REPORT

Updated odour impact assessment of a proposed amendment to operations at Knockharley Landfill

Client:
Beauparc

Report Number:
BEPC22A_odourmodelling_final

Project Code:
BEPC22A

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Executive Summary

This report presents an update to the odour impact assessment of the proposed development of Knockharley landfill, County Meath, which was originally conducted in 2018 as part of the EIAR for the development[1]. The assessment investigates the odour exposure levels that are expected to occur around the site under the following four operational scenarios of the site, as per the original EIA:

- Scenario 0: Baseline conditions in 2018.
- Scenario 1: Year 4 without the development. The situation which is likely to occur in the final active deposition stages of the landfill if it continues to operate in line with current planning and licence conditions.
- Scenario 2: Year 4 of proposed development.
- Scenario 3: Year 6 of proposed development. The situation which will occur in the final stages of the landfill if the development proceeds.

The worst case scenario from an odour impact perspective if the development goes ahead is scenario 3, where gas generation is predicted to be at its highest and the active cell will be located to the north of the site. This compares to scenario 1 if the development does not go ahead. Scenario 1 also broadly corresponds to the current operational conditions at the site.

The odour emissions from the site under each operational scenario were estimated on the basis of site measurement data, gas modelling data provided by Fehily Timoney during preparation of the EIA, and Olfasense's broader industry experience.

Updates have been applied to the assessment to reflect requests made by the Environmental Protection Agency (EPA) as per letter reference W0146-04 dated the 14 June 2022 section 1, which are summarised as follows:

1. Undertake additional sampling of the emissions from the incoming waste, the surface of the active cell and landfill gas and update the model emission assumptions to reflect the results of these tests.
2. Update the dispersion model to include emissions from the gas engines and leachate lagoons.
3. Run the model using an inland meteorological station i.e. Dunsany, rather the Dublin airport dataset applied in the EIA.
4. Compare the results to the odour impact criterion of 1.5 ou_E/m^3 as a 98th %ile taking no account of differences in the offensiveness or odour character of the emissions.

[1] Appendix 7.1 of the EIAR. ENVIRONMENTAL IMPACT ASSESSMENT REPORT (EIAR) FOR THE PROPOSED DEVELOPMENT AT KNOCKHARLEY LANDFILL. November 2018

Amendments have also been made to the landfill gas containment and flux rate assumptions applied in the emission calculations, to better reflect what is likely to occur in real world conditions and ensure that the assessment is not overly conservative. These amendments are as follows:

- Application of a 95% gas containment rate for temporary capping from in scenario 0 and 1, rather than 90%.
- Application of a 97% containment rate for the temporary capping in scenario 1 and 2, rather than 95%.

These modifications lead to gas and odour flux rates from the intermediate capping which are more in keeping with industrial expectation based on the values defined in LFTGN07 [2] for the new cells than was originally modelled during the EIAR and are considered to better reflect the potential emissions from the type of capping applied, whilst maintaining an element of conservatism.

The modelling was conducted using the latest version of the US Environmental Protection Agency AERMOD dispersion model, which was applied in accordance with guidance provided by the model developer, and the latest version of the Environmental Protection Agency guidance note AG4[3].

The one possible exception relates to the selection of meteorological data from the inland station at Dunsany. This is contrary to the original EIA which identified Dublin airport as the most appropriate site on the basis of comparison of annual mean windspeed as per the procedure defined in Section 6.1 of AG4. Whilst it is acknowledged that AG4 also suggests that inland data may be more appropriate for sites further than 10 km from the coast, this cannot be confirmed. The Dunsany dataset may therefore lead to an overprediction in impact risk and this should be considered when interpreting the results.

The findings of the updated assessment are as follows:

1. The odour emissions generated from the site are predicted to decrease if the development goes ahead, in comparison to the baseline situation (scenario 0) and the situation which would occur in the final stages of the landfill if the proposal did not go ahead (scenario 1). This is despite the increase in waste input and is due to the enhancement in the intermediate capping proposed as part of the development and the fact that the majority of additional waste which will be accepted will be stabilised, inert or non-biodegradable and hence has a low gas and odour generation potential.
2. The odour exposure levels around the site are also predicted to decrease in comparison to the baseline and year 4 without development situation, which will result in a reduction in the number of properties that are exposed to odour levels that exceed the Environmental Protection Agency's impact benchmark of $C_{98,\,1\text{-hour}} \geq 1.5\ ou_E/m^3$. The model predicts that the odour exposure levels will marginally exceed the EPA impact criteria at 1 no. property

[2] Guidance on monitoring landfill gas surface emissions. LFTGN07 V2 2010. Published by the Environment Agency.
[3] Air dispersion modelling from industrial Installations Guidance (AG4). Environmental Protection Agency. Office of Environmental Enforcement. December 2019

during year 4 of the development and 3 no. properties during the worst case year 6. This compares to 7 no. properties in the worst case year without the development.

3. The overall conclusion of the study is that the development will have a beneficial effect on odour exposure and reduce impact risk in comparison to the situation that would occur if the site continued to operate under its existing permit.

4. It should be noted that a degree of conservatism has been applied in the selection of odour emission rates and the choice of meteorological data. Hence, the predictions should be viewed as a precautionary. This assertion is supported by the complaint record for the site which indicates a low level of complaints which have been decreasing over the last four years.

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1 Introduction

1.1 Introduction

This report presents an update to the odour impact assessment of the proposed development of Knockharley landfill, Country Meath which was originally conducted in 2018 as part of the EIAR for the development[4]. The assessment investigates the odour exposure levels that are expected to occur around the site under the following four operational scenarios of the site, as per the original EIAR prepared in 2018.

- Scenario 0: Baseline conditions in 2018.
- Scenario 1: Year 4 without development. The situation which is likely to occur in the final active deposition stages of the landfill if it continues to operate in line with current planning and licence conditions (i.e. the development does not go ahead).
- Scenario 2: Year 4 of proposed development.
- Scenario 3: Year 6 of proposed development. The situation which will occur in the final stages of the landfill if the development proceeds.

The modelling approach has been updated to reflect requests made by the Environmental Protection Agency as per letter reference W0146-04 dated the 14 June 2022 section 1, issued under Regulation 10(2)(b)(ii) of the EPA (Industrial Emissions) (Licensing) Regulations 2013 in respect of a license review of the site, the requests are summarised as follows:

1. Undertake additional sampling of the emissions from the incoming waste, the surface of the active cell and landfill gas and update the model emission assumptions to reflect the results of these tests.
2. Update the dispersion model to include emissions from the gas engines and leachate lagoons.
3. Run the model using an inland meteorological station i.e. Dunsany, rather the Dublin airport dataset applied in the EIA.
4. Compare the results to the odour impact criterion of 1.5 ou_E/m^3 as a 98^{th} %ile taking no account of differences in the offensiveness or odour character of the emissions.

In addition, the original gas containment assumptions have been reviewed and updated as necessary to ensure the emission assumptions are realistic and not overly conservative.

Full details of the assumptions applied within the model, the modelling approach and results are presented in the remainder of this report.

[4] Appendix 7.1 of the EIAR. ENVIRONMENTAL IMPACT ASSESSMENT REPORT (EIAR) FOR THE PROPOSED DEVELOPMENT AT KNOCKHARLEY LANDFILL. November 2018

1.2 Scope

The scope of the study was as follows:

1. Review and update the dispersion modelling assumptions.
2. Apply the model to assess offsite exposure levels under each scenario.
3. Compare the odour exposure levels to the impact criteria recommended by the EPA.
4. Assess the implications of the development of offsite in terms of odour impact risk.

1.3 Quality Control and Assurance

All activities are conducted by trained and experienced specialist staff in accordance with quality management procedures that are certified to ISO 9001 (Certificate No. A13725).

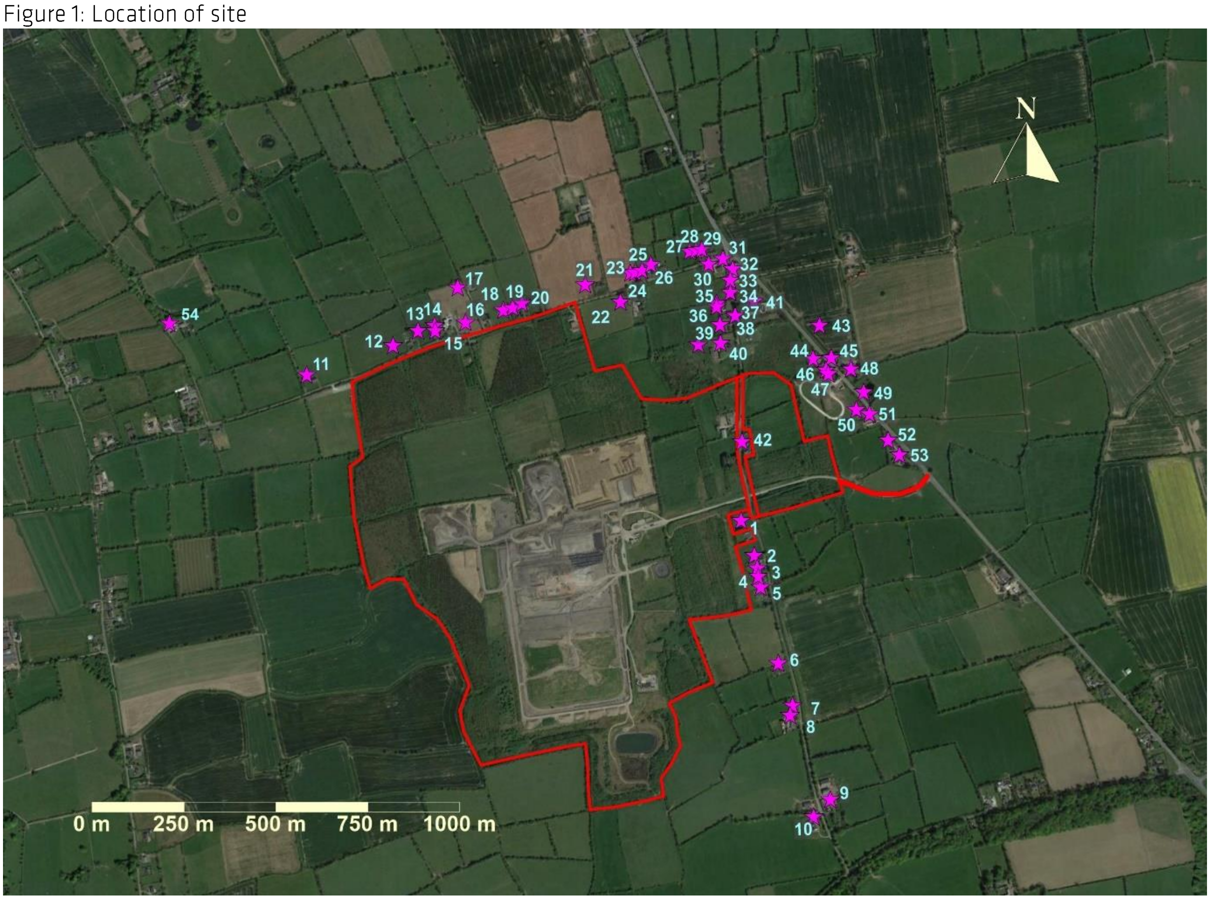
2 Overview of study area

2.1 Site location

Knockharley landfill is located near Kentstown in County Meath, Ireland. The site lies to the west of the N2 and to the north of the R150 in a rural location.

The location of the site in relation to nearby residential properties is illustrated in Figure 1 below. Each residential property is marked with a number for ease of reference.

Figure 1: Location of site



Map imagery: Google Earth. The red line indicates the planning boundary of the facility. Selected nearby residential properties presented as pink stars.

2.2 Description of site activities

2.2.1 Current operating conditions

The existing landfill is licensed to accept 88,000 tonnes per annum (tpa) of domestic, commercial, industrial and construction wastes. Waste inputs are received between the hours of 08:00 to 18:00 Monday to Saturday inclusive.

The landfill is made up of 7 No. phases, with each phase segregated into 4 No. cells.

Incoming waste is transported to the site by road. Waste lorries enter the site via the access road from the N2 and waste is conveyed and deposited directly into the active filling area. Following deposition, the waste is compacted by front-end loader to form waste lifts approximately 2.5 m high. As part of the existing site licence, the depositional area is restricted to an area of 625 m^2. Outside of operating hours a daily cover is applied to the active cell. Once filling of a cell is complete, intermediate caps are applied within 6 months after completion, with a permanent cap applied the following year. 2 No. cells are normally worked on in parallel although the depositional area is still restricted to an area of 625 m^2.

The construction and development of each filling cell incorporates measures to allow collection of leachate and landfill gas that is generated within the waste mass.

Landfill gas extracted by these systems is utilised in gas engines or incinerated in enclosed flares. There are currently 4 No. gas engines with a combined capacity of 3,600 m^3/hr, as well as 3 No. enclosed flares with a combined capacity of 5,500 m^3/hr. The gas compound is situated to the east of Phase 1 of the landfill. A 500 m^3/hr open flare is also present for odour control by flaring of landfill gas within the active cell. Based on current and predicted gas yield, no more than 2 No. engines and 1 No. flare (Flare No.2) are operational at any given time.

Leachate is collected through a leachate drainage layer and is then pumped to a covered leachate lagoon located to the east of the landfill area from which it is periodically loaded to road tankers. During filling, odorous air displaced from the tanker is treated in a carbon filter before being released to the atmosphere.

2.2.2 Description of proposed development (including increase in waste accepted)

The proposed development is for the acceptance of 440,000 tonnes per annum of non-hazardous wastes, which will comprise up to 150,000 tonnes of incinerator bottom ash (IBA), as well as household, commercial and industrial wastes including residual fines, non-hazardous contaminated soils, construction and demolition (C&D) wastes and baled recyclables.

A summary of the waste that will be accepted is presented in the table below:

Table 1: Summary of quantities of each waste type received per annum

Year	Biodegradable municipal waste and fines [tonnes]	Stabilised and inert waste and MSW* [tonnes]	Incinerator bottom ash [tonnes]	Total waste accepted [tonnes]
Year 1-5	65,000	225,000	150,000	440,000

* non-biodegradable fraction

The proposed development will include the following:

- Intensification of the existing permitted landfill by increasing the final height profile. The height increase is proposed to be 11 m to take it to a height of 85 m AOD. The intensification is sought for future landfilling operations only.
- Construction of an incinerator bottom ash (IBA) facility to the north of the site office to accept up to 150,000 tonnes per annum of IBA. This will include the construction of dedicated cells for the acceptance, placement and storage of IBA until a market is identified for the recovery of IBA.

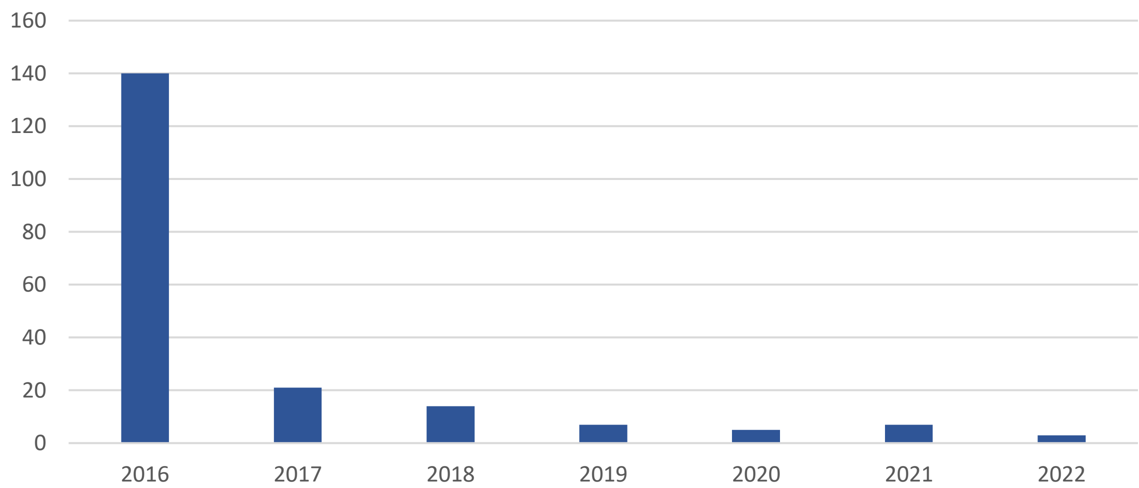
- Modification in the filling schedule so that stabilised waste from biological waste treatment and other inert wastes will start filling at cells 27/28 and move south. Non-stabilised MSW will not be stored above cell 21. It will continue to be landfilled in a northerly direction.
- The construction and operation of a leachate management facility which includes plans to add 2 No. additional leachate lagoons to handle the increased leachate from the expansion of the landfill and the operation of the IBA facility. The leachate lagoons will be covered as per the existing lagoon and displaced air during filling will be passed through a carbon filter to minimise odorous emissions.
- Enhancement of the intermediate capping system from stitched geo-multicover and recovered soils and construction and demolition waste to hermetically sealed geo-multicovers, to provide tighter control of potential fugitive landfill gas emissions and increase the volume of gas extracted to the landfill gas generation plant.

Permission is also sought to store IBA until recovery outlets are identified and conduct trials to prepare IBA for recovery and removal off site. The IBA facility will consist of 5 no. cells which will be constructed in accordance with the requirements of the Landfill Directive 99/31/EC for non-hazardous wastes.

2.3 Odour complaint history

The number of odour complaints linked to the site since 2016 are presented in Figure 2 below. The figure indicates that odour complaints have fallen significantly since 2016 and have remained low in recent years.

Figure 2: No of complaints reported since 2016



A breakdown of the odour complaints since 2019 in terms of location[5] is presented in the table below. Generally speaking, the majority of complaint have been reported from the nearest residential receptors to the north and east of the site and typically relate to landfill gas type

[5] The location numbers correspond to the receptors as indicated in Figure 1

odours. Site investigations indicate that such odours are most likely to be generated from incidental activities such as equipment breakdown or pipe laying.

There are also a number of outliers from sensitive receptors further afield, although it should be noted that the landfill has not been confirmed as the source of such odours and it possible that they may have been due to other odour sources in the area.

Table 2: Location of odour complaints reported since 2019 (where location is known)

Year	No. of reported complaints	Location of known odour complaints
2019	5	2 No. @ location 3 1 No. @ location 22 1 No. @ location 54 1 No. ~1.9 km to the south-south-east of site
2020	1	1 No. @ location 3
2021	7	3 No. @ location 6 2 No. @ location 16 1 No. 1.3 km to the south of the site) 1 No. 1.9 km to the south-south-east of site
2022	3	1 No. @ location 6 1 No. @ location 20 1 No. @ location 22

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3 Estimation of emissions

3.1 Operational scenarios considered

The following operational scenarios have been considered as per the original EIAR:

- Scenario 0: Baseline conditions in 2018.
- Scenario 1: Year 4 without development. The situation which is likely to occur in the final active deposition stages of the landfill if it continues to operate in line with current planning and licence conditions (i.e. the development does not go ahead).
- Scenario 2: Year 4 of proposed development.
- Scenario 3: Year 6 of proposed development. The situation which will occur in the final stages of the landfill if the development proceeds.

Scenario 1 is anticipated to reflect the worst case scenario from an odour impact perspective from the landfill prior to the development and scenario 3 is the worst case scenario if the development goes ahead.

The assumed waste inputs into the site under these scenarios are summarised in the table below.

Table 3: Summary of waste inputs for each modelled scenario

Summary of changes to operational conditions	Scenario 0: 2018 baseline	Scenario 1: Year 4 without development	Scenario 2: Year 4 with development	Scenario 3: Year 6 with development
Biodegradable municipal waste and fines (tpa)	40,000	40,000	65,000	65,000
Estimated total landfill gas generation potential (m^3/hour)	1,620	1,438	2,059	2,150
Filling of stabilised, inert waste and MSW* (tpa)	48,000	48,000	225,000	225,000
Acceptance of incinerator bottom ash (tpa)	yes**	yes**	150,000	150,000

*non-biodegradable fraction
**IBA tonnage included in stabilised and inert fraction

3.2 Odour sources considered

The model considerers the odour sources described in the table below.

It important to note that whilst the proposed development will increase the amount of inert waste that will be filled into the landfill, such waste has a low odour potential and will not contribute to landfill gas generation. Furthermore, the proposed IBA facility has not been considered as an odour source since the material has a negligible odour potential, and no odour emissions have been included for landfill gas flares due to their high temperature of operation.

Table 4: Odour sources associated with current and proposed operations

Area of landfill	Odour source	Nature of odour	Intensity and offensiveness of odours released	Frequency and duration
Non-stabilised biowaste to landfill (current and proposed site activities)	Filling face	Waste	Moderate/high intensity; Moderate/high offensiveness	Semi-continuous during operational hours
	Active cell	Landfill gas	Moderate intensity; Moderate/high offensiveness	Variable depending upon atmospheric conditions
Deposition of inert wastes (proposed site activities)	Filling face	Earthy/compost like	Low/moderate intensity; Low/moderate offensiveness	Semi-continuous during operational hours
Intermediate and final capped cells (current and proposed site activities)	Gas flux through capping & leakage from gas infrastructure	Landfill gas	Low to high intensity; Low to high offensiveness	Variable depending upon containment effectiveness and atmospheric conditions
Gas utilisation plant (engines)	Combustion of landfill gas	Combustion	Low intensity; moderate offensiveness	Continuous
Leachate storage and export	Leachate export tanker	Residual odour from carbon filter	Low intensity; Low/moderate offensiveness	During tanker filling

3.3 Estimation of site odour emissions

3.3.1 Emissions from the operational areas

On the basis of Olfasense's experience, the odour emissions generated from the operational area are influenced by the following:

- The quantity and type of waste actively deposited during the working day.
- The type of cover applied at the end of the working day.
- The underlying age of the waste in the active cell, and hence potential for generation and flux of landfill gas.

For the operational areas receiving MSW waste under the current and proposed operational scenarios of the landfill site, the emissions from the active cell were calculated using the emission rates presented in Table 4 below. These emission rates have been updated on request of the EPA in comparison to the original EIA. The techniques applied to collect the data and monitoring results are presented in Annex A.

Table 5: Emission estimates derived from onsite monitoring data area sources

Source	Scenario	Date of sampling	Geomean odour emission rate ($ou_E/m^2/s$)
Freshly tipped waste	0	11/04/2018	9.2
	1	22/09/2022	5.8
	2		
	3		
Daily cover applied	0	11/04/2018	0.8
	1	22/09/2022	0.4
	2		
	3		

For activities involving the active deposition of waste from trucks the odour emission rate is typically linked to the odour potential of the waste expressed in ou_E/tonne. For the wastes received at Knockharley, an emission rate per kg of 20 times the surface emissions per metre squared ($ou_E/m^2/s$) measured from MSW has been assumed (i.e. 184,000 ou_E/tonne in 2018, 116,000 ou_E/tonne for all other operational scenarios considered).

The emission estimates for each scenario are therefore summarised as follows.

Table 6: Emission estimates from the operational area under each operational scenario

Scenario	Source	Area odour emission rate [$ou_E/m^2/s$]	Total area [m^2]	Operating hours	Odour emission rate [$x10^3$ ou_E/s]
Sc0	Temporary capped area[6]	0.8	17,860	Continuous	14.3
	Working face	9.2	625	08:00 – 18:00	5.7
	Fresh waste tipping	26.1	25	08:00 – 18:00	0.7
	Total				**20.7**
Sc1	Temporary capped area	0.4	8,930	Continuous	3.6
	Working face	5.8	625	08:00 – 18:00	3.6
	Fresh waste tipping	16.5	25	08:00 – 18:00	0.4
	Total				**7.6**
Sc2&3	Temporary capped area	0.4	8,930	Continuous	3.6
	Working face	5.8	625	08:00 – 18:00	3.6
	Fresh waste tipping	26.8	25	08:00 – 18:00	0.7
	Stabilised waste face	1.0	625	08:00 – 18:00	0.6
	Stabilised waste tipping	7.5	25	08:00 – 18:00	0.2
	Total				**8.7**

[6] The measured emission from overnight capped areas has conservatively been applied to temporary capped areas.

3.3.2 Estimation of emissions of landfill gas

Landfill gas emissions generally represent the highest potential contributor to odours from landfills and can exhibit significant variations from site-to-site and over time depending upon the rate of production of the gas from the underlying waste, the containment effectiveness of the cap, and the odour potential of the gas.

For the purposes of this study, an estimate of the flux rate of gas for each scenario was derived using data from the calibrated LandGem model provided by Fehily Timoney (see Annex C). These were then converted to odour emissions using the measured concentration of landfill gas in odour units and on the basis of an assumed percentage containment of the cap.

The odour concentration and containment assumptions are summarised in Table 7 below. Note that the capping efficiencies have been revised since the EIA as follows, since the original assumptions are now considered to be too conservative:

- Containment efficiency of the intermediate capping has been increased to 95% for sc0 & 1.
- Containment efficiency of the intermediate capping has been increased to 97% for sc2 & 3.
- The odour concentration of the landfill gas has been reduced to 1.8 million odour units as per the results of recent gas analysis, compared to the 2.3 million odour units applied in the EIAR, which was measured in 2010.

As a logic check, the resultant gas flux figures have been compared to the flux standard defined for temporary capping in Environment Agency guidance LFTGN07[7] of 0.1 mg/m^2/s. The estimated average methane flux rates in the model for intermediate capping range from 0.11 to 0.29 mg/m^2/s (or 0.55 to 1.47 ou_E/m^2/s), which are closer to expectation whilst still retaining a degree of conservatism.

Table 7: Estimation of emissions of landfill gas

Scenario	Containment offered by permanent capping [%]	Containment offered by intermediate capping [%]	Odour concentration of landfill gas [ou_E/m^3][8]
Scenario 0	98	95	1.8 million
Scenario 1	98	95	1.8 million
Scenario 2	98	97	1.8 million
Scenario 3	98	97	1.8 million

A summary of the derived emission estimates for each landfill cell is presented in Annex C.

3.3.3 Estimation of emissions of leachate lagoons and tanker export

Odours displaced from the leachate tankers are treated using carbon filters prior to release to atmosphere. The following assumptions were applied to define odour emissions for modelling purposes:

[7] Guidance on monitoring landfill gas surface emissions. LFTGN07 V2 2010. Published by the Environment Agency.
[8] As per September 2022 monitoring. Actual result was a 1,816,123 ou_E/m^3. Refer to Annex A.

- 1 No. tanker is loaded per day in scenario 0 and 1, and up to 2 No. tankers per day in scenario 2 and 3.
- Each tanker is loaded over a period of 15 minutes and has a 25 m^3 capacity.
- The air displaced from the tanker is treated prior to release to atmosphere using a carbon filter with an average abatement efficiency of 95%. The average concentration of air discharged from the tanker is 50,000 ou_E/m^3 which is a conservative estimate drawn from the Olfasense odour emission database.

The estimated emissions included in the model are therefore as follows:

Table 8: Emissions from filling of leachate tankers

Scenario	Estimated headspace odour concentration[8] [ou_E/m^3]	No. of 25m^3 tankers per day	Displacement rate (15 mins per tanker) [m^3/s]	Emission [ou_E/s]
Scenario 0 & 1	50,000	1	0.028	69
Scenario 2 & 3	50,000	2	0.028	69

3.3.4 Estimation of emissions from landfill gas utilisation

Odour emissions from the gas utilisation plant were estimated assuming that 2 No. engines were operational on average during all of the operational scenarios assessed.

Air flow rates were obtained from the monitoring conducted by Odour Monitoring Ireland as presented in the air quality chapter of the original EIA. The residual odour emissions were estimated based on data contained the Olfasense library data which indicates that engine emissions are likely to have an odour concentration of 5,000 ou_E/m^3 . It is not possible to measure this directly since the emissions are too hot.

Table 9: Estimated emissions from gas engines

Scenario	Engine	Residual odour conc. of combusted gas [ou_E/m^3]	Stack height [m]	Stack diameter [m]	Actual air flow [m^3/s]	Exhaust temperature [k]	Air flow[9] [m^3/s]	Odour emission rate [ou_E/s]
Scenario 0 & 1	Gas engine 1	5,000	10	0.4	2.12	665	0.93	4,662
	Gas engine 2	5,000	10	0.4	2.16	670	0.94	4,720
Scenario 2 & 3	Gas engine 3	5,000	10	0.4	1.99	698	0.83	4,164
	Gas engine 4	5,000	10	0.4	1.90	693	0.80	4,014

[9] Measured flow corrected to 293 K and 101.3 kPa. For engines 1 and 2, flow and temperature are based on the average of the monitoring results obtained in 2019 and 2021. For engines 3 and 4, the flow and temperature are drawn from the last set of monitoring results collected in 2019 which are understood to reflect the flow of the newly installed engines which have not yet been tested.

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4 Dispersion modelling and impact risk assessment

4.1 General approach

The emission estimates using the process described above were input into a dispersion model which was applied to assess the level of exposure to odour that is likely to occur around the site under the full range of meteorological conditions representative of the area. The outputs of the model were then compared against the odour impact criteria (see below) to assess how the risk of odour impact is likely to change as a result of the development.

The model was constructed using the AERMOD atmospheric dispersion model published by the US Environmental Protection Agency (US EPA). Impact risk was assessed on the basis of the worst case meteorological year from a 5 year data set of sequential hourly average data. Further details of the dispersion model and the reasons for selecting this model are presented in Annex B.

The model was constructed and applied in accordance with guidance published by the model developer (US EPA) and relevant guidance published by the Irish EPA[10], the UK Environment Agency[11] and the institute of Air Quality Management (IAQM)[12].

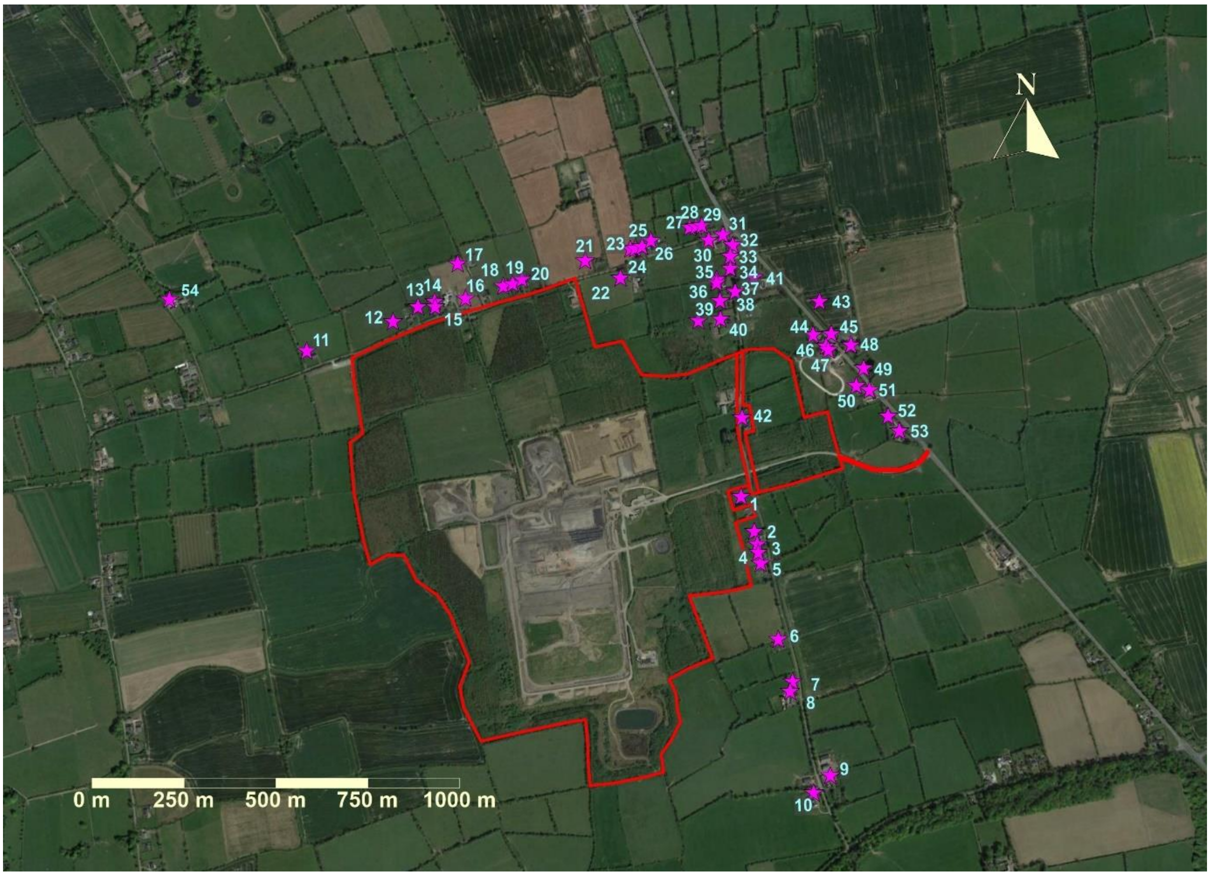
4.2 Modelling assumptions

The assumptions applied in the dispersion modelling for the baseline scenario were as follows:

- Data describing the topography of the area surrounding the works was obtained from Ordnance Survey Ireland for the area surrounding the proposed facility. A receptor grid of 3.7 km by 3.7 km (50 m resolution), centred on the site, was utilised in the model. The height of the receptors is set at 1.5 m which represents the breathing level of humans.
- The study area was defined as rural, in line with land use classification techniques described in the Aermod User Guide issued by the US EPA.
- The capped cells have been modelled as volume sources to represent diffuse fugitive landfill gas release from the capped cells rather than the top of the landfill; the temporary capped cells have been modelled as area sources. A 74 m AOD release height has been defined for all volume/area sources.
- The following receptors were also included within the dispersion model, to allow a comparison of predicted odour exposure levels between the modelled scenarios.

[10] Irish EPA (2010). Air Dispersion Modelling from Industrial Installations Guidance Note (AG4). Irish EPA
[11] IPPC H4 Technical Guidance Note "H4 Odour Management", Environment Agency (England), March 2011.
[12] Guidance on the assessment of odour for planning, Version 1.1 - July 2018, Institute of Air Quality Management, UK

Figure 3: Discrete receptors included within dispersion model



Map imagery: Google Earth. The red line indicates the planning boundary of the facility. Discrete receptors considered within the dispersion model are presented as pink stars.

Table 10: Discrete receptors

Receptor number	Coordinate (UTM)	
	X	Y
1	663887.5	5947144.5
2	663927.8	5947038.0
3	663938.7	5946975.5
4	663936.8	5946998.7
5	663946.7	5946940.3
6	664001.2	5946708.6
7	664043.8	5946578.6
8	664036.9	5946548.4
9	664157.9	5946290.5
10	664108.3	5946238.1
11	662569.7	5947590.4
12	662832.1	5947679.7
13	662908.5	5947724.1
14	662958.1	5947741.2
15	662960.0	5947724.1

16	663051.5	5947750.0
17	663028.5	5947856.0
18	663166.3	5947787.5
19	663194.1	5947795.6
20	663222.8	5947808.7
21	663414.2	5947866.1
22	663521.3	5947812.7
23	663552.0	5947901.4
24	663565.9	5947903.4
25	663587.7	5947909.4
26	663614.5	5947927.6
27	663731.5	5947966.9
28	663750.3	5947970.9
29	663768.2	5947973.9
30	663789.0	5947928.6
31	663832.6	5947944.7
32	663862.4	5947913.5
33	663854.5	5947879.2
34	663856.4	5947836.9
35	663812.8	5947808.7
36	663813.8	5947797.6
37	663869.3	5947771.4
38	663823.7	5947742.2
39	663758.7	5947683.4
40	663825.7	5947687.0
41	663925.8	5947814.7
42	663890.2	5947385.6
43	664125.0	5947741.0
44	664106.3	5947639.4
45	664161.8	5947642.5
46	664145.0	5947604.2
47	664151.9	5947593.1
48	664221.3	5947607.2
49	664260.0	5947536.7
50	664237.2	5947483.3
51	664276.9	5947469.2
52	664333.4	5947390.6
53	664367.1	5947345.3
54	662153.9	5947747.6

- The model only considered emissions generated under the normal running conditions for the facility. The impact of abnormal or incidental emissions are not included e.g. from flare failure.

4.3 Meteorological data

The original EIAR study utilised meteorological data from Dublin Airport. This was selected as a suitable source of the meteorological data for the dispersion model on the basis of the procedure recommended by the UK Atmospheric Dispersion Modelling Liaison Committee (ADMLC), after they concluded that the most important factor in the selection of meteorological station was annual windspeed. This procedure, as outlined in the EPA guidance note AG4, is as follows:

- Estimate the mean annual wind speed in the region of the installation using a wind map (available from the Met Eireann website https://www.met.ie/climate/what-we-measure/wind).
- Calculate the ratio of the mean annual wind speed for the source and the mean annual wind speed for the nearby meteorological sites (as shown in Table 6.1 in AG4).
- Choose a meteorological station with the mean annual wind speed ratio between 0.9 to 1.1. to estimate the dispersion from the site.

Application of the procedure in this case indicated that the annual mean windspeed at the study site is likely to fall between 5 and 6 m/s and is estimated at 5.2 m/s based on the wind speed contours presented on the Met Eireann website. This compared favourably with Dublin Airport where the annual mean windspeed stated in AG4 is 5.3 m/s, giving a ratio of 0.98 and within the 0.9 to 1.1 limits detailed in AG4. Dublin airport also appeared to be a good choice based on the similarities in topography, surface roughness and elevation in comparison to the study site; the availability of a full set of meteorological data including cloud cover measurements; and the fact that the station had been used for other impact assessments in the area historically including previous odour modelling studies at Knockharley landfill.

In comparison, the nearest inland stations at Dunsany and Mullingar have average windspeeds of 4.1 and 4.3 m/s respectively, which is not within the recommended range based on the ADMLC approach. Casement Aerodrome is an appropriate choice in terms of wind speed but is noted in AG4 as being in proximity to complex terrain and is therefore unlikely to provide a suitable representation of conditions at Knockharley Landfill.

Notwithstanding these technical issues, to comply with the EPA request the updated modelling has been conducted using meteorological data from Dunsany[13]. Five years of data was obtained for each site (2012 to 2016) and adjusted to reflect the surface characteristics of the meteorological site in accordance with the guidelines in the Implementation Guide.[14] Each year was processed to establish the worst-case year, in terms of highest predicted odour exposure at local receptors, which was determined to be 2016 for Dunsany.[15]

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[13] Missing cloud data was substituted from the Dublin Airport dataset.
[14] AERMOD Implementation Guide, Published by the US EPA: March 2009. See Annex
[15] The worst case meteorological year has been defined on the basis of highest predicted odour exposure for the discrete receptors modelled in any of the future operational scenarios.

The wind roses for each site are provided below:

Figure 4: Wind-rose for the combined meteorological dataset (Dublin 2012-2016)

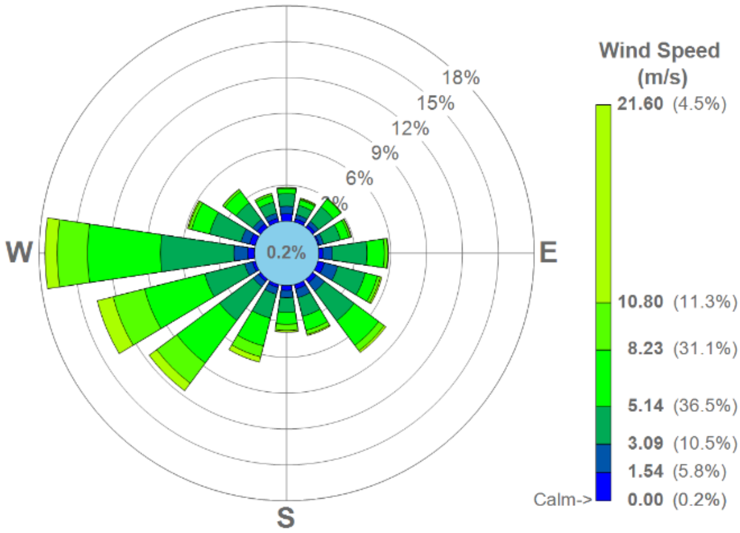
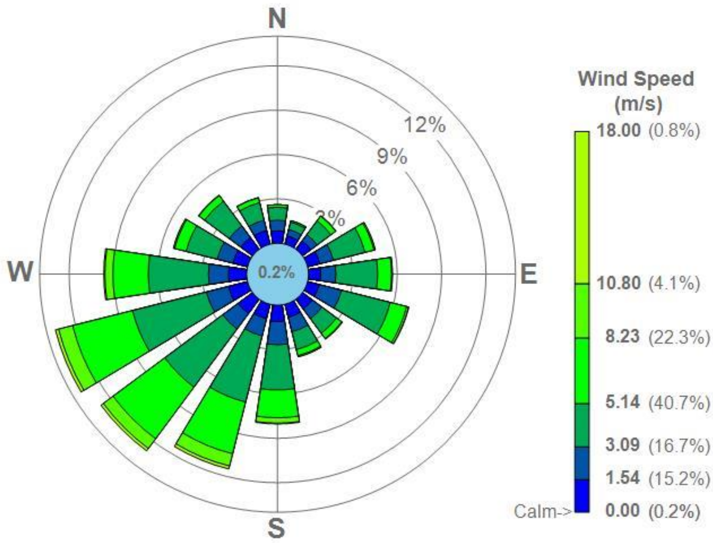


Figure 5: Wind-rose for the combined meteorological dataset (Dunsany 2012- 2016)



4.4 Significance criteria

The following significance criteria were applied on request of the EPA.

- $C_{98,\ 1\text{-hour}} \geq 1.5\ ou_E/m^3$ reflecting the impact criterion for highly offensive odours.

This criteria was applied to the cumulative exposure levels from all odour sources on the site. Hence, the assessment assumed that the odours from all activities were highly offensive in nature.

5 Results

5.1 Comparison of odour emissions for each scenario

A summary of the time weighted odour emissions estimated for each operational scenario is presented below:

Table 11: Estimated emissions for each operational scenario

Area of site	Source	Time weighted emission [x 10 ^{3} ou_E/s]			
		Scenario 0	Scenario 1	Scenario 2	Scenario 3
Landfilling	Active cell operations	20.7	7.6	8.7	8.7
	Gas flux/leakage from capping	31.7	27.3	24.0	25.3
Gas compound	CHP engines and flares	9.4	9.4	8.2	8.2
Lagoons	Lagoons and tankers	<0.1	<0.1	<0.1	<0.1
	Total	**61.8**	**44.3**	**40.9**	**42.2**

Review of the table indicates the following:

- The highest odour emissions occur in the baseline year (scenario 0), which is due to a combination of the higher odour potential of the waste received by the site, and the fact that the four cells had intermediate capping rather than two

- Emissions decrease in scenario 2 (year 4 without the development) which is a result of the reduction of the number of cells with intermediate capping to two, and the reduction in the odour potential of received waste as evidenced by recent survey data.

- A further reduction is evident in scenario 3 (year 4 with development) which is primarily due to the application of hermetically sealed geo-multicovers as intermediate capping which will be introduced as part of the development. The emissions are then predicted to increase slightly in the worst case with development scenario (scenario 3) as the gas generation from the site reaches a peak. However, the total emission remain below those predicted for scenario 1.

In overall terms, the analysis indicates that the odour emissions from the site are predicted to decrease if the development goes ahead.

5.2 Dispersion modelling outputs

The outputs of the dispersion modelling are presented in Figure 6, Figure 7 and Figure 8 below,

Each figure presents isopleths defining the area where the predicted odour exposure level is to $C_{98, 1\text{-hour}}$ = 1.5 ou_E/m^3 for the worst-case year of the meteorological dataset.

Map imagery for each figure has been obtained from Google Earth. The red line indicates the planning boundary of the facility and receptors are marked in pink.

Figure 6: Odour exposure isopleths for Scenario 0 (baseline) and Scenario 1 (Year 4 without development)

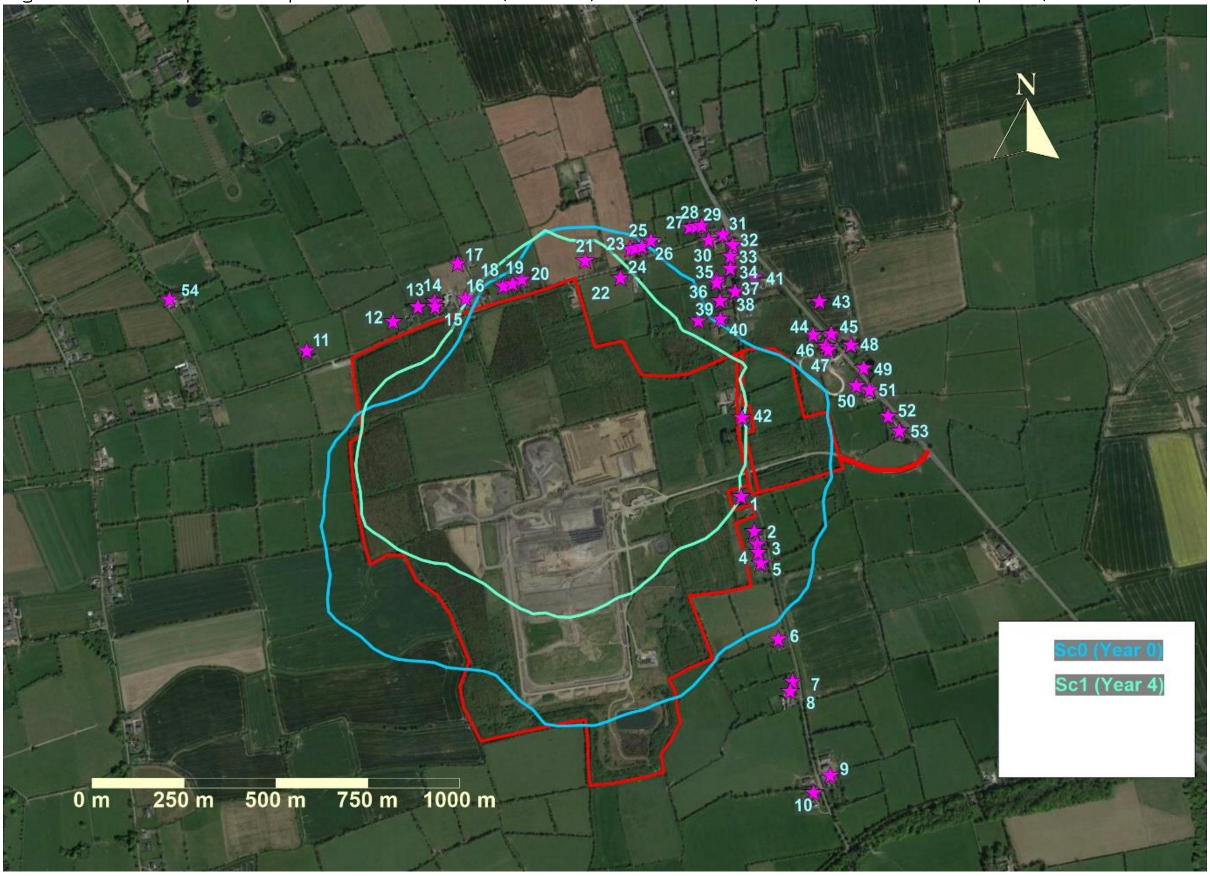


Figure 7: Odour exposure isopleths for Scenario 1 (Year 4 without development) & Scenario 2 (Year 4 with development).

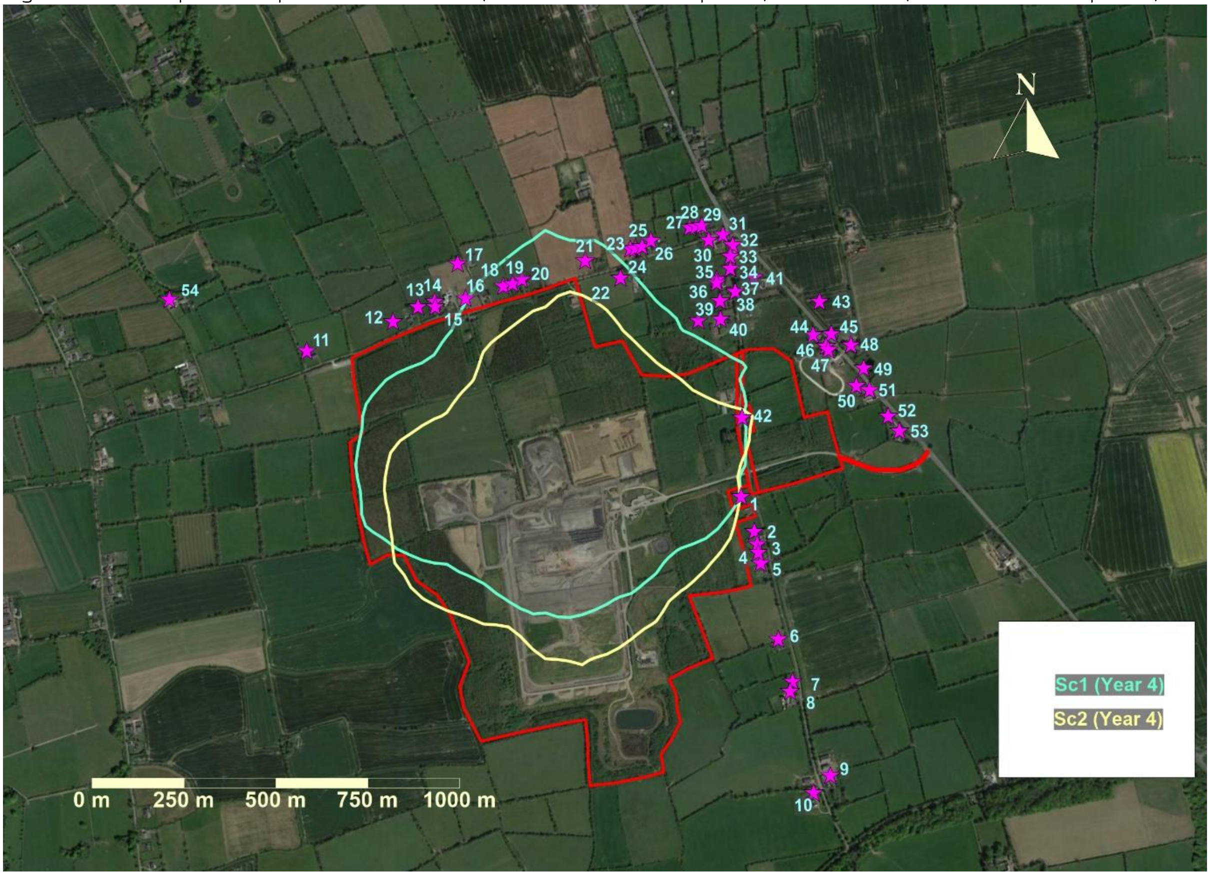
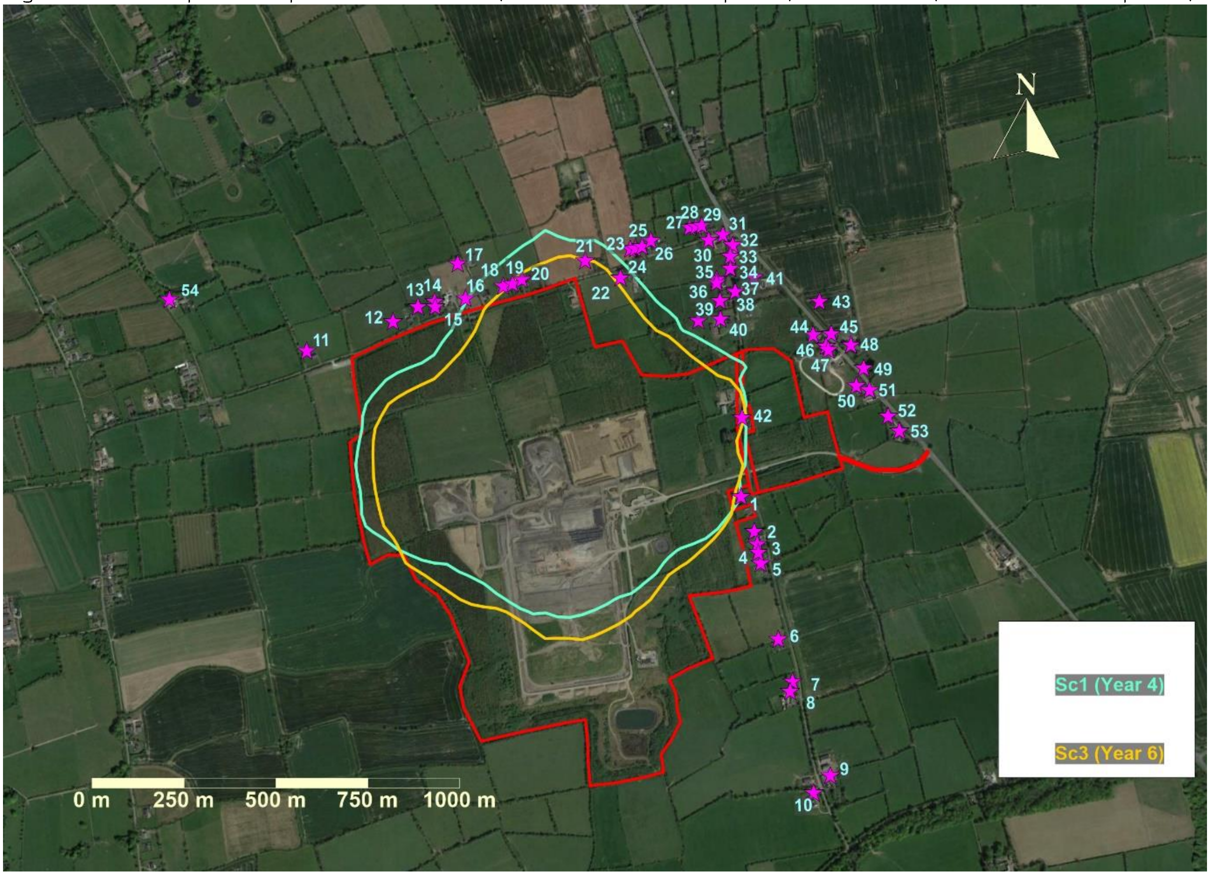


Figure 8: Odour exposure isopleths for Scenario 1 (Year 4 without development) & Scenario 3 (Year 6 with development).



The predicted odour exposure at discrete receptors for each model scenario are presented below:

Table 12: Predicted odour exposure ($C_{98,\ 1\text{-hour}}$) in ou_E/m^3 at modelled discreet receptor locations. Figures marked in red represent an exceedance of the EPA impact benchmark

Receptor	Sc0: 2018 baseline	Sc1: Yr 4 without development	Sc2: Yr 4 with development	Sc3: Yr 6 with development
1	2.42	1.50	1.48	1.41
2	2.26	1.11	1.27	1.18
3	2.01	0.98	1.17	1.04
4	2.04	1.06	1.18	1.09
5	2.01	0.85	1.07	0.97
6	1.32	0.51	0.69	0.61
7	0.86	0.43	0.52	0.49
8	0.87	0.41	0.49	0.51
9	0.63	0.33	0.39	0.39
10	0.61	0.34	0.39	0.39
11	0.85	0.88	0.60	0.76
12	0.83	0.83	0.56	0.73
13	0.93	0.94	0.68	0.79
14	0.98	1.06	0.68	0.82

15	1.00	1.12	0.67	0.86
16	1.34	1.45	0.96	1.14
17	1.15	1.16	0.78	0.93
18	1.59	1.78	1.15	1.46
19	1.68	1.80	1.17	1.52
20	1.71	1.87	1.18	1.60
21	1.78	1.75	1.24	1.49
22	1.92	1.65	1.25	1.45
23	1.61	1.32	1.06	1.21
24	1.57	1.32	1.01	1.16
25	1.52	1.28	0.98	1.12
26	1.48	1.20	0.93	1.06
27	1.24	0.99	0.77	0.90
28	1.19	0.97	0.77	0.87
29	1.16	0.93	0.78	0.85
30	1.29	0.95	0.78	0.85
31	1.16	0.88	0.72	0.79
32	1.11	0.92	0.71	0.81
33	1.19	0.91	0.72	0.86
34	1.23	0.95	0.77	0.86
35	1.34	1.04	0.80	0.96
36	1.37	1.07	0.83	0.97
37	1.22	1.01	0.81	0.89
38	1.30	1.11	0.87	0.99
39	1.64	1.34	1.03	1.19
40	1.47	1.24	0.93	1.04
41	1.13	0.94	0.74	0.83
42	2.37	1.50	1.60	1.53
43	1.01	0.88	0.68	0.75
44	1.25	0.97	0.78	0.89
45	1.17	0.90	0.73	0.87
46	1.29	0.92	0.79	0.94
47	1.30	0.92	0.80	0.92
48	1.19	0.83	0.74	0.81
49	1.23	0.77	0.74	0.76
50	1.34	0.75	0.76	0.78
51	1.23	0.72	0.72	0.73
52	1.15	0.65	0.67	0.67
53	1.08	0.63	0.61	0.63
54	0.53	0.43	0.35	0.41
Max	2.42	1.87	1.60	1.60

Average	1.34	1.02	0.84	0.94

The number of residential properties exposed to odours that exceed the EPA impact benchmark are presented in the table below:

Table 13: Receptors exposed to odour levels above the EPA criterion for highly offensive odours

Without development		With development	
Sc0	Sc1	Sc2	Sc3
15	7	1	3

Review of the model outputs indicates the following:

- The predicted odour exposure levels are highest in the baseline scenario, where up to 15 No. residential properties are predicted to be exposed to odour levels that exceed the EPA impact benchmark.
- The number of properties exposed to odour levels above the benchmark decreases to 7 in the final stages of the landfill if the development does not go ahead (i.e. scenario 1).
- With the development, the odour exposure levels at nearby sensitive receptors are predicted to decrease in comparison to the both the baseline and scenario 1, even during the worst case year (i.e. scenario 3 year 6). The model predicts that the odour exposure levels will marginally exceed the EPA impact criteria at 1 no. property in scenario 2 and 3 no. properties in scenario 3.

The results therefore indicate that the odour impact risk posed by the site is likely to reduce if the development goes ahead and will limited to a small number of properties to the immediate north and east of the site under worst-case conditions.

It is important to recognise that the model has been defined using conservative assumptions in terms of gas release and selection of meteorological data. The results should therefore be treated as precautionary.

6 Summary of findings

The findings of the updated assessment are as follows:

1. The odour emissions generated from the site are predicted to decrease if the development goes ahead, in comparison to the baseline situation (scenario 0) and the situation which would occur in the final stages of the landfill if the proposal did not go ahead (scenario 1). This is despite the increase in waste input and is due to the enhancement in the intermediate capping proposed as part of the development and the fact that the majority of additional waste which will be accepted will be stabilised, inert or non-biodegradable and hence has a low gas and odour generation potential.
2. The odour exposure levels around the site are also predicted to decrease in comparison to the baseline and year 4 without development situation, which will result in a reduction in the number of properties that are exposed to odour levels that exceed the Environmental Protection Agency's impact benchmark of $C_{98, 1\text{-hour}} \geq 1.5\ ou_E/m^3$. The model predicts that the odour exposure levels will marginally exceed the EPA impact criteria at 1 no. property during year 3 of the development and 3 no. properties during the worst case year 6. This compares to 7 no. properties in the worst case year without the development.
3. The overall conclusion of the study is that the development will have a beneficial effect on odour exposure and reduce impact risk in comparison to the situation that would occur if the site continued to operate under its existing permit.
4. It should be noted that a degree of conservatism has been applied in the selection of odour emission rates and the choice of meteorological data. Hence, the predictions should be viewed as a precautionary. This assertion is supported by the complaint record for the site which indicates a low level of complaints which have been decreasing over the last four years.

Annex A: Odour sampling and analysis techniques.

A.1 Collection of odour samples from sources with no measurable flow.

Collection of samples from area sources where there is no measurable flow were conducted using a ventilated canopy known as a 'Lindvall hood'. The canopy was placed on the odorous material and ventilated at a known rate with clean odourless air. A sample of odour was collected from the outlet port of the hood using the Lung principle.

The rate of air injected into the hood was monitored for each sample and used to calculate a specific odour emission rate per unit area per second (E_{sp}) as follows:

$E_{sp} = C_{hood} \times L \times V$

Where:

C_{hood} is the odour concentration measured from the sample bag.

L is the hood factor, which is equal to the path length (m^2) of the hood divided by the covered area (m^2).

V is the velocity (m/s) of air presented to the hood.

A.2 Collection of gas samples

Odour samples were extracted from the gas extract system upstream of the engines using the lung principle.

A.3 Measurement of odour concentration using olfactometry

Odour measurement is aimed at characterising environmental odours, relevant to human beings. As no methods exist at present that simulates and predict the responses of our sense of smell satisfactorily, the human nose is the most suitable 'sensor'. Objective methods have been developed to establish odour concentration, using human assessors. A British standard applies to odour concentration measurement:

> BS EN 13725:2003, *Air quality - Determination of odour concentration by dynamic olfactometry.*

The odour concentration of a gaseous sample of odorants is determined by presenting a panel of selected and screened human subjects with that sample, in varying dilutions with neutral gas, in order to determine the dilution factor at the 50% detection threshold (D_{50}). The odour concentration of the examined sample is then expressed as multiples of one European Odour Unit per cubic meter [ou_E/m^3] at standard conditions.

A.4 Odour monitoring results

The results of the odour monitoring conducted at the landfill are presented in the tables below:

Table 14: Surface odour emission measurements

Source	Date of sampling	Area odour emission rate [$ou_E/m^2/s$]			
		Geomean	Sample 1	Sample 2	Sample 3
Freshly tipped waste	02/10/2010	**15.5**	11.1	21.5	-
	14/10/2010	**5.7**	6.8	4.9	-
	11/04/2018	**9.2**	9.0	10.0	8.5
	07/09/2022	**5.8**	15.5	6.6	1.9
Daily cover applied	02/10/2010	**1.3**	0.9	1.8	-
	14/10/2010	**1.0**	1.0	1.1	-
	11/04/2018	**0.8**	0.7	0.8	1.1
	07/09/2022	**0.4**	0.4	0.4	0.4

Table 15: Landfill gas odour concentration

Source	Date of sampling	Odour concentration [ou_E/m^3]		
		Geomean	Sample 1	Sample 2
Landfill gas	02/10/2010	2,330,158	2,444,108	2,221,614
	07/09/2022	1,816,123	1,718,860	1,918,890

Review of the data indicates the following:

- The odour potential of the freshly tipped waste measured in 2022 has decreased compared to both the 2010 and 2018 dataset. i.e. the geometric mean of the 2022 dataset is 5.8 $ou_E/m^2/s$ compared to 9.4 $ou_E/m^2/s$ in 2010 and 9.2 $ou_E/m^2/s$ in 2018.
- The odour emission rate measured from the daily covered area in 2022 has decreased compared to both the 2010 and 2018 dataset. i.e. the geometric mean of the 2022 dataset is 0.4 $ou_E/m^2/s$ compared to 1.2 $ou_E/m^2/s$ in 2010 and 0.8 $ou_E/m^2/s$ in 2018.
- The odour potential of the landfill gas generated from the site has decreased in comparison to 2010, from approximately 2.3 million odour units to 1.8 million odour units.

Annex B: Selection of dispersion model

B.1 Description of dispersion model

AERMOD is a steady-state Gaussian plume model which is designed to assess short-range (up to 50 kilometres) dispersion of air pollutant emissions. The AERMOD dispersion model was developed by the US Environment Protection Agency and the American Meteorological Society and is routinely used by environmental impact assessment practitioners in the UK to assess the likely dispersion of pollutants, including odour.

Algorithms within the model consider a number of elements when assessing how pollutants will disperse, including the following:

- Dispersion in both the convective and stable boundary layers.
- Plume rise and buoyancy.
- Plume penetration into elevated inversions.
- Computation of vertical profiles of wind, turbulence, and temperature.
- The urban night-time boundary layer.
- The treatment of building wake effects.
- The treatment of plume meander.

The model has two important pre-processors, AERMET and BPIPPRIME. AERMET is a meteorological data pre-processor that calculates the atmospheric parameters needed by the dispersion model, such as atmospheric turbulence characteristics, mixing heights, friction velocity, Monin-Obukov length and surface heat flux. Unlike with earlier, more basic dispersion models, vertical profiles of wind, turbulence and temperature are created.

BPIPPRIME is a dispersion algorithm used in AERMOD to factor in the effect of turbulence in the wake regions of buildings. PPRIME calculates turbulent intensity and wind fields as a function of the building dimension, these are then used in AERMOD to alter the downwind plume.

This model is appropriate for this assessment as in the region of the site there are no complex terrain features in the region of the site which would significantly alter meteorological conditions. Also, due to the low source stack heights in this assessment, pollutant concentrations over long distances are not considered significant. Therefore, the prediction of pollutant concentrations within 10 km of the source is sufficient. The site location is not in close proximity to a coastline therefore the impacts of coastal fumigation do not need to be modelled in this assessment.

Annex C: Landfill gas production and containment estimates

The estimated gas production and containment rates for each cell under each of the scenarios studied are presented in the tables below. The magnitude of landfill gas generated is influenced by the age of the waste within each cell, and has been estimated using LandGem landfill gas modelling tool, calibrated against historic data for Knockharley by Fehily Timoney and Co. The estimated landfill gas production data were processed alongside waste deposition rates per year to estimate the landfill gas production for each cell. The table below presents these emission estimates.

Table 16 Odour emissions associated with LFG residual flux – Sc0

Source	Scenario 0 - 2018			
	Predicted methane production [m^3/annum]	Total landfill gas production* [m^3 per hour]	Capping containment assumption	Odour emission [ou_E/s]
cell 1	97,600	22	98%	225
cell 2	113,845	26	98%	262
cell 3	129,819	30	98%	299
cell 4	179,232	41	98%	413
cell 5	210,457	48	98%	485
cell 6	245,581	56	98%	566
cell 7	251,568	57	98%	579
cell 8	347,197	79	98%	800
cell 9	444,186	101	98%	1,023
cell 10	638,560	146	98%	1,471
cell 11	1,109,215	253	95%	6,388
cell 12	1,109,215	253	95%	6,388
cell 13	1,109,215	253	95%	6,388
cell 14	1,109,215	253	95%	6,388
Total	7,094,905	1,620	-	31,674

* Assumes 50% methane content
** Assumes 75% permanent capping and 25% intermediate capping

Table 17: Odour emissions associated with LFG residual flux – Sc1

Source	Scenario 1 – 2022			
	Predicted methane production [m³/annum]	Total landfill gas production* [m³ per hour]	Capping containment assumption	Odour emission [ou_E/s]
cell 1	10,998	3	98%	25
cell 2	10,891	2	98%	25
cell 3	14,762	3	98%	34
cell 4	15,744	4	98%	36
cell 5	21,541	5	98%	50
cell 6	22,394	5	98%	52
cell 7	30,344	7	98%	70
cell 8	32,619	7	98%	75
cell 9	34,029	8	98%	78
cell 10	34,029	8	98%	78
cell 11	57,335	13	98%	132
cell 12	63,269	14	98%	146
cell 13	83,276	19	98%	192
cell 14	131,084	30	98%	302
cell 15	266,301	61	98%	613
cell 16	296,452	68	98%	683
cell 17	318,209	73	98%	733
cell 18	427,054	98	98%	984
cell 19	729,212	166	98%	1,680
cell 20	1,427,236	326	95%	8,219
cell 21	2,273,180	519	95%	13,091
Total	6,299,960	1,438		27,298

* Assumes 50% methane content

Table 18: Odour emissions associated with LFG residual flux – Sc2

Source	Scenario 2 – 2022			
	Predicted methane production [m³/annum]	Total landfill gas production* [m³ per hour]	Capping containment assumption	Odour emission [ou_E/s]
cell 1	31,165	7	98%	72
cell 2	36,606	8	98%	84
cell 3	92,222	21	98%	212
cell 4	94,976	22	98%	219
cell 5	79,870	18	98%	184
cell 6	92,770	21	98%	214
cell 7	136,369	31	98%	314
cell 8	180,832	41	98%	417
cell 9	273,302	62	98%	630
cell 10	468,735	107	98%	1,080
cell 11	523,074	119	98%	1,205
cell 12	1,277,365	292	98%	2,942
cell 13	816,504	186	98%	1,881
cell 14	944,559	216	98%	2,176
cell 15	1,140,171	260	98%	2,626
cell 16	1,420,343	324	97%	4,908
cell 17	1,410,814	322	97%	4,875
Total	9,019,678	2,059		24,038

* Assumes 50% methane content

Table 19: Odour emissions associated with LFG residual flux – Sc3

Source	Scenario 1 – 2022			
	Predicted methane production [m³/annum]	Total landfill gas production* [m³ per hour]	Capping containment assumption	Odour emission [ou_E/s]
cell 1	17,003	4	98%	39
cell 2	20,090	5	98%	46
cell 3	50,613	12	98%	117
cell 4	52,124	12	98%	120
cell 5	43,834	10	98%	101
cell 6	50,913	12	98%	117
cell 7	74,841	17	98%	172
cell 8	99,243	23	98%	229
cell 9	149,991	34	98%	346
cell 10	257,247	59	98%	593
cell 11	287,069	66	98%	661
cell 12	701,033	160	98%	1,615
cell 13	448,107	102	98%	1,032
cell 14	518,385	118	98%	1,194
cell 15	625,739	143	98%	1,441
cell 16	779,501	178	98%	1,796
cell 17	869,286	198	98%	2,002
cell 18	1,197,180	273	98%	2,758
cell 19	1,454,580	332	97%	5,026
cell 20	1,718,629	392	97%	5,938
Total	9,415,406	2,150		25,344

* Assumes 50% methane content

Annex D: Dispersion model sensitivity to meteorological year

Table 20: Predicted odour exposure ($C_{98,\ 1\text{-hour}}$) at modelled discreet receptor locations: Dunsany

Receptor	ScO: Baseline				
	$C_{98,\ 1\text{-hour}}$ [ou_E/m^3]				
	2012	2013	2014	2015	2016
1	2.38	2.27	2.30	2.39	2.42
2	2.00	2.13	1.88	1.91	2.26
3	1.94	1.99	1.81	1.76	2.01
4	1.90	2.09	1.79	1.80	2.04
5	1.92	1.79	1.72	1.58	2.01
6	1.31	1.26	1.13	1.33	1.32
7	1.01	1.02	0.87	1.07	0.86
8	0.96	0.96	0.87	1.03	0.87
9	0.66	0.67	0.54	0.69	0.63
10	0.66	0.70	0.51	0.69	0.61
11	0.66	0.66	0.80	0.67	0.85
12	0.86	0.60	0.72	1.00	0.83
13	0.96	0.72	0.87	1.04	0.93
14	1.03	0.75	0.99	1.11	0.98
15	1.06	0.79	1.02	1.15	1.00
16	1.38	0.91	1.33	1.33	1.34
17	1.16	0.76	1.11	1.09	1.15
18	1.52	1.05	1.68	1.35	1.59
19	1.52	1.12	1.74	1.38	1.68
20	1.44	1.25	1.83	1.40	1.71
21	1.20	1.25	1.71	1.24	1.78
22	1.25	1.21	1.68	1.23	1.92
23	1.07	1.00	1.42	1.05	1.61
24	1.08	1.01	1.31	1.02	1.57
25	1.03	1.00	1.30	0.99	1.52
26	0.98	0.96	1.25	0.99	1.48
27	0.83	0.83	1.13	0.76	1.24
28	0.82	0.79	1.11	0.73	1.19
29	0.81	0.79	1.08	0.72	1.16
30	0.79	0.84	1.10	0.75	1.29
31	0.70	0.77	0.97	0.68	1.16
32	0.74	0.79	1.02	0.69	1.11
33	0.79	0.81	1.04	0.74	1.19
34	0.82	0.83	1.05	0.75	1.23
35	0.91	0.91	1.19	0.82	1.34

36	0.91	0.93	1.17	0.83	1.37
37	0.93	0.91	1.05	0.80	1.22
38	0.96	0.99	1.20	0.87	1.30
39	1.13	1.17	1.47	1.01	1.64
40	1.12	1.05	1.23	0.92	1.47
41	0.86	0.80	0.98	0.72	1.13
42	2.55	1.67	2.13	1.88	2.37
43	1.13	0.74	0.96	0.75	1.01
44	1.31	0.87	1.10	0.91	1.25
45	1.29	0.85	1.00	0.89	1.17
46	1.36	0.91	1.14	0.95	1.29
47	1.38	0.91	1.15	0.99	1.30
48	1.27	0.86	1.06	0.91	1.19
49	1.23	0.90	1.18	0.93	1.23
50	1.27	0.98	1.27	1.04	1.34
51	1.19	0.97	1.23	0.93	1.23
52	1.07	0.94	1.09	0.92	1.15
53	1.02	0.90	1.02	0.92	1.08
54	0.42	0.43	0.52	0.42	0.53
Max	2.55	2.27	2.30	2.39	2.42
Average	1.16	1.02	1.22	1.05	1.34

Table 21: Predicted odour exposure ($C_{98,\ 1\text{-hour}}$) at modelled discreet receptor locations: Dunsany

Receptor	Sc1: Year 4 without development				
	$C_{98,\ 1\text{-hour}}$ [ou_E/m^3]				
	2012	2013	2014	2015	2016
1	1.43	1.30	1.25	1.12	1.50
2	1.11	1.02	1.00	0.97	1.11
3	0.98	0.91	0.87	0.90	0.98
4	1.04	0.94	0.95	0.91	1.06
5	0.92	0.84	0.77	0.85	0.85
6	0.59	0.57	0.52	0.64	0.51
7	0.46	0.47	0.36	0.46	0.43
8	0.45	0.45	0.35	0.46	0.41
9	0.34	0.36	0.28	0.37	0.33
10	0.34	0.37	0.25	0.37	0.34
11	0.82	0.77	0.93	0.77	0.88
12	0.83	0.76	0.80	0.81	0.83
13	0.96	0.70	0.83	1.15	0.94
14	1.10	0.79	0.99	1.20	1.06
15	1.14	0.81	1.03	1.29	1.12

16	1.54	1.03	1.40	1.42	1.45
17	1.23	0.80	1.11	1.10	1.16
18	1.61	1.27	1.80	1.50	1.78
19	1.54	1.33	1.87	1.54	1.80
20	1.52	1.41	1.81	1.47	1.87
21	1.16	1.11	1.51	1.19	1.75
22	1.13	1.10	1.48	1.08	1.65
23	0.94	0.93	1.26	0.90	1.32
24	0.93	0.91	1.19	0.86	1.32
25	0.89	0.89	1.18	0.83	1.28
26	0.83	0.84	1.11	0.78	1.20
27	0.70	0.69	0.89	0.61	0.99
28	0.67	0.68	0.86	0.59	0.97
29	0.65	0.65	0.84	0.57	0.93
30	0.70	0.68	0.79	0.59	0.95
31	0.69	0.60	0.75	0.54	0.88
32	0.77	0.62	0.79	0.55	0.92
33	0.84	0.67	0.81	0.60	0.91
34	0.95	0.69	0.87	0.67	0.95
35	1.01	0.74	0.96	0.72	1.04
36	1.05	0.75	0.95	0.74	1.07
37	1.09	0.77	0.91	0.74	1.01
38	1.18	0.84	1.02	0.83	1.11
39	1.38	1.01	1.23	1.02	1.34
40	1.29	0.90	1.18	0.94	1.24
41	0.99	0.68	0.83	0.68	0.94
42	1.44	1.37	1.43	1.39	1.50
43	0.91	0.63	0.79	0.66	0.88
44	0.94	0.73	0.94	0.75	0.97
45	0.86	0.70	0.88	0.68	0.90
46	0.89	0.75	0.90	0.70	0.92
47	0.88	0.80	0.90	0.70	0.92
48	0.79	0.69	0.80	0.65	0.83
49	0.73	0.66	0.71	0.66	0.77
50	0.68	0.69	0.74	0.68	0.75
51	0.66	0.66	0.66	0.62	0.72
52	0.55	0.60	0.58	0.58	0.65
53	0.53	0.59	0.53	0.53	0.63
54	0.43	0.41	0.46	0.42	0.43
Max	1.61	1.41	1.87	1.54	1.87
Average	0.93	0.80	0.94	0.82	1.02

Table 22: Predicted odour exposure ($C_{98, 1\text{-hour}}$) at modelled discreet receptor locations: Dunsany

Receptor	Sc2: Year 4 development				
	$C_{98, 1\text{-hour}}$ [ou_E/m^3]				
	2012	2013	2014	2015	2016
1	1.28	1.37	1.28	1.27	1.48
2	1.15	1.20	1.11	1.11	1.27
3	1.10	1.06	1.02	1.02	1.17
4	1.12	1.10	1.04	1.01	1.18
5	1.06	1.01	0.96	0.91	1.07
6	0.72	0.72	0.69	0.76	0.69
7	0.58	0.57	0.52	0.59	0.52
8	0.58	0.54	0.51	0.58	0.49
9	0.40	0.42	0.31	0.41	0.39
10	0.41	0.41	0.31	0.43	0.39
11	0.51	0.50	0.56	0.51	0.60
12	0.65	0.46	0.52	0.64	0.56
13	0.68	0.48	0.62	0.79	0.68
14	0.73	0.54	0.67	0.76	0.68
15	0.75	0.56	0.67	0.80	0.67
16	0.99	0.65	0.92	0.92	0.96
17	0.78	0.54	0.76	0.75	0.78
18	1.06	0.75	1.17	0.98	1.15
19	1.05	0.83	1.17	0.95	1.17
20	1.03	0.91	1.28	0.98	1.18
21	0.80	0.85	1.10	0.83	1.24
22	0.82	0.80	1.04	0.82	1.25
23	0.70	0.69	0.89	0.70	1.06
24	0.70	0.68	0.90	0.70	1.01
25	0.67	0.69	0.87	0.68	0.98
26	0.63	0.66	0.82	0.64	0.93
27	0.54	0.54	0.73	0.49	0.77
28	0.51	0.53	0.70	0.48	0.77
29	0.50	0.52	0.67	0.46	0.78
30	0.50	0.56	0.70	0.46	0.78
31	0.50	0.52	0.65	0.44	0.72
32	0.49	0.49	0.62	0.44	0.71
33	0.53	0.53	0.65	0.47	0.72
34	0.57	0.56	0.66	0.48	0.77
35	0.61	0.60	0.74	0.52	0.80
36	0.61	0.61	0.73	0.53	0.83

37	0.64	0.56	0.70	0.49	0.81
38	0.69	0.63	0.77	0.54	0.87
39	0.80	0.74	0.90	0.65	1.03
40	0.83	0.67	0.86	0.59	0.93
41	0.62	0.51	0.67	0.45	0.74
42	1.53	1.12	1.38	1.19	1.60
43	0.71	0.49	0.64	0.50	0.68
44	0.87	0.56	0.72	0.62	0.78
45	0.83	0.54	0.68	0.59	0.73
46	0.85	0.56	0.75	0.63	0.79
47	0.86	0.56	0.75	0.61	0.80
48	0.77	0.53	0.69	0.57	0.74
49	0.72	0.59	0.71	0.61	0.74
50	0.73	0.65	0.73	0.61	0.76
51	0.71	0.64	0.72	0.60	0.72
52	0.64	0.57	0.64	0.57	0.67
53	0.60	0.56	0.58	0.55	0.61
54	0.31	0.30	0.37	0.31	0.35
Max	1.53	1.37	1.38	1.27	1.60
Average	0.74	0.65	0.77	0.67	0.84

Table 23: Predicted odour exposure ($C_{98,\ 1\text{-hour}}$) at modelled discreet receptor locations: Dunsany

Receptor	Sc3: Year 6 development				
	$C_{98,\ 1\text{-hour}}$ [ou_E/m^3]				
	2012	2013	2014	2015	2016
1	1.27	1.40	1.23	1.29	1.41
2	1.17	1.11	1.08	1.03	1.18
3	1.04	0.98	0.95	0.88	1.04
4	1.08	1.04	0.97	0.95	1.09
5	0.99	0.91	0.91	0.83	0.97
6	0.65	0.67	0.60	0.68	0.61
7	0.53	0.51	0.45	0.55	0.49
8	0.52	0.47	0.44	0.51	0.51
9	0.37	0.39	0.29	0.38	0.39
10	0.38	0.39	0.28	0.40	0.39
11	0.70	0.64	0.75	0.63	0.76
12	0.73	0.61	0.63	0.73	0.73
13	0.78	0.57	0.70	0.91	0.79
14	0.87	0.64	0.80	0.93	0.82
15	0.92	0.68	0.84	1.00	0.86
16	1.20	0.76	1.15	1.13	1.14

17	0.94	0.63	0.94	0.94	0.93
18	1.31	0.95	1.51	1.18	1.46
19	1.30	1.10	1.54	1.23	1.52
20	1.25	1.06	1.59	1.27	1.60
21	0.97	0.98	1.33	1.04	1.49
22	0.97	0.95	1.26	0.95	1.45
23	0.80	0.82	1.07	0.79	1.21
24	0.80	0.80	1.07	0.79	1.16
25	0.78	0.78	1.05	0.76	1.12
26	0.75	0.73	0.98	0.70	1.06
27	0.58	0.63	0.79	0.55	0.90
28	0.57	0.62	0.78	0.53	0.87
29	0.58	0.59	0.75	0.51	0.85
30	0.60	0.60	0.78	0.52	0.85
31	0.59	0.58	0.70	0.49	0.79
32	0.63	0.56	0.68	0.50	0.81
33	0.67	0.58	0.73	0.50	0.86
34	0.79	0.59	0.81	0.55	0.86
35	0.82	0.64	0.84	0.58	0.96
36	0.85	0.66	0.86	0.61	0.97
37	0.90	0.65	0.83	0.66	0.89
38	0.96	0.70	0.91	0.71	0.99
39	1.12	0.82	1.09	0.84	1.19
40	1.12	0.77	0.99	0.79	1.04
41	0.83	0.59	0.78	0.60	0.83
42	1.41	1.23	1.41	1.25	1.53
43	0.88	0.56	0.70	0.61	0.75
44	0.93	0.62	0.81	0.71	0.89
45	0.87	0.62	0.76	0.66	0.87
46	0.88	0.67	0.81	0.69	0.94
47	0.86	0.67	0.81	0.71	0.92
48	0.76	0.61	0.74	0.65	0.81
49	0.74	0.68	0.74	0.63	0.76
50	0.74	0.66	0.74	0.67	0.78
51	0.70	0.63	0.70	0.63	0.73
52	0.61	0.58	0.57	0.58	0.67
53	0.52	0.58	0.54	0.54	0.63
54	0.37	0.36	0.43	0.36	0.41
Max	1.41	1.40	1.59	1.29	1.60
Average	0.83	0.71	0.86	0.74	0.94

Annex E: Model parameters

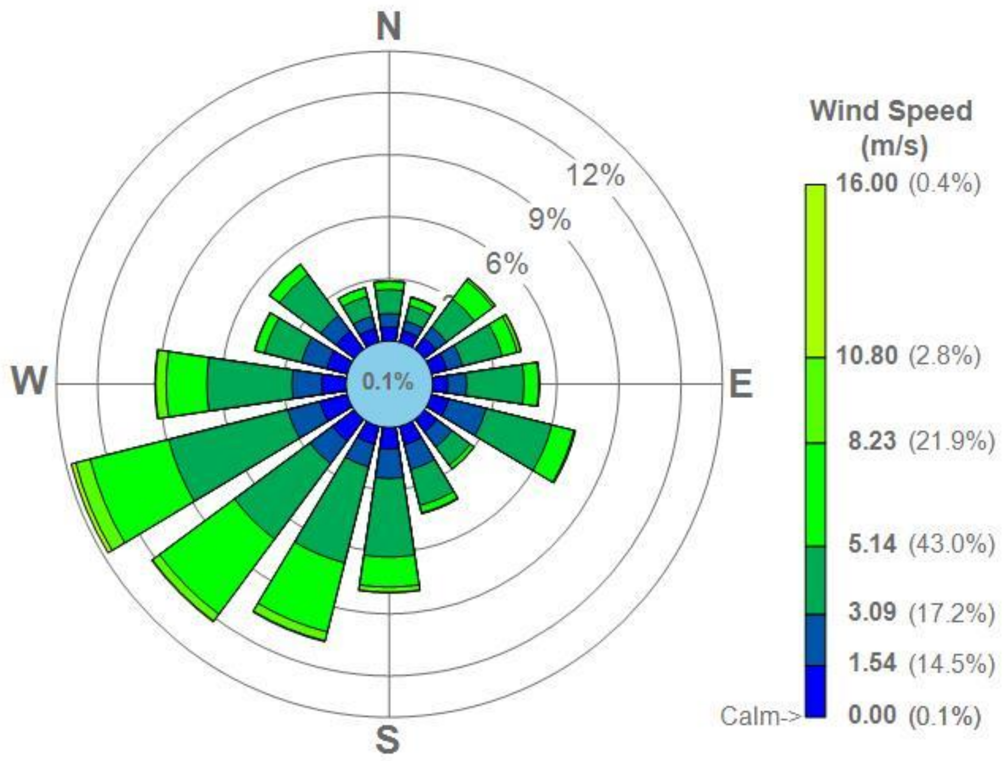
E.1 Meteorological data pre-processing

Five years of data was obtained for Dunsany (2012 to 2016) and adjusted to reflect the surface characteristics of the meteorological site in accordance with the guidelines in the Implementation Guide[16].

Table 24: Land use roughness values applied during meteorological processing.

Sector [degrees]	Surface roughness [m]	Albedo / Bowen ratio
335-80	0.12	0.278 / 0.761
80-165	0.10	
165-280	0.07	
280-335	0.08	

Figure 9: Wind-rose for the combined meteorological dataset (Dunsany 2012)



[16] AERMOD Implementation Guide, Published by the US EPA: Last Revised: June 2022.

Figure 10: Wind-rose for the combined meteorological dataset (Dunsany 2013)

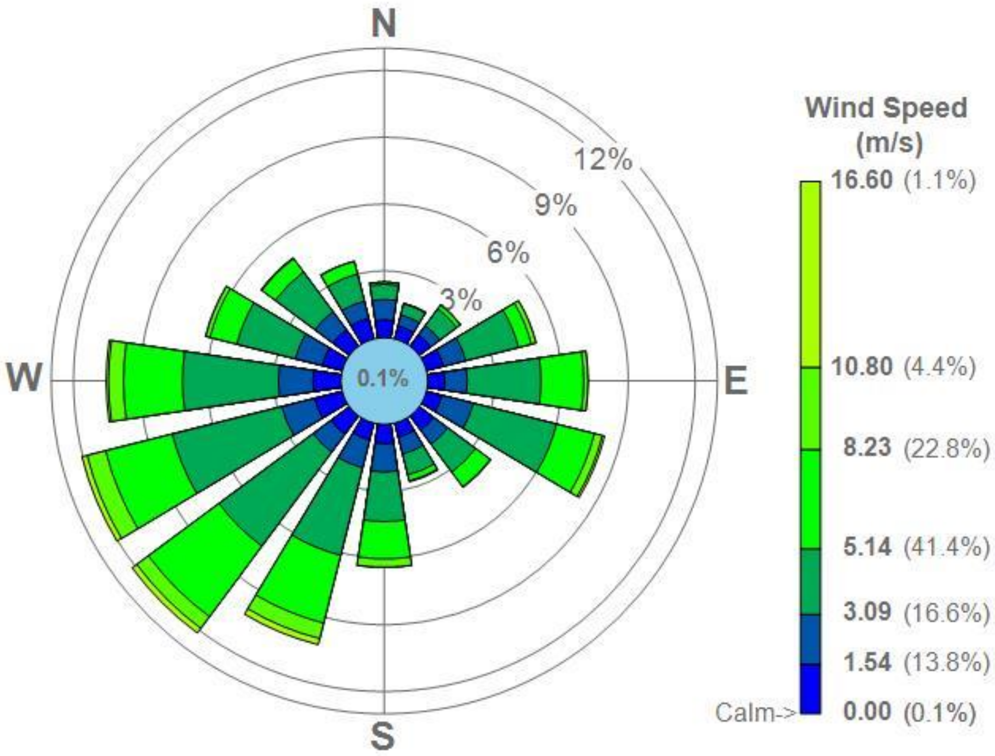


Figure 11: Wind-rose for the combined meteorological dataset (Dunsany 2014)

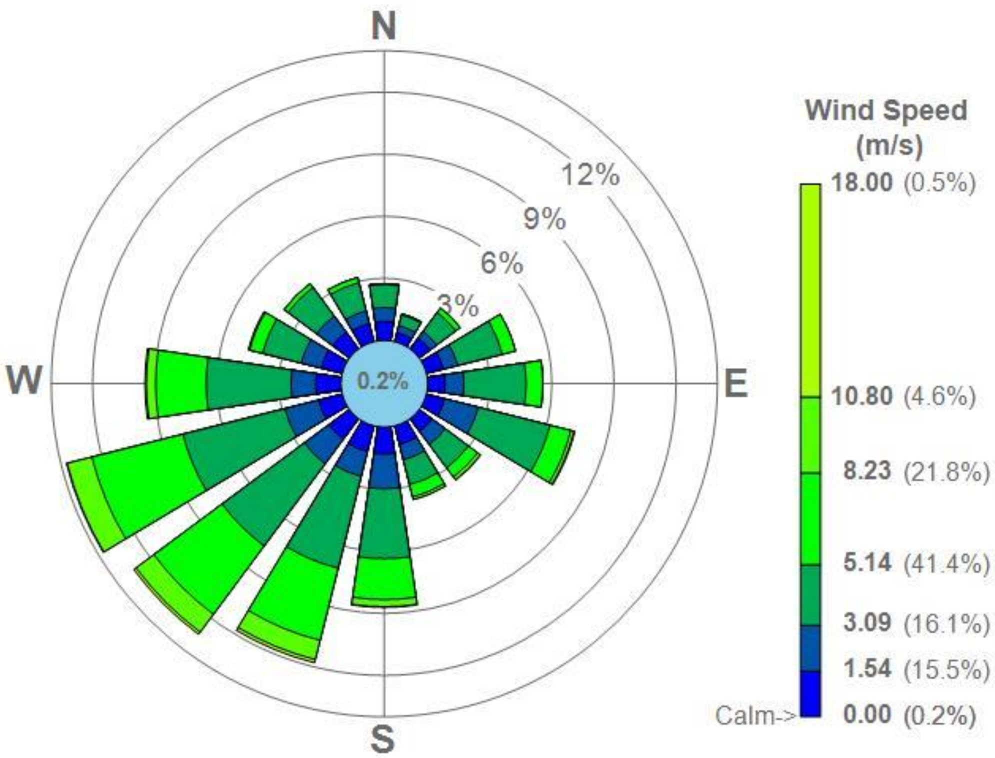


Figure 12: Wind-rose for the combined meteorological dataset (Dunsany 2015)

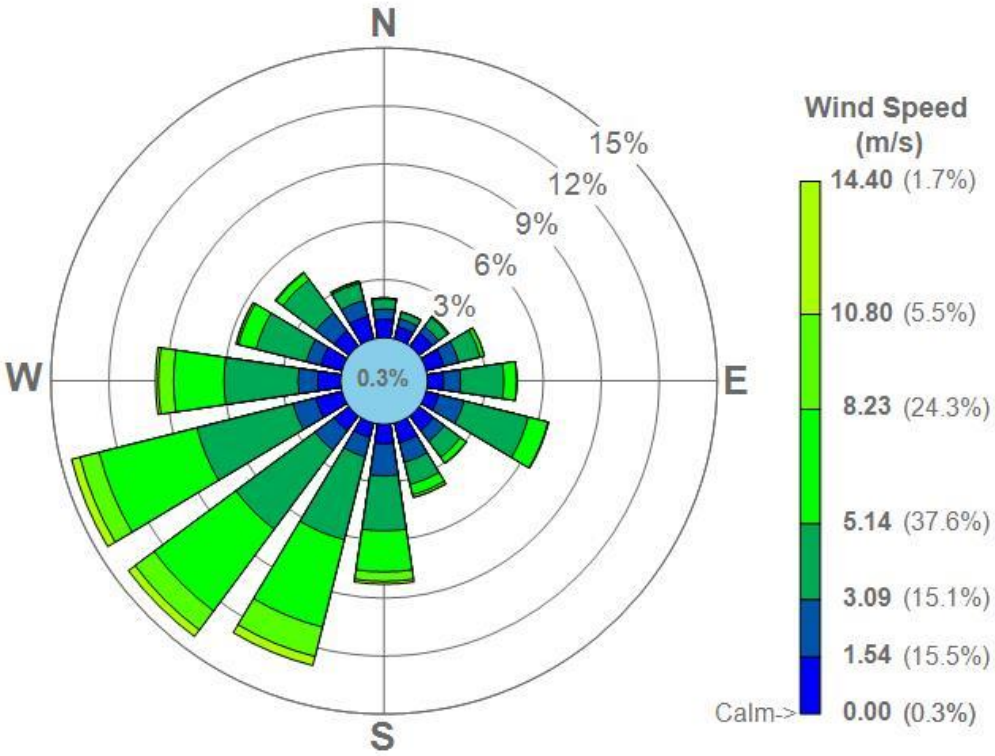
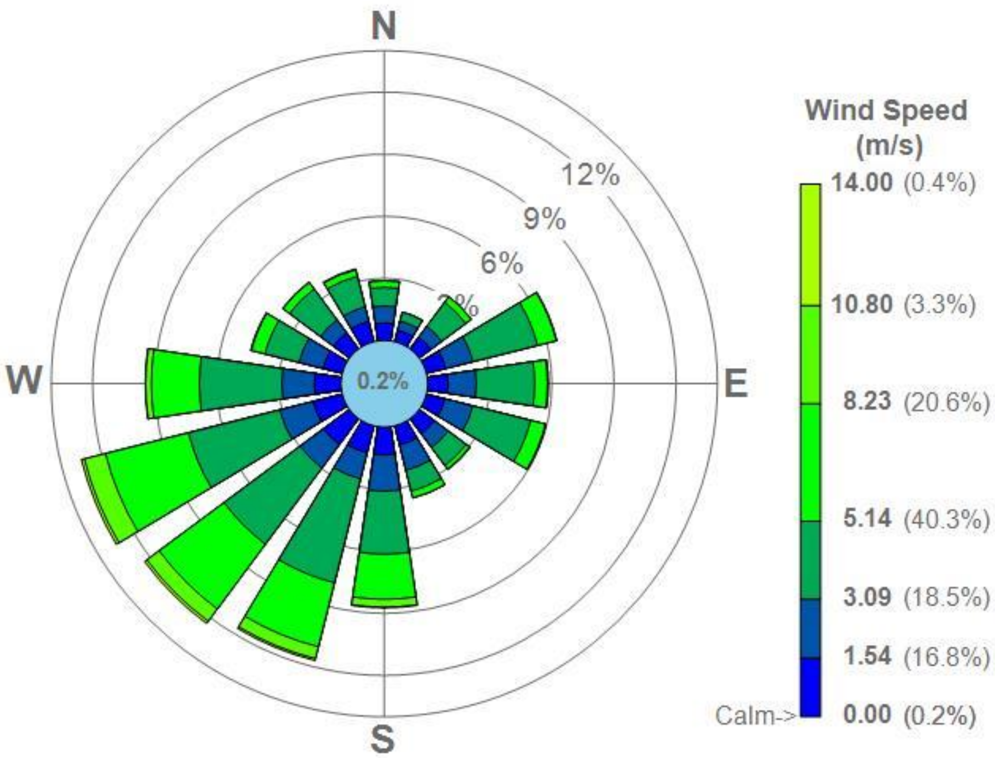


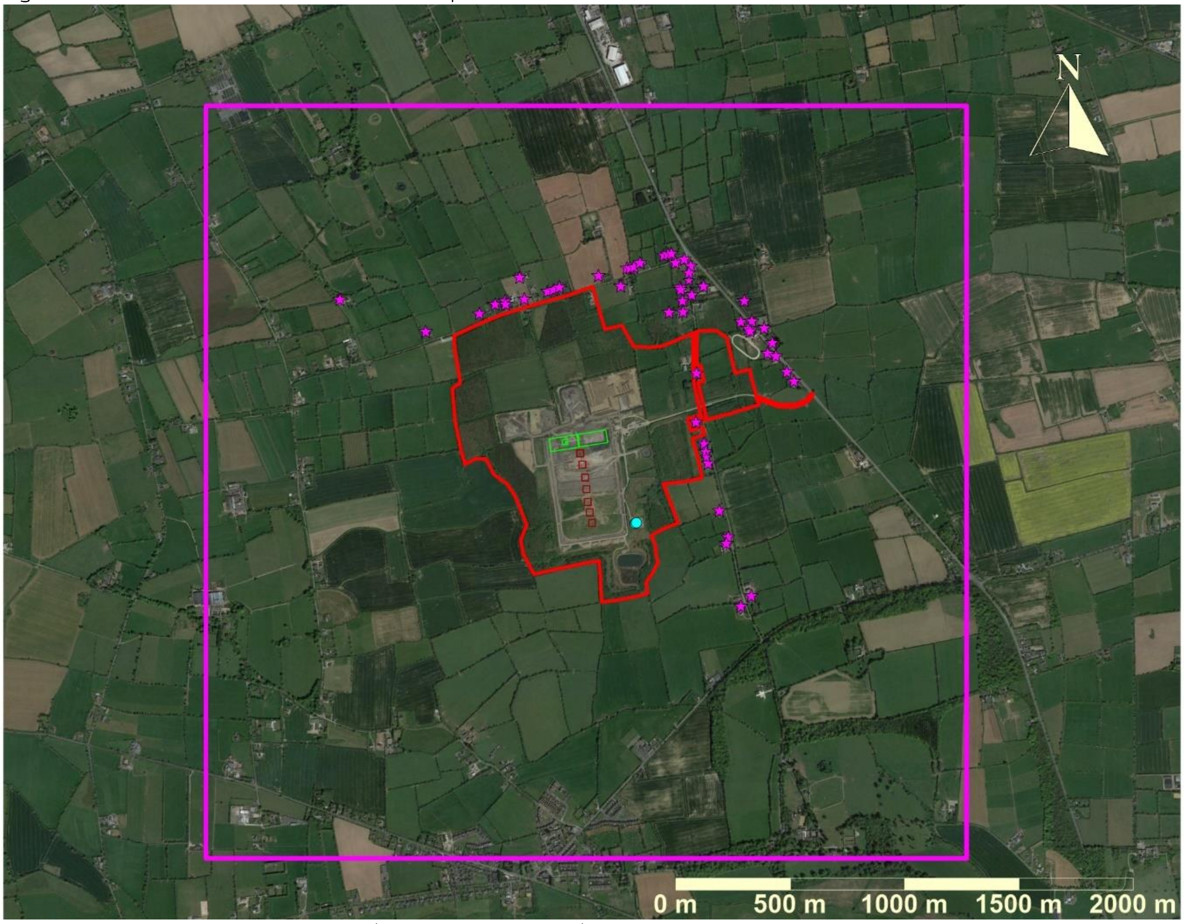
Figure 13: Wind-rose for the combined meteorological dataset (Dunsany 2016)



E.2: Model sources

Sc0 – Baseline conditions

Figure 14: Location of odour sources and receptors included in model Sc0



Pink square = extent of receptor grid (50 m resolution grid). Red line = site boundary. Pink stars = discrete receptors. Green polygons = area sources. Dark red polygons = volume sources. Blue circle = engine stack source

Table 25: Sources included within the model Sc0

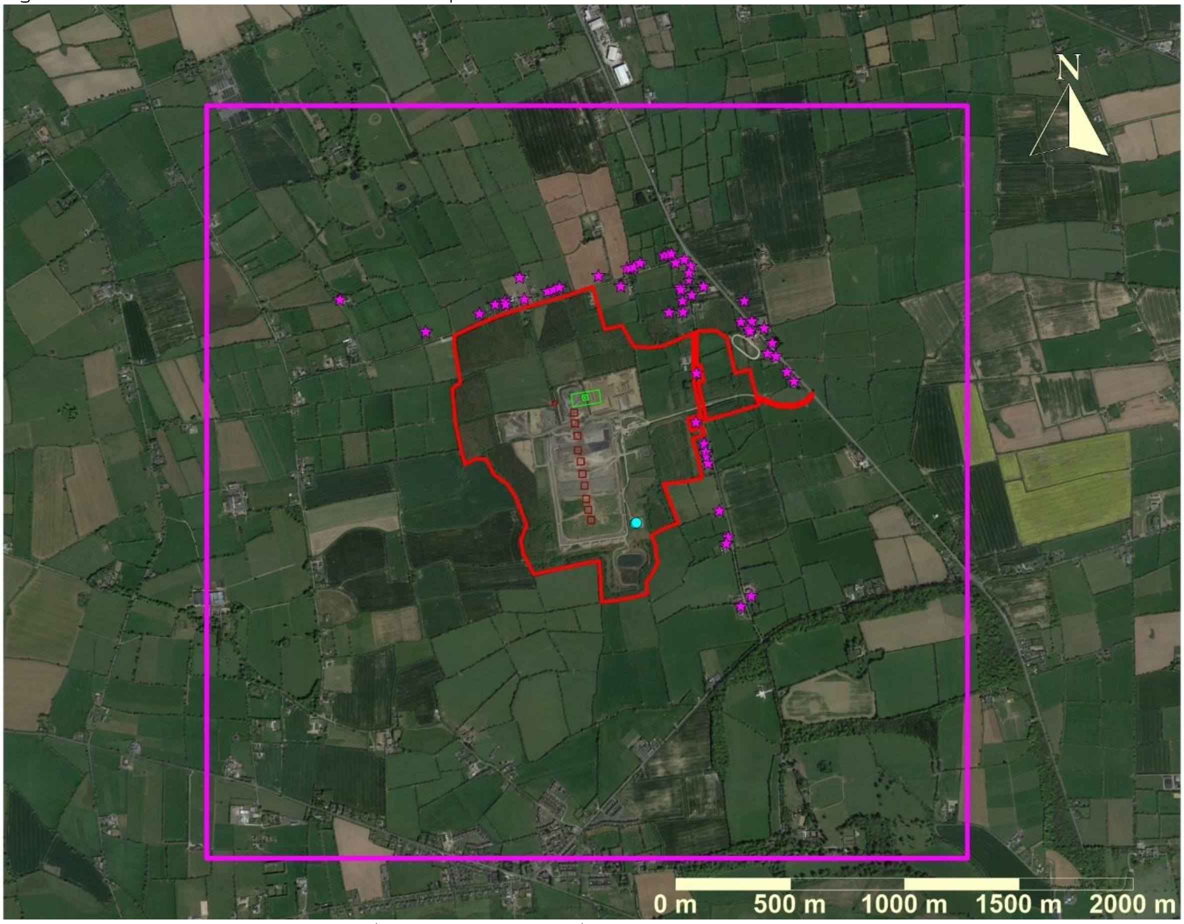
Source type	Source	Elevation (m)	Coordinates (UTM)		Source dimensions	Release height
Point	Engine 1 stack	55.82	63591.8	5946649.1	-	-
Point	Engine 2 stack	55.7	663598.0	5946650.1	-	-
Area	Temporary cap	64	663240.5	5947060.2	625.5/142.9	10
Area	Temporary cap	64	663225.0	5947069.9	625.5/142.9	10
Area	Freshly deposited waste	64	663160.4	5947075.3	25/25	10
Area	Waste tipping	64	663298.7	5947095.1	5/5	10
Volume	Lagoon tanker	60.51	663618.6	5947036.8	0.23/0.47	0.5
Volume	Cell 1&2	64	663373.4	5946662.5	31/0.05	10
Volume	Cell 3&4	64	663360.6	5946714.5	31/0.05	10
Volume	Cell 5&6	64	663351.9	5946765.0	31/0.05	10
Volume	Cell 7&8	64	663343.1	5946830.0	31/0.05	10
Volume	Cell 9&10	64	663336.6	5946885.9	31/0.05	10

Volume	Cell 11&12	64	663324.2	5946949.5	31/0.05	10
Volume	Cell 13&14	64	663313.7	5947004.1	31/0.05	10

Area source – x length/y length in m. Volume source – initial lateral and vertical dimensions in m

Sc1 – Year 4: Without development

Figure 15: Location of odour sources and receptors included in model Sc1



Pink square = extent of receptor grid (50 m resolution grid). Red line = site boundary. Pink stars = discrete receptors. Green polygons = area sources. Dark red polygons = volume sources. Blue circle = engine stack source

Table 26: Sources included within the model Sc1

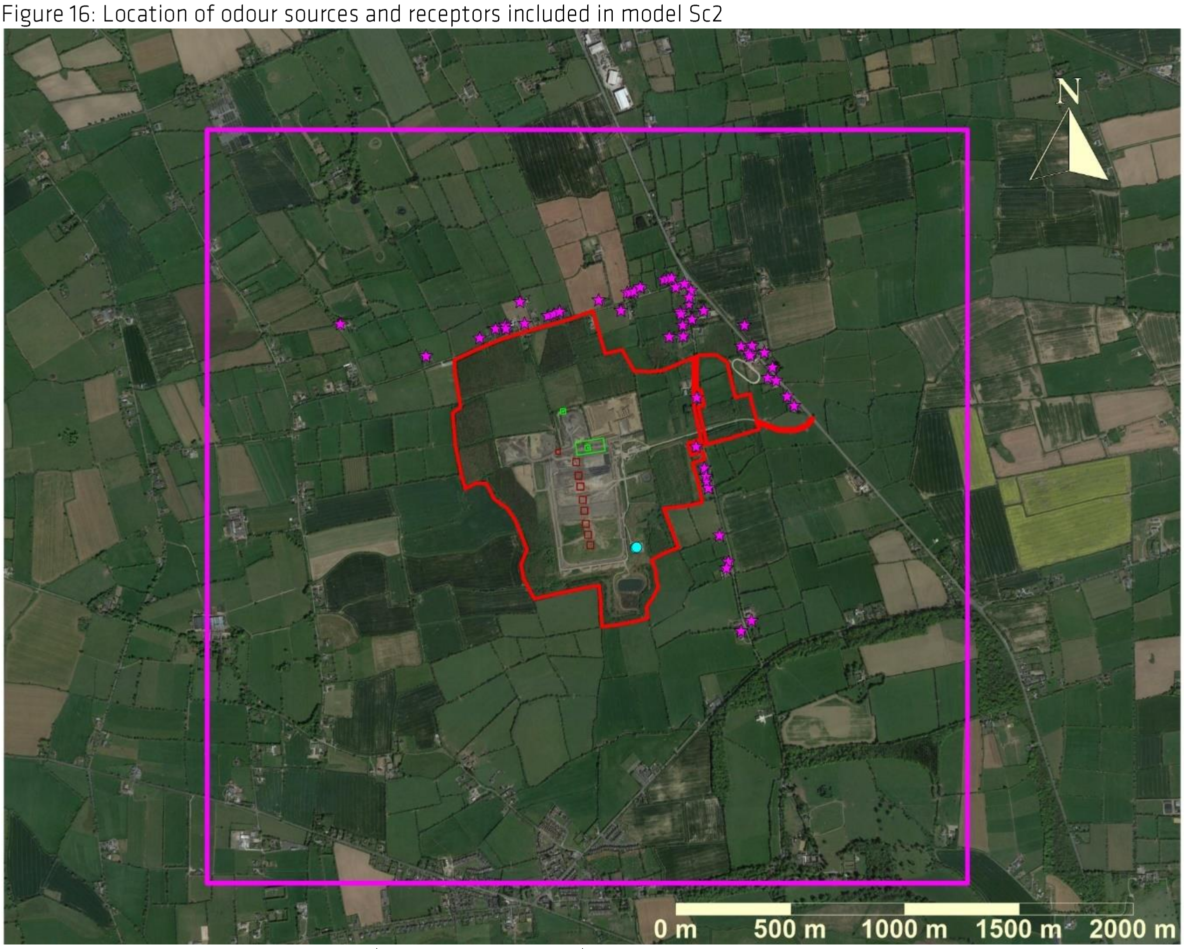
Source type	Source	Elevation (m)	Coordinates (UTM)		Source dimensions	Release height
Point	Engine 1 stack	55.82	63591.8	5946649.1	-	-
Point	Engine 2 stack	55.7	663598.0	5946650.1	-	-
Area	Temporary cap	64	663274.8	5947277.1	625.5/142.9	10
Area	Freshly deposited waste	64	663332.7	5947269.7	25/25	10
Area	Waste tipping	64	663343.9	5947260.5	5/5	10
Volume	Lagoon tanker	60.51	663618.6	5947036.8	0.23/0.47	0.5
Volume	Cell 1&2	64	663373.4	5946662.5	31/0.05	10
Volume	Cell 3&4	64	663360.6	5946714.5	31/0.05	10
Volume	Cell 5&6	64	663351.9	5946765.0	31/0.05	10
Volume	Cell 7&8	64	663343.1	5946830.0	31/0.05	10

Volume	Cell 9&10	64	663336.6	5946885.9	31/0.05	10
Volume	Cell 11&12	64	663324.2	5946949.5	31/0.05	10
Volume	Cell 13&14	64	663313.7	5947004.1	31/0.05	10
Volume	Cell 15&16	64	663299.5	5947131.5	31/0.05	10
Volume	Cell 17&18	64	663306.3	5947072.0	31/0.05	10
Volume	Cell 19&20	64	663291.4	663291.4	31/0.05	10
Volume	Cell 21	64	663198.4	5947232.4	22/0.05	10

Area source – x length/y length in m. Volume source – initial lateral and vertical dimensions in m

Sc2 – Year 4: Development

Figure 16: Location of odour sources and receptors included in model Sc2



Pink square = extent of receptor grid (50 m resolution grid). Red line = site boundary. Pink stars = discrete receptors. Green polygons = area sources. Dark red polygons = volume sources. Blue circle = engine stack source

Table 27: Sources included within the model Sc2

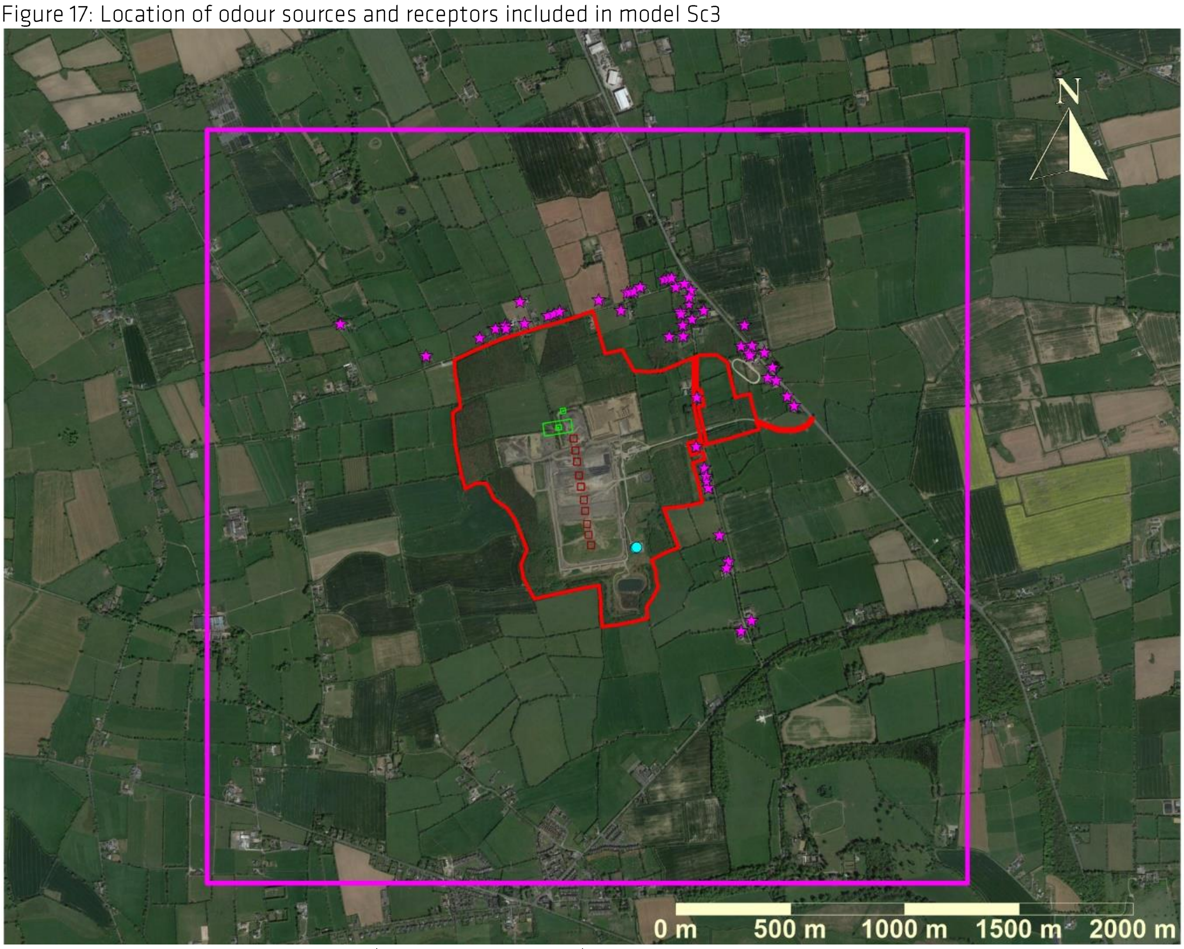
Source type	Source	Elevation (m)	Coordinates (UTM)		Source dimensions	Release height
Point	Engine 3 stack	55.58	663604	5946651.1	-	-
Point	Engine 4 stack	55.47	663609.7	5946652.2	-	-
Area	Temporary cap	64	663293	5947168.4	625.5/142.9	10
Area	Freshly deposited waste	64	663341	5947151.5	25/25	10
Area	Waste tipping	64	663356.6	5947143.1	5/5	10

Area	Stabilised waste	64	663221.6	5947332	25/25	10
Area	Stabilised waste tipping	64	663234.5	5947323.6	5/5	10
Volume	Lagoon tanker	60.51	663618.6	5947036.8	0.23/0.47	0.5
Volume	Cell 1&2	64	663373.4	5946662.5	31/0.05	10
Volume	Cell 3&4	64	663360.6	5946714.5	31/0.05	10
Volume	Cell 5&6	64	663351.9	5946765.0	31/0.05	10
Volume	Cell 7&8	64	663343.1	5946830.0	31/0.05	10
Volume	Cell 9&10	64	663336.6	5946885.9	31/0.05	10
Volume	Cell 11&12	64	663324.2	5946949.5	31/0.05	10
Volume	Cell 13&14	64	663313.7	5947004.1	31/0.05	10
Volume	Cell 15&16	64	663302.9	5947070.2	31/0.05	10
Volume	Cell 17	64	663213.4	5947119.3	22/0.05	10

Area source – x length/y length in m. Volume source – initial lateral and vertical dimensions in m

Sc3 – Year 6: Development

Figure 17: Location of odour sources and receptors included in model Sc3



Pink square = extent of receptor grid (50 m resolution grid). Red line = site boundary. Pink stars = discrete receptors. Green polygons = area sources. Dark red polygons = volume sources. Blue circle = engine stack source

28: Sources included within the model Sc3

Source type	Source	Elevation (m)	Coordinates (UTM)		Source dimensions	Release height

Point	Engine 3 stack	55.58	663604	5946651.1	-	-
Point	Engine 4 stack	55.47	663609.7	5946652.2	-	-
Area	Temporary cap	64	663133.8	5947260.6	625.5/142.9	10
Area	Freshly deposited waste	64	663201.4	5947249	25/25	10
Area	Waste tipping	64	663209	5947239.3	5/5	10
Area	Stabilised waste	64	663221.6	5947332	25/25	10
Area	Stabilised waste tipping	64	663234.5	5947323.6	5/5	10
Volume	Lagoon tanker	60.51	663618.6	5947036.8	0.23/0.47	0.5
Volume	Cell 1&2	64	663373.4	5946662.5	31/0.05	10
Volume	Cell 3&4	64	663360.6	5946714.5	31/0.05	10
Volume	Cell 5&6	64	663351.9	5946765.0	31/0.05	10
Volume	Cell 7&8	64	663343.1	5946830.0	31/0.05	10
Volume	Cell 9&10	64	663336.6	5946885.9	31/0.05	10
Volume	Cell 11&12	64	663324.2	5946949.5	31/0.05	10
Volume	Cell 13&14	64	663313.7	5947004.1	31/0.05	10
Volume	Cell 15&16	64	663296.6	5947126.6	31/0.05	10
Volume	Cell 17&18	64	663304.0	5947073.9	31/0.05	10
Volume	Cell 19&20	64	663287.0	5947185.4	31/0.05	10

Area source – x length/y length in m. Volume source – initial lateral and vertical dimensions in m

E.3 Model buildings

Figure 18: Location of buildings included in model

Red dots represent engine stacks. 1 & 2 active in Sc0 and Sc1. 3 & 4 active in Sc2 and Sc3

Table 29: Buildings included within the model

Ref	Building	Height (m)	Elevation (m)	X length (m)	Y length (m)	Coordinates (UTM)
B1	Engine container 1	4	55.48	12	2.5	663609, 5946652
B2	Engine container	4	55.83	12	2.5	663591, 5946650
B3	Engine container	4	55.71	12	2.5	663597, 5946651
B4	Engine container	4	55.59	12	2.5	663603, 5946651
B5	Electrical sub station	4.5	55.13	4.6	11	663617, 5946639
B6	Container adj to flare	3	55.98	12	1.7	663583, 5946648
B7	Structure	3	55.79	2.5	6.3	663575, 5946657
B8	Structure	3.5	55.89	4	4	663580, 5946654
B9	Structure	3.5	55.85	5	2.5	663581, 5946659