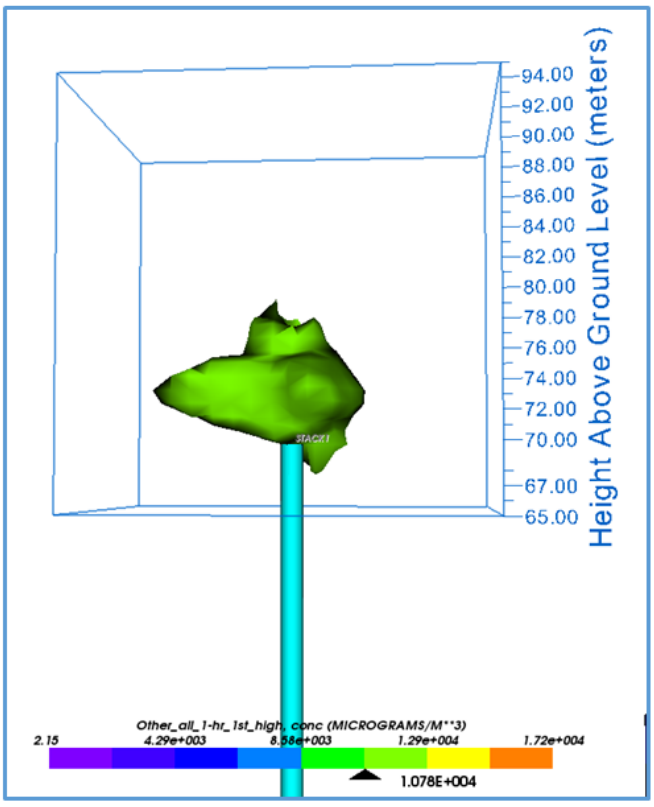
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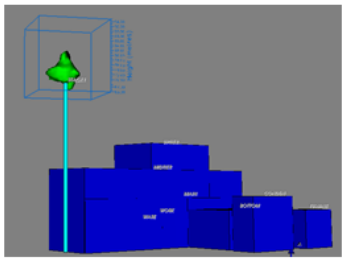
17/9474AT01

Figure A1

AERMOD 3-D Grid - Plot Of Oxygen Content Of The Plume (%) With Distance (m) From Stack Top Year 2010

Maximum Distance Below 12% Oxygen – **11 metres**





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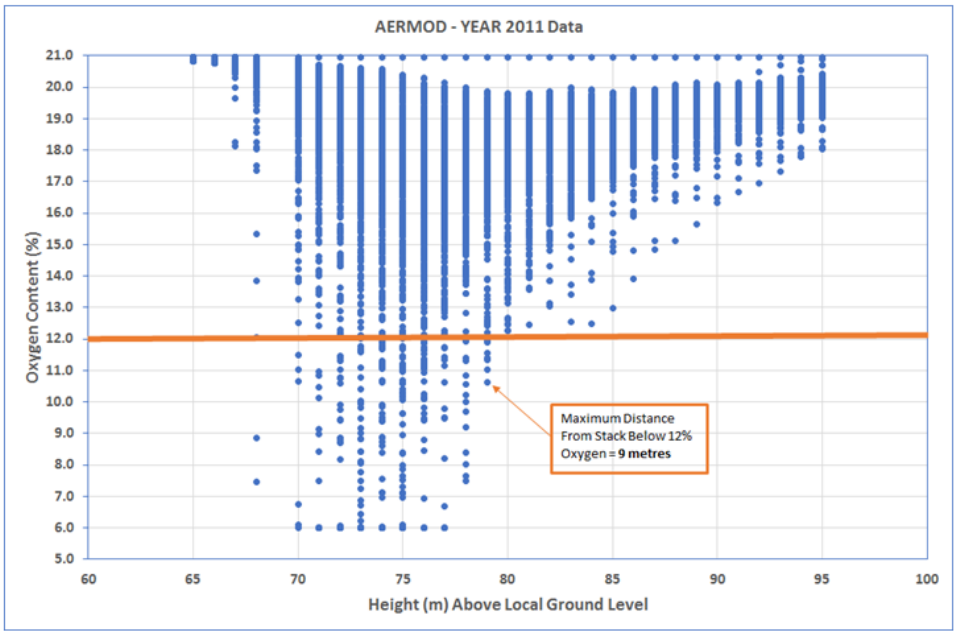
Reference

17/9474AT02

Figure A2

Modelled Receptor Grid At Heights 65m – 95m Above Local Ground Level (2m resolution) – Year 2010

Maximum Distance Below 12% Oxygen – **11 metres**



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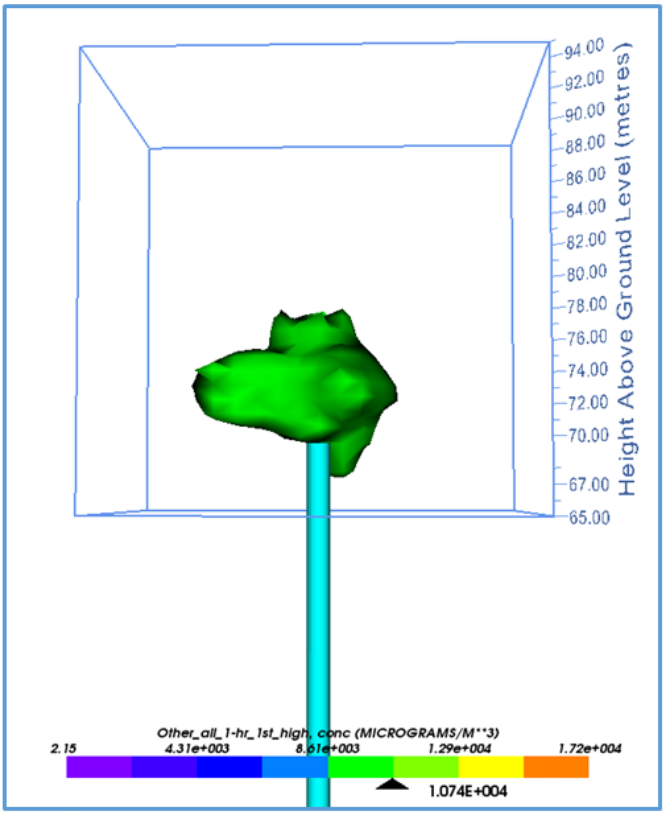
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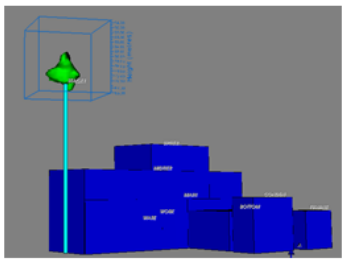
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Figure A3

AERMOD 3-D Grid - Plot Of Oxygen Content Of The Plume (%) With Distance (m) From Stack Top Year 2011

Maximum Distance Below 12% Oxygen – **9 metres**





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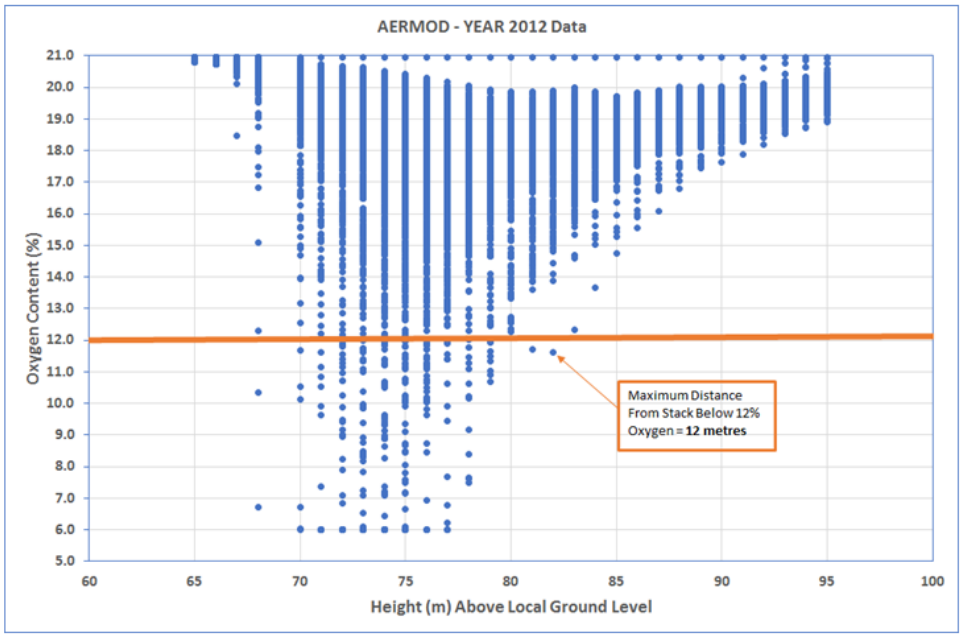
Reference

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Figure A4

Modelled Receptor Grid At Heights 65m – 95m Above Local Ground Level (2m resolution) – Year 2011

Maximum Distance Below 12% Oxygen – **9 metres**



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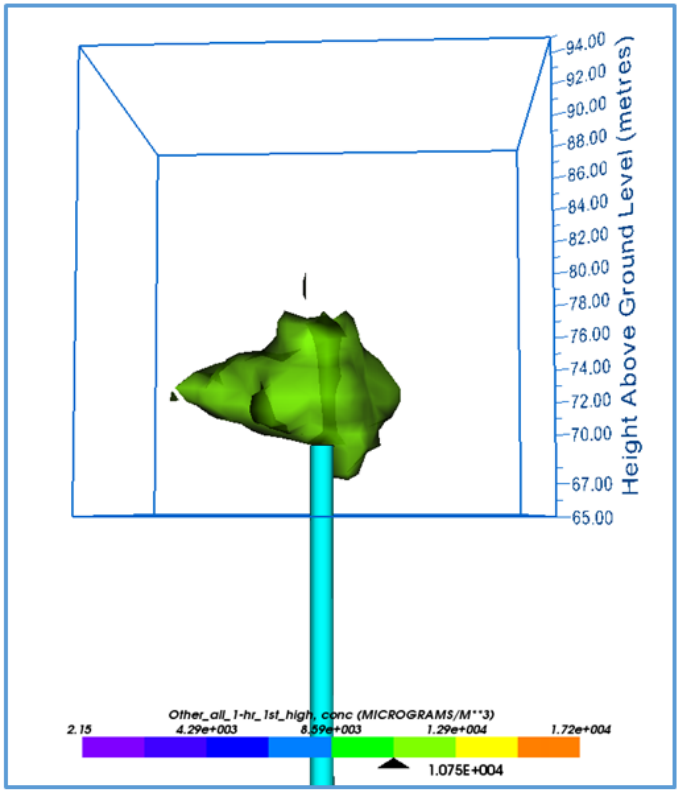
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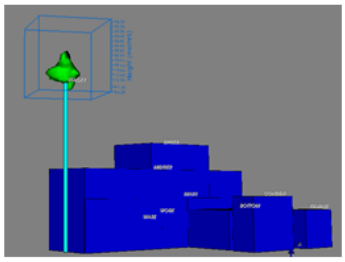
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Figure A5

AERMOD 3-D Grid - Plot Of Oxygen Content Of The Plume (%) With Distance (m) From Stack Top

Maximum Distance Below 12% Oxygen – **12 metres**





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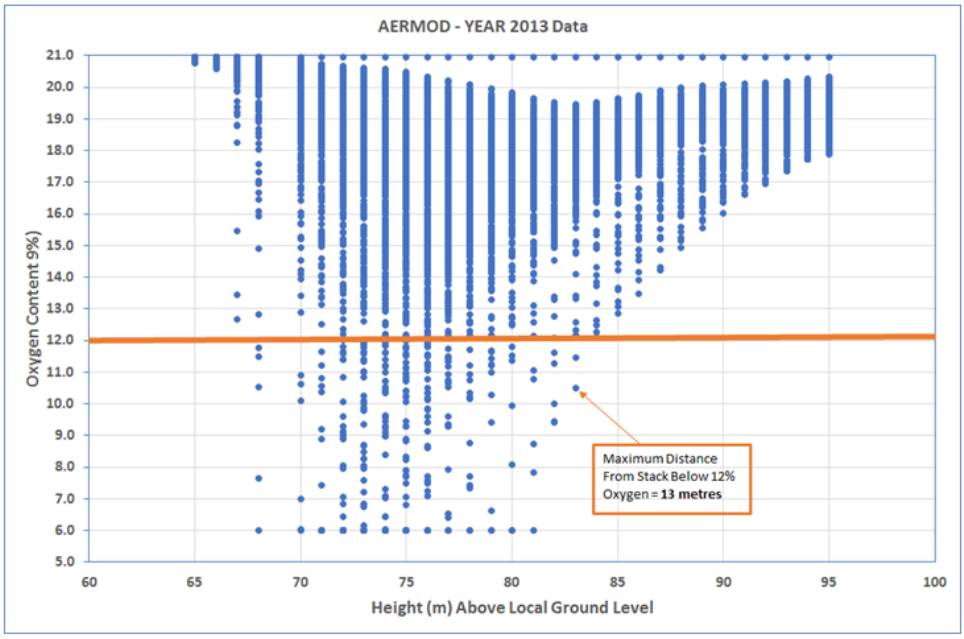
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Figure A6

Modelled Receptor Grid At Heights 65m – 95m Above Local Ground Level (2m resolution) – Year 2012

Maximum Distance Below 12% Oxygen – **12 metres**



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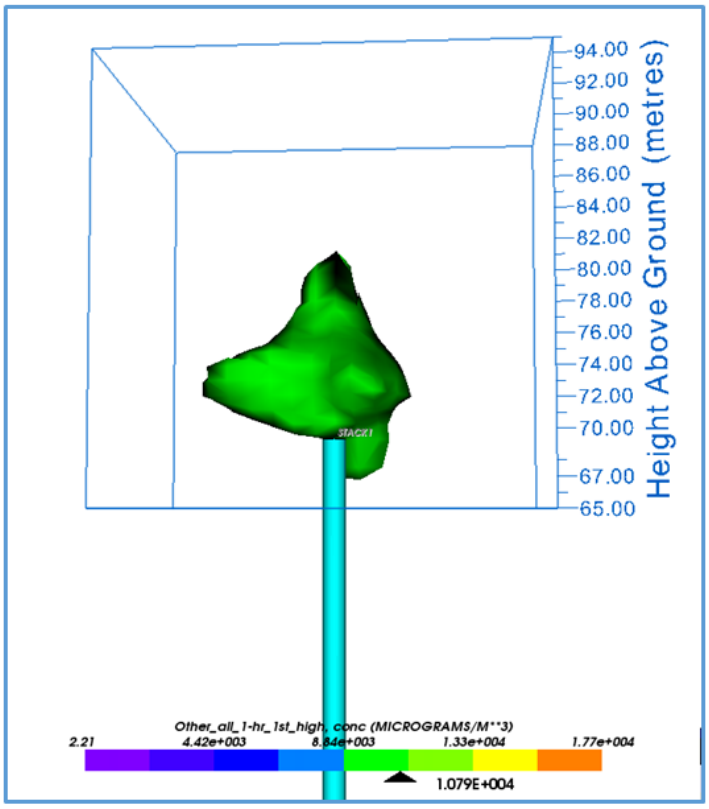
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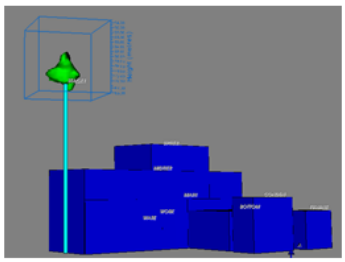
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Figure A7

AERMOD 3-D Grid - Plot Of Oxygen Content Of The Plume (%) With Distance (m) From Stack Top Year 2013

Maximum Distance Below 12% Oxygen – **13 metres**





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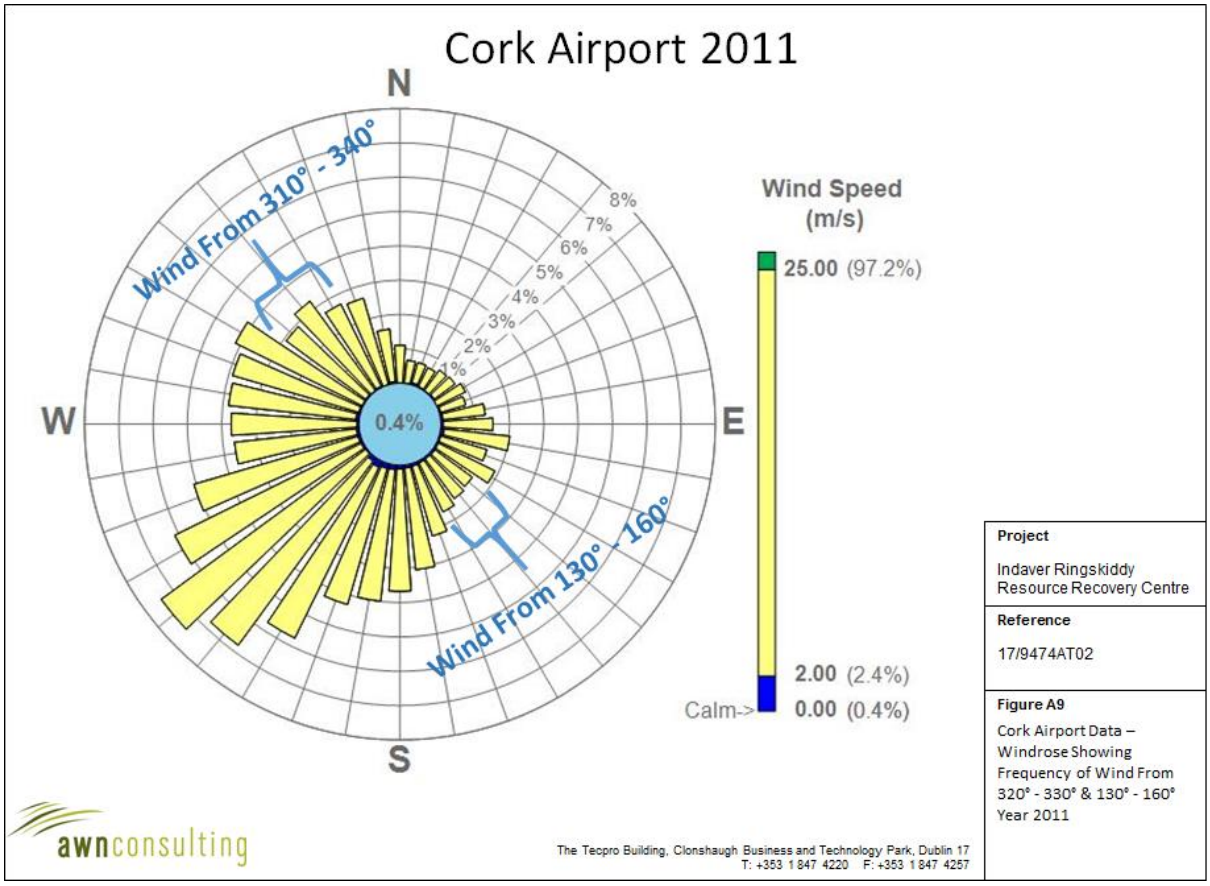
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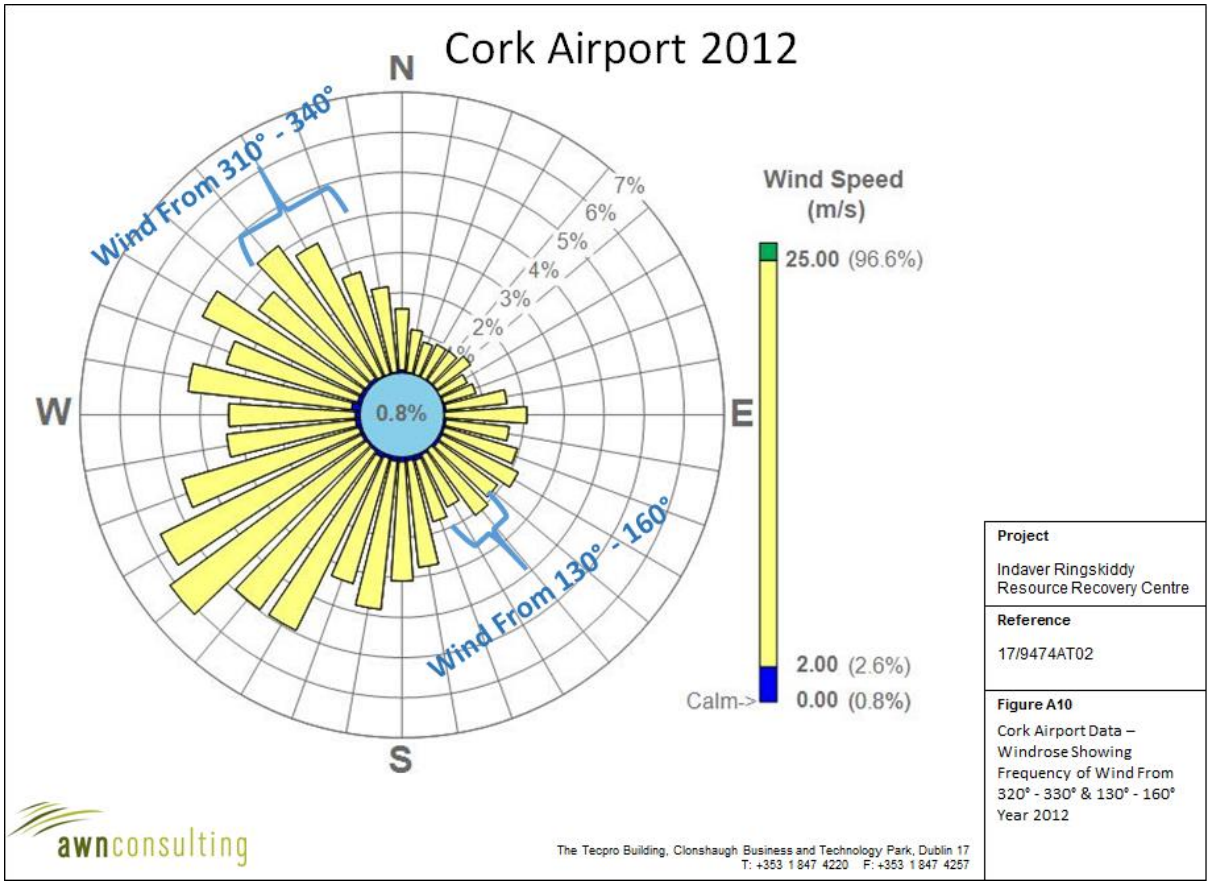
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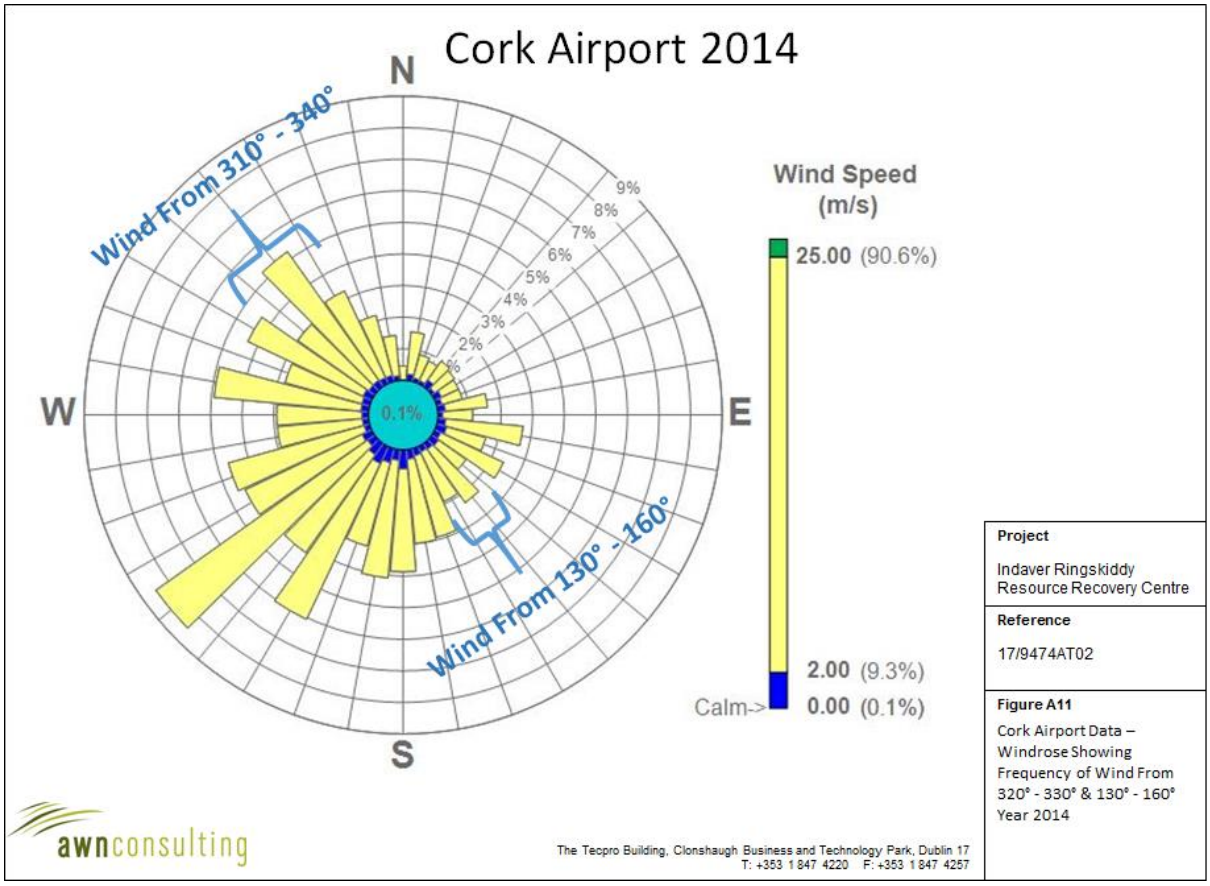
Figure A8

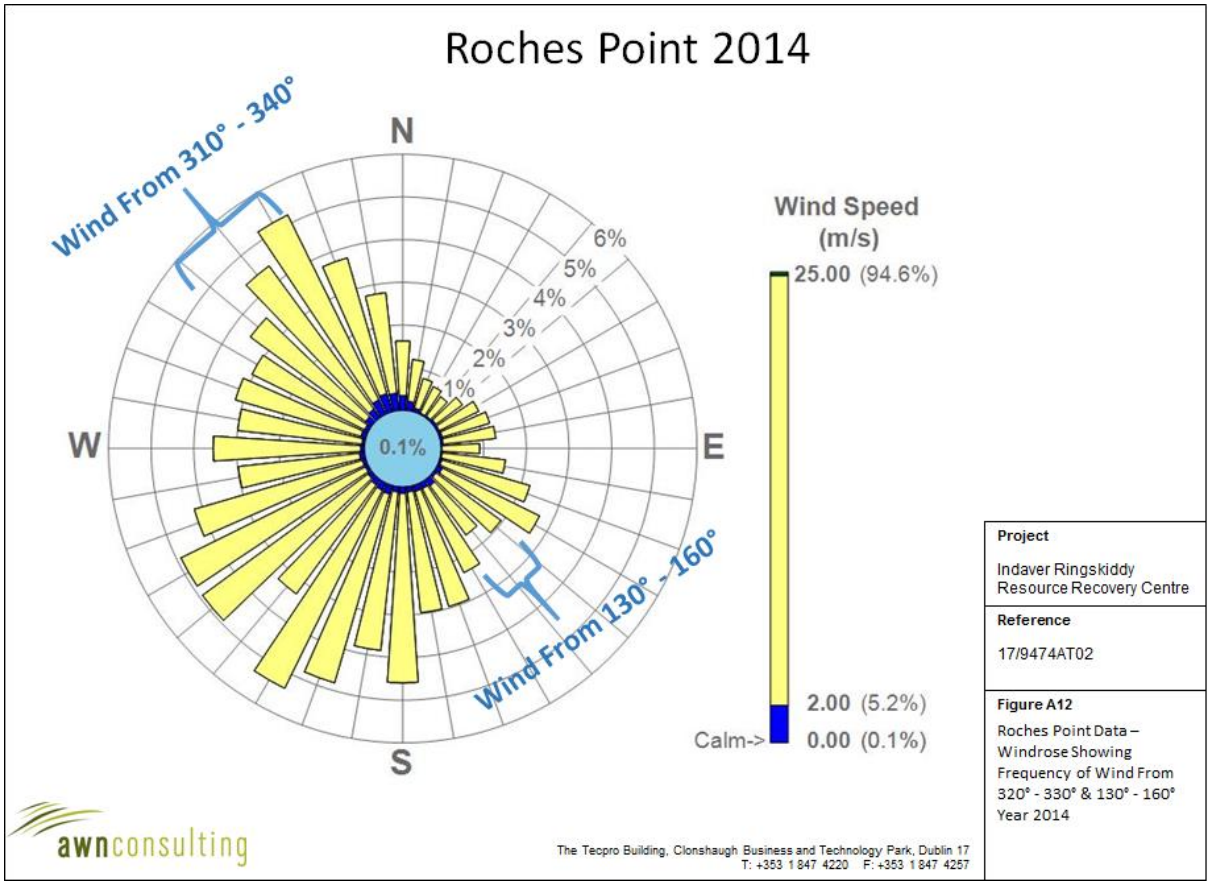
Modelled Receptor Grid At Heights 65m – 95m Above Local Ground Level (2m resolution) – Year 2013

Maximum Distance Below 12% Oxygen – **13 metres**


Cork Airport 2011
N
W
E
S
Wind From 310° - 340°
Wind From 130° - 160°
0.4%
1%
2%
3%
4%
5%
6%
7%
8%
Wind Speed
(m/s)
25.00 (97.2%)
2.00 (2.4%)
Calm->
0.00 (0.4%)
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Figure A9
Cork Airport Data – Windrose Showing Frequency of Wind From 320° - 330° & 130° - 160° Year 2011


Cork Airport 2012
N
W
E
S
Wind From 310° - 340°
Wind From 130° - 160°
0.8%
2%
3%
4%
5%
6%
7%
Wind Speed
(m/s)
25.00 (96.6%)
2.00 (2.6%)
Calm->
0.00 (0.8%)
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Figure A10
Cork Airport Data – Windrose Showing Frequency of Wind From 320° - 330° & 130° - 160° Year 2012


Cork Airport 2014
N
E
S
W
Wind From 310° - 340°
Wind From 130° - 160°
9%
8%
7%
6%
5%
4%
3%
2%
0.1%
Wind Speed
(m/s)
25.00 (90.6%)
2.00 (9.3%)
Calm-> 0.00 (0.1%)
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Figure A11
Cork Airport Data – Windrose Showing Frequency of Wind From 320° - 330° & 130° - 160° Year 2014


Roches Point 2014
N
E
S
W
Wind From 310° - 340°
Wind From 130° - 160°
6%
5%
4%
3%
2%
1%
0.1%
Wind Speed
(m/s)
25.00 (94.6%)
2.00 (5.2%)
Calm-> 0.00 (0.1%)
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Figure A12
Roches Point Data – Windrose Showing Frequency of Wind From 320° - 330° & 130° - 160° Year 2014