REPORT

Tonkin+Taylor

For a comprehensive understanding of this report, please also refer to the relevant s92 responses

Auckland Regional Landfill

Air Quality Assessment

Prepared for
Waste Management NZ Ltd
Prepared by
Tonkin & Taylor Ltd
Date
May 2019
Job Number
1005069

Exceptional thinking together
www.tonkintaylor.co.nz

Document Control

Title: Auckland Regional Landfill					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
30/05/2019	1.0	Final	J. Simpson	S. Eldridge	S. Eldridge

Table of contents

1 Introduction

Tonkin & Taylor Ltd (T+T) has been commissioned by Waste Management NZ Ltd (WMNZ) to prepare a technical assessment of the environmental effects of discharges to air to support resource consent applications for the Auckland Regional Landfill project.

The project comprises the construction of a 25.8 Mm^3 landfill to provide for the disposal of municipal solid waste for a period in excess of 35 years. A full description of the project is provided in Section 5 of the Assessment of Environmental Effects (AEE) Report.

The discharges to air from landfilling activities principally comprise:

- Combustion products generated by the burning of collected landfill gas in flares and generators;
- Fugitive emissions of landfill gas (LFG);
- Odour from the waste itself; and
- Dust emissions from construction activities or dusty wastes.

This report assesses the effects of emissions of combustion products, the effects of odour (which can arise from the waste itself or fugitive emissions of LFG) and emissions of dust. The effects of other contaminants that may be present in LFG (such as volatile organic compounds or other elemental compounds) where there is potential for effects from lifetime exposure are considered in the separate Health Risk Assessment report.

This report is structured as follows:

- Section 2 - Discussion of the site and context as this relates to the dispersion of discharges to air and location of sensitive receptors;
- Section 3 - Estimates of landfill gas generation and collection rates and a description of the measures that will be used to capture LFG and beneficially use it to generate electricity, whilst effectively destroying the methane and associated odorous compounds;
- Section 4 - Description of the range of measures that will be used to manage odour from the receipt and placement of waste;
- Section 5 - An assessment of the environmental effects of odours using a combination of dispersion modelling and qualitative assessment techniques;
- Section 6 - An assessment of the environmental effects of discharges of products of LFG combustion using dispersion modelling and comparison with relevant national and regional air quality assessment criteria;
- Section 7 - An assessment of the environmental effects of dust emissions;
- Section 8 - A summary of the mitigation measures and monitoring proposed to assist in pro-active site management and monitoring the effectiveness of controls;
- Section 9 - Consideration of the statutory provisions specifically relevant to discharges to air; and
- Section 10 - Final concluding statements.

2 Site description and context

2.1 Site description

The proposed landfill is located in the Wayby Valley area, approximately 6 km southwest of Wellsford and 70 km north of Auckland. The landfill is to be constructed in a northwest facing valley currently vegetated with pine forest. This portion of the site is described as the Eastern Block or Forestry Block. The landfill will be constructed entirely in the catchment of this valley.

Access to the landfill is proposed off State Highway 1 just south of the Hōteo River Bridge, where a sealed road will be constructed approximately 2 km in length commencing at an intersection on SH1 and climbing up a valley before crossing a ridge into the main landfill valley. The predominant vegetation in this access road valley is a plantation wattle forest. This portion of the site is described as the Southern Block.

A plan showing the overall site is shown in Figure 7 in the set of drawings in Appendix C to the AEE Report and a full description of the site and surroundings can be found in Section 4 of the AEE Report.

The aspects of the site and context that are particularly relevant to the effects of discharges to air are wind patterns and topography (particularly as it influences localised wind patterns and dispersion of contaminants), background air quality and the location of sensitive receptors around the proposed site. These are discussed in turn in the following sub-sections.

A site location plan showing the landholding, landfill footprint and location of sensitive receptors is shown in Figure 7 of the set of drawings in Appendix C to the AEE Report (reproduced in Appendix A of this report for ease of reference).

2.2 Topography and wind patterns

The landholding is located in the Wayby Valley area. The wider terrain comprises a series of relatively steep sided valleys, with river flats to the west. The landfill is proposed to be located in a valley that is oriented approximately southeast to northwest. Topography is relevant to the dispersion of emissions to air. Complex topography will tend to create localised wind patterns and shift winds to the orientation of the valley. During calm conditions, drainage flows will generally follow the topography of the valley from highest to lowest elevation.

The closest meteorological station to the proposed landfill footprint is the Mahurangi Forest automated weather station (Auckland Council reference 643514), located approximately 3 km south of the proposed landfill footprint. The weather station is located in an elevated position within the forestry area.

Wind speed and direction patterns can be depicted using a wind rose. The arms of the wind rose represent the direction that wind is blowing from, and the length of the arms represents the frequency (as a percentage of trial hours). The wind rose for the Mahurangi Forest weather station (see Figure 2.1) shows a dominance of southerly and south-southwesterly winds, with a secondary prevalence of winds from the north-northwest (see wind rose). The wind direction pattern observed at the weather station is typical of conditions in the wider Auckland region, which tend to be dominated by southwesterlies and a secondary prevalence of northeasterlies.

Data is available from the Mahurangi Forest weather station commencing August 2013, with full years' meteorological data available for years 2014 to 2017. In general, wind patterns vary from year to year, particularly with the El Niño/Southern Oscillation effect. In El Niño years, New Zealand tends to experience stronger and/or more frequent winds from the west in summer. In winter, the winds tend to be more from the south, bringing colder conditions and in spring and autumn southwesterlies tend to be stronger or more frequent. The main feature of the opposite La Niña events is more frequent northeasterly winds.

As discussed in Appendix B, the years 2015 and 2017 have been selected for the dispersion modelling study as best representing the differing El Niño and La Niña cycles (respectively) within the available dataset (see windroses for each year in Figure 2.2). The CALMET model predicts that, compared to wider regional wind patterns, the site will generally experience a greater frequency of low wind speed conditions (less than 2 m/s). The wind roses suggest that the site will experience a predominance of southwesterly winds in El Niño years when winds from the southwest quadrant tend to be stronger (e.g. 2015). In La Niña years (e.g. 2017) there is a more evenly distributed pattern of wind directions and a particularly high frequency of low wind speed conditions.

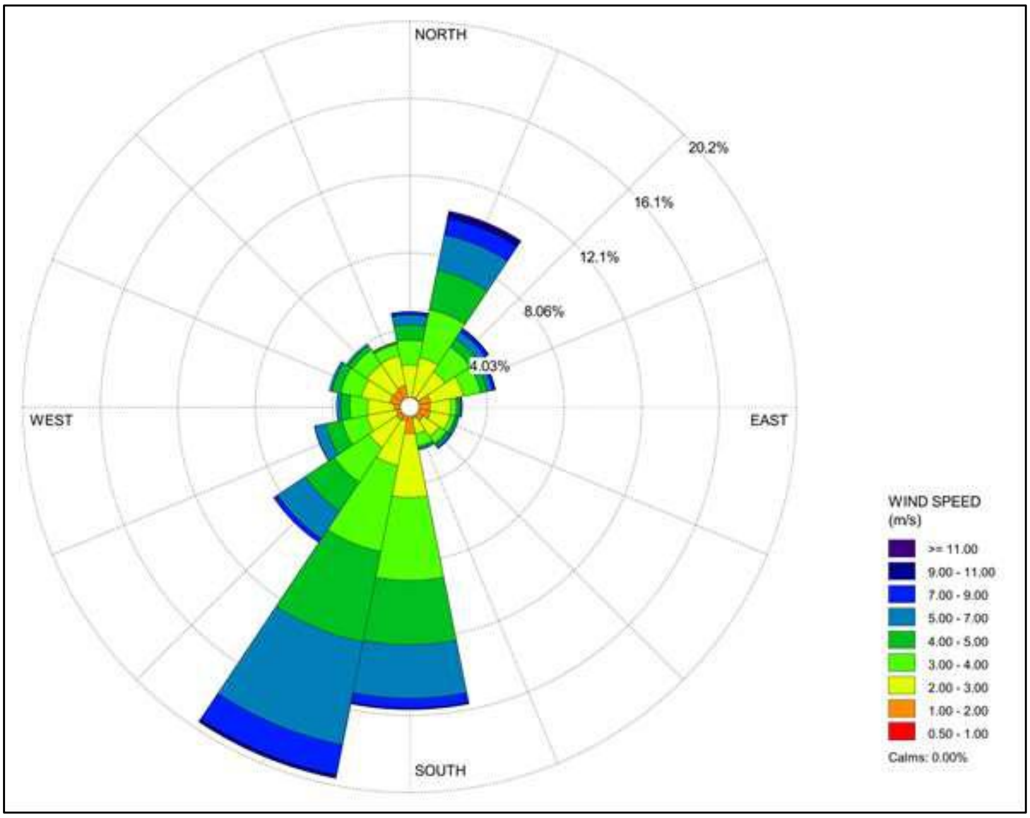


Figure 2.1: Wind rose for Mahurangi Forest Weather Station, 2014-2017 (one-hour average)

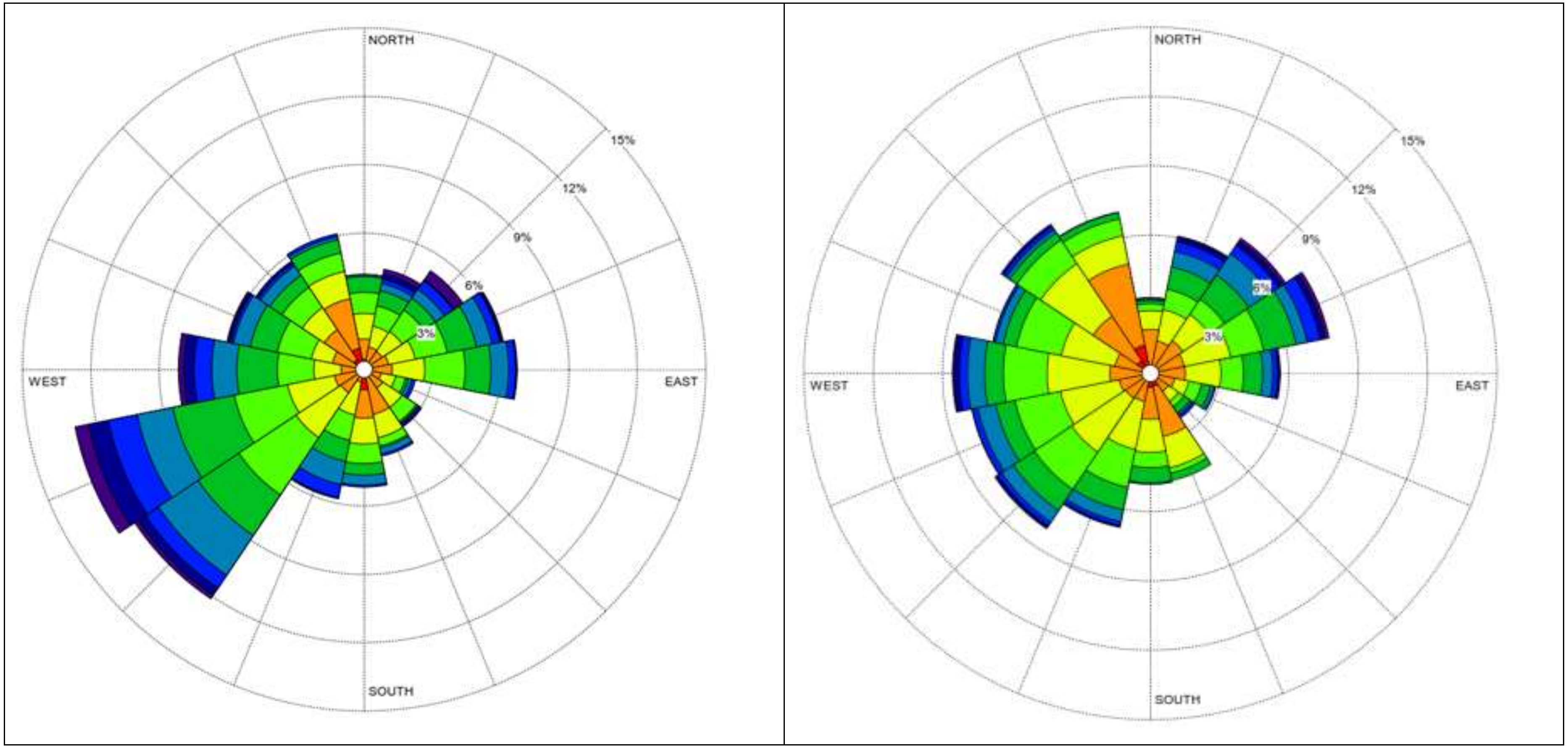


Figure 2.2: Wind roses for the site based on CALMET predictions, 2015 (left) and 2017 (right) (one-hour average)

2.3 Background air quality

The contaminants of interest for this assessment are combustion products of landfill gas (LFG), particularly:

- Particulate matter, expressed as particles less than 10 micron (PM_{10}) and particles less than 2.5 micron ($PM_{2.5}$);
- Oxides of nitrogen (NO_x), particularly nitrogen dioxide (NO_2);
- Sulphur dioxide (SO_2); and
- Carbon monoxide (CO).

Existing air quality in the vicinity of the site is expected to be very good. Potential sources of the combustion-related air pollutants in the area include:

- Motor vehicle emissions from State Highway 1 (between 1.2 and 1.5 km south of the landfill footprint) and local roads;
- Dust emissions from forestry-related activities;
- Domestic heating emissions (mainly in winter); and
- Discharges from agricultural activities, which may include burning of vegetation, aerial spraying, ground-based fertiliser application, etc.

Apart from motor vehicle emissions on State Highway 1, these contaminant sources are either intermittent (e.g. outdoor burning and forestry activities) or of a relatively small scale, such that effects will tend to be confined within about 100 m of the source.

In the absence of local air quality monitoring data, the Ministry for the Environment Good Practice Guide for Assessing Discharges to Air from Industry (Industry GPG) recommends using default background air quality values for rural areas, as follows:

- Fine particulate as PM_{10} – 28.4 $\mu g/m^3$ (24-hour average) based on the NZTA on-line tool that assigns a default background air quality value to each census area unit[1];
- Sulphur dioxide (SO_2) – zero; and
- Carbon monoxide (CO) – 5.0 mg/m^3 (one-hour average) and 2.0 mg/m^3 (8-hour average)

For other contaminants or averaging periods, such as $PM_{2.5}$ or annual average PM_{10}, background concentrations have been derived from the Auckland Council monitoring data at Patumahoe (in rural south Auckland). A summary of the most recent available 5 years' particulate air monitoring results is shown in Table 2.1.

---

[1] Air quality map | NZ Transport Agency. (2019). Retrieved from https://www.nzta.govt.nz/roads-and-rail/highways-information-portal/tools/air-quality-map/

Table 2.1: Particulate air quality monitoring data for Patumahoe

Contaminant	Parameter	Measured concentration (µg/m³)					Average
		2012	2013	2014	2015	2016	
PM_{10}	2^{nd} highest 24-hour average	25	31	31	33	29	30
	Annual average	11	13	12	11	12	12
$PM_{2.5}$	2^{nd} highest 24-hour average	14	11	10	12	9	11
	Annual average	4	5	4	4	4	4

For 24-hour average PM_{10}, there is good agreement between the average of the 2^{nd} highest concentration measured in each year at Patumahoe (30 µg/m³) and the default background value for the proposed site using the NZTA online tool (28.4 µg/m³). On this basis, we consider that the 5-year average values shown in the last column of Table 2.1 are likely to be representative of background concentrations of $PM_{2.5}$ and annual average PM_{10} at the site.

The approach used to assess effects of NOx emissions, which is described in Section 6.1.3 of this report, takes into account both the NO_2 background concentration and the amount of ozone available to convert nitric oxide (NO) to NO_2. Therefore a site-specific specific NO_2 background concentration has not been used in this study.

The representative background concentrations selected for this assessment are shown in Table 5.4 of this report (along with the dispersion modelling results and cumulative predictions of air contaminant levels).

2.4 Receiving environment and sensitive activities

The landfill is located in a rural area that is predominantly used for forestry on the surrounding hilly land, with pastoral activities on flatter land to the west. In a rural environment, residential dwellings are considered to be the most sensitive receptors for amenity effects of emissions to air such as odour and dust. This is because people tend to spend the majority of their time in the immediate environs of the house, and odours are more likely to be offensive when people are relaxing or eating compared to activities such as working on rural land. Rural land (beyond and dwellings and their immediate environs) is characterised as having a low sensitivity to amenity effects.

With regard to exposure to other air contaminants, such as combustion products from burning LFG, both acute (short term) and chronic (long term) exposures need to be considered. Ambient air quality guidelines are expressed over different averaging periods to address these different types of health effects. In a rural area, residential dwellings are sensitive to both acute and chronic effects of air contaminants as people may be present almost continuously. However, in the wider rural environment, it is unlikely that people would be present at a single location for more than a few hours at a time.

A key feature of the proposed site is the large land-holding, which means that separation distances in excess of 1 km can be maintained to houses in the wider area. The figure in Appendix A shows the locations of the closest houses in the vicinity of the site. These locations have been identified off aerial maps and where it was not clear whether a structure was a shed/outbuilding or a dwelling, it has been included – therefore not all of the identified locations will be dwellings.

The closest house to the Energy Centre and northern extent of the landfill footprint is at 302 Wilson Road, with a separation distance of approximately 1590 m. The closest houses to the southern extent of the landfill footprint are 792, 776 and 762 State Highway 1 (near the intersection with the southern end of Wilson Road) with separation distances in the range 1050 to 1160 m.

As the application is for a resource consent with a duration of 35 years, we have also evaluated the potential for foreseeable future changes to the sensitivity of the receiving environment. The land surrounding the proposed site is zoned Rural Production. In terms of residential activities, permitted activities in the Rural Production zone include:

- Two dwellings per site where the site is equal to or greater than 40ha (H19.8.2 (A73)); and
- Three dwellings per site where the site is greater than 100ha (H19.8.2 (A75)).

Our evaluation of the land parcels and existing dwellings around the site has not identified any properties where an additional dwelling could be constructed as a permitted activity within 2km of the landfill footprint. Therefore, we consider that the sensitivity of the receiving environment is unlikely to change in the foreseeable future compared to the sensitive receptors considered in this assessment.

The Sunnybrook Scenic Reserve is located south of the landfill, adjoining State Highway 1. We understand that this area does not have formed tracks and is not in regular recreational use, but is sometimes accessed by hunters.

As part of the overall proposal, there may be walking tracks formed within the wider site. One suggested route for a track is alongside the existing forestry road southwest of the landfill, before turning down to the Waiwhiu Stream. This track comes within in approximately 300 m of the landfill footprint at its closest point (see Figure 5.1). Recreational areas are typically characterised as having a high sensitivity to odour effects as people would not expect to experience landfill-type odours in a bush setting. However, the sensitivity of this area will also be influenced (reduced) by the low frequency and duration of people being present.

3 Landfill gas generation and management

3.1 LFG composition

LFG is generated by the decomposition of organic waste materials by bacteria within a landfill, and consists mainly of methane and carbon dioxide with trace amounts of odorous reduced sulphur compounds (including hydrogen sulphide) and other volatile organic compounds. The typical composition of LFG is shown in Table 3.1.

Methane is flammable in air at concentrations between 5 and 15 % by volume. Therefore, the main hazard associated with LFG that needs to be managed at the landfill itself, is its explosive/flammable properties. LFG can be distinctly odorous depending on concentration of odorous components and dilution. Odours are the main potential off-site effects of fugitive LFG emissions.

Table 3.1: Typical composition of landfill gas

Compound	Percent (dry volume basis)		
	Min.		Max.
Methane	45	-	60
Carbon dioxide	40	-	60
Nitrogen	2	-	5
Oxygen	0.1	-	1.0
Sulphides, disulphides, mercaptans, etc.	0	-	1.0
Hydrogen	0	-	0.2
Carbon monoxide	0	-	0.2
Trace constituents	0.01	-	0.6

3.2 Rate of landfill gas generation and collection

The rate at which LFG is generated at a landfill is related to waste acceptance rates, the composition of the waste (particularly the organic fraction) and factors that influence how quickly the waste decomposes.

The degradation of the waste (and consequently the rate of LFG generation) is influenced by the following factors:

- Landfill construction and site operation procedures, particularly cover practices;
- Waste type, density and age;
- Physical and chemical conditions within the landfill – particularly moisture content, temperature and pH; and
- Climate.

The combination of weather conditions and operational practices at the proposed Landfill are expected to result in "average" rates of waste degradation and LFG generation rates are expected to be typical for a covered landfill under New Zealand conditions (temperate to subtropical). Estimates of LFG generation rates over time are set out in Appendix C.

Under optimum conditions, the putrescible content of a modern landfill may be largely biodegraded within ten years or less, but paper and less biodegradable material may continue to break down for

30 years or more. This means that LFG continues to be generated for a number of years after the closure of the landfill site.

The amount of LFG collected is a function of the rate at which LFG is generated and the efficiency of the collection system. The landfill will be progressively filled as a series of cells. Over the first year after waste is placed in a new cell, LFG begins to be generated as methanogenic bacteria establish and the temperature within the waste mass increases.

LFG collection wells are installed progressively as the waste is placed. However, initially the vacuum must be kept relatively low to avoid drawing air into the landfill and collection system, and creating a potentially explosive atmosphere. The collection efficiency increases as the depth of waste and extent of cover in the cell increases.

The ultimate LFG collection efficiency, once the final cap has been placed, is estimated to be of the order of 95 %. The balance of the LFG generally permeates through the landfill cap and is bioremediated by bacteria and natural processes within the cap layer. Surface methane emission measurements at a well-run landfill facility show that there is typically no detectable methane at the surface of the final cap (in the absence of cracks or defects in the capping layer).

The assumed progressive increase in LFG collection efficiency in each new cell is shown in Table 3.2.

Table 3.2: LFG collection efficiency

Year of waste placement in stage	LFG collection efficiency in stage
Year 1	0%[1]
Year 2	50%
Year 3	60%
Year 4	75%
Year 5	80%
Post filling	90%
Post closure	95%

Notes:

1. A combination of time for methanogenic conditions to be established (typically 6 to 12 months) and for there to be sufficient waste in place for extraction to be established.

Upper bound and lower bound estimates of the rate of LFG collection are shown in Figure 3.1, based on the LFG generation rates in Appendix B and the variable collection efficiencies in each stage as the landfill is developed.

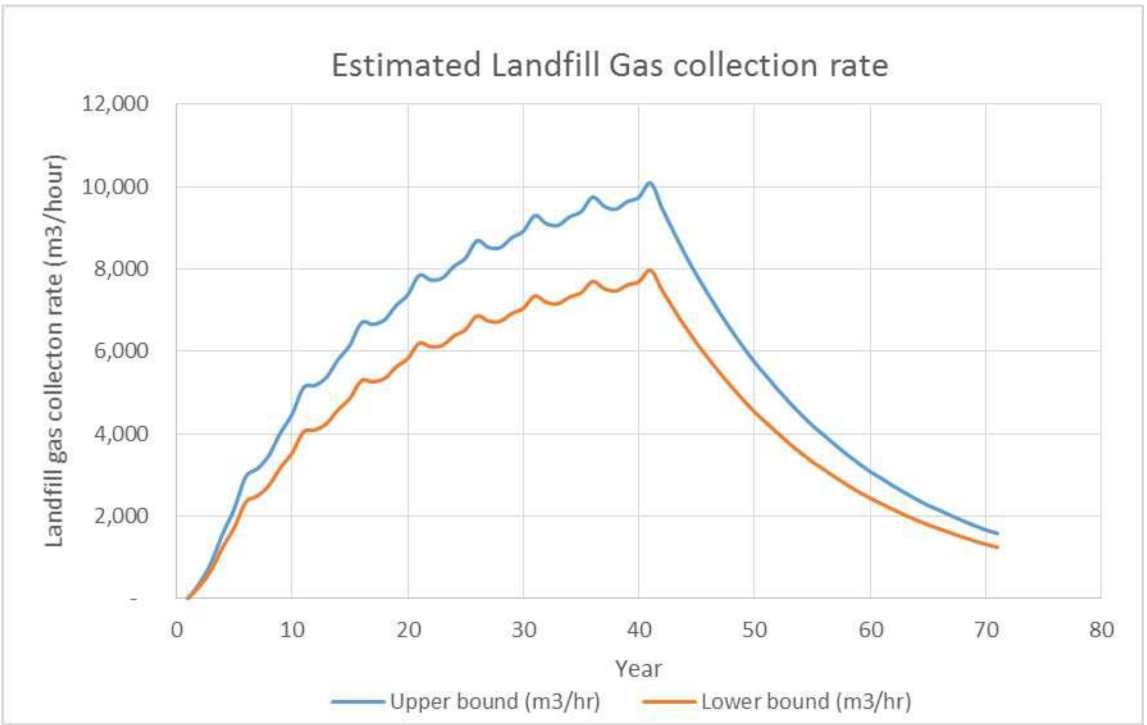


Figure 3.1: Predicted rates of LFG collection

3.3 Landfill gas management system

3.3.1 Introduction

If not managed, LFG will migrate from higher pressure zones to lower pressure zones (typically the atmosphere). LFG management systems are designed to actively extract LFG from the landfill mass, thus avoiding or minimising the migration of LFG. Creating a uniformly distributed negative pressure (slightly below atmospheric pressure) within the landfill has been shown to be the best way to minimise fugitive LFG escaping from the landfill, thereby minimising LFG hazard and odour nuisance.

A LFG management system generally incorporates the following elements:

- A system to retain LFG within the landfill site and prevent off-site migration, i.e. liner and capping systems;
- A LFG collection system comprising a network of collection wells and pipework;
- A destruction system using flaring or electricity generation (or some other means of effective combustion); and
- Monitoring to confirm the effectiveness of the system, including LFG monitoring boreholes/wells outside the waste boundary (footprint) and regular surface methane emission monitoring on capped areas.

3.3.2 Landfill liner and capping

At a landfill with a well-constructed cap and an effective LFG extraction system, the emission of fugitive LFG through the cap is usually negligible. However, LFG can escape through any cracks in the cap or areas of poor cover, and from the working face. This risk is reduced by applying careful management to cap areas and by ensuring that the cap is placed progressively as both intermediate and final cells profiles are completed. When areas of intermediate cap have been completed and are to be left for more than a few months, they are covered with topsoil and seeded with grass. The vegetation cover minimises erosion and drying out, helping to maintain slope stability and minimise the potential for scouring.

The integrity of the cap will be regularly monitored through a combination of visual inspections and surface monitoring. Weekly visual inspections will be made to identify any distressed vegetation, visible cracking or drying out of the cap and discernible LFG odours. Quarterly instantaneous surface emissions monitoring will be carried out using a hand held Flame Ionisation Detector (FID), or similar device, to detect any fugitive LFG emissions.

This system has proven to be very effective at Redvale Landfill in identifying areas of the cap that require remediation. The site records from Redvale confirm a very low level of fugitive LFG or odour emissions through cap areas.

3.3.3 LFG management during early stages of landfill development

LFG begins to be generated once anaerobic (oxygen-deprived) conditions, and associated methanogenic bacteria, have established in the waste. During the initial stages of waste placement, the waste will be under aerobic conditions. The time that it will take for anaerobic conditions to develop is dependent on a number of factors, including the nature of the waste, the rate of filling and the waste depth, but would typically be at least 6 months. Until anaerobic conditions are well-developed, methane concentrations in any collected gas would be too low to maintain a gas flare.

In order to efficiently collect LFG in vertical gas wells there needs to be sufficient waste depth between the end of the well and the liner (approximately 2 m), and sufficient waste depth above the top of the perforated section of the well (approximately 5 m) to avoid drawing air into the waste mass. In practical terms, this means that extraction cannot be applied to vertical gas wells until the waste depth is approximately 15 m. Horizontal collectors can be connected to a vertical well to collect gas in more shallow areas of waste (for example closer to the sidewalls). Given the geometry of Stage I of the proposed landfill and the anticipated filling rates, it is expected that active gas extraction and treatment in an enclosed flare will commence between and around 18 months and 2 years from initial waste placement.

Modern enclosed flares have a turn down ratio of at least 10:1 and therefore assuming a 2,000 – 2,500 m^3/hr capacity flare is installed (similar to the flares at Redvale Landfill), an enclosed ground flare can be reliably operated at minimum LFG collection rates of the order of 200 to 250 m^3/hr LFG (or 100 to 125 m^3/hour methane).

Prior to operation of the permanent LFG collection system and enclosed flare, methanogenic activity will be monitored, principally to ensure that methane levels do not pose a health and safety risk. In the event that methane is generated in sufficient quantities that it needs to be managed, sacrificial horizontal gas wells can be installed in the shallow waste mass. The collected gas can be burnt in a small ‘pencil’ flare. Although a pencil flare does not have the same destruction efficiency as an enclosed flare, the quantity of LFG being burnt will be sufficiently small that there would be no appreciable effects of combustion products.

3.3.4 Landfill gas collection system

The long term extraction and destruction of LFG will be achieved through the use of a comprehensive network of LFG extraction wells that are progressively installed into the waste as cells are filled. WMNZ proposes to use a similar well and extraction system to that used at the existing Redvale Landfill. The system incorporates features such as horizontal feeders to vertical wells (“Norfolk Pine” design), carefully graded header network and control systems that provide early warning of any damage to the extraction system.

The wells are installed from the bottom up in each cell and feature a slipform riser that enables the wells to be extracted from an early stage and progressively raised as each cell is filled.

Maximum LFG extraction is achieved by the adjustment of the vacuum at individual wells, promptly repairing any damage to the extraction system such as the extraction pipes or the seal at the well heads, and the installation of additional supplementary gas extraction wells as required.

The LFG collection system will incorporate a high degree of flexibility to allow for variations in LFG generation over the life of the landfill. This flexibility includes:

- The ability to vary the well spacing;
- The ability to install additional headers; and
- Blowers are fitted with variable speed drive to adjust the field vacuum and additional blowers can be installed as required.

3.3.5 Landfill gas flaring and utilisation

3.3.5.1 Overview

The Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins, and Other Toxics) Regulations 2004 (NESAQ) provides for LFG to be burnt in a flare (meeting a number of performance standards) or beneficially used, for example in electricity generators. There are other options available for the beneficial use of LFG that may be considered in the future, however for the purposes of assessing the potential effects of activities at the Landfill, it has been assumed that LFG will be managed by a combination of electricity generation and burning any residual LFG in a flare.

The capture and destruction of methane by flaring (or any combustion process) produces an equivalent amount of carbon dioxide compared to aerobic decomposition of the original waste material. Therefore the capture and flaring of landfill gas can be considered carbon neutral.

The nature of discharges to air from LFG-fired generators and flares are very similar and comprise the combustion products of LFG:

- Carbon dioxide (CO_2);
- Carbon monoxide (CO);
- Particulate matter, expressed as particles less than 10 micron (PM_{10}) and particles less than 2.5 micron ($PM_{2.5}$);
- Oxides of nitrogen (NO_x);
- Water vapour.

Minor amounts of volatile organic compounds and methane from incomplete combustion will also be discharged.

3.3.5.2 Renewable energy facility

LFG control facilities will be located in the area referred to as the “Renewable Energy Facility” at the western end of the ridge to the north of the site (refer Figure 3 in the AEE Report). An aerial photograph of the Renewable Energy Facility at Redvale Landfill is shown in Photograph 3.1. The key features are the row of generators and the flares, which can be seen at the right hand side of the photograph.

Photograph 3.1: Renewable Energy Facility at Redvale Landfill

This application seeks consent for the operation of up to 12 generators with the balance of LFG destroyed in one or more enclosed flares. In order to provide redundancy and so that generators can be taken off-line for servicing, there will need to be up to 14 generators installed at the site. However, only 12 generators will operate at any one time. It has been assumed that the generators installed at the site will be similar to the most recent GE-Jenbacher generators installed at the Redvale Landfill. These generators have a nominal generation capacity of 1 MW and LFG throughput of approximately 600 m^3/hour. Each generator is housed in a standard shipping container and is fully enclosed (refer Photograph 3.2). The generators exhaust via individual stacks approximately 10 m high and 0.3 m diameter.

The technology for generating electricity from LFG is continually improving. With improved efficiency in harnessing energy from LFG, future generators may have a greater capacity.

Photograph 3.2: Generators at Redvale Landfill

The balance of LFG not beneficially used in the generators will be destroyed in one or more flare(s). The enclosed ground flares will be approximately 9 m tall and will be fully compliant with the requirements of the NESAQ for a principal flare, including:

- A minimum flue gas retention time of 0.5 seconds and a minimum temperature of 750°C;
- A flame arrestor and automatic back-flow protection device or an equivalent system between the flare and the landfill to prevent flash-back and landfill fires;
- A continuous automatic ignition system;
- An automatic isolation system to ensure that there is no significant discharge of unburnt landfill gas from the flare in the event of flame loss;
- A permanent temperature indicator;
- Adequate sampling ports to enable emissions testing to be undertaken; and
- Provision for safe access to sampling ports while any emission tests are being undertaken.

A photograph of the flares at Redvale Landfill is shown in Photograph 3.3.

Photograph 3.3: Flares at Redvale Landfill

The modular nature of the LFG generators means that the volume of LFG incinerated by the flare(s) will fluctuate during each period before a new generator is added. The turndown ratio available in the enclosed flares will ensure that they can accommodate the reduced, but varying, flaring requirements as additional generators are introduced. The system will be managed to ensure that the capacity of the flare(s) and blower will not be exceeded prior to commissioning of additional LFG management capacity.

To ensure that there is always sufficient LFG destruction capacity in the system (including accounting for breakdowns, network outages and planned plant shutdowns), the quantity of LFG generated is closely monitored and assessed for future planning purposes. There will always be adequate flaring capacity to cater for any network outages when generation is not possible.

The flares and generators will be maintained in good working order to ensure adequate destruction of LFG and the odorous compounds in the LFG. Overall the LFG capture and destruction efficiency is expected to be very high.

4 Odour management

4.1 Sources of odour

Nuisance odours from landfills result from the waste itself and from fugitive emissions of LFG, which contains odorous compounds. There is potential for odour whenever waste is exposed to open air. This can occur when daily or intermediate cover is pulled back, when fresh waste is tipped or when excavating into old waste for gas extraction or leachate re-injection points. Leachate will be stored at the site in enclosed tanks and therefore leachate storage is not expected to be a source of odour.

A range of odour management measures will be implemented at the Landfill to minimise odours from waste delivery and placement, as discussed in the following sub-sections. Operational practices at the site will be based on those currently used at other WMNZ-operated landfills, such as Redvale Landfill, and are considered to represent best practice for landfills in New Zealand.

Even with best practice management measures it is not possible to completely eliminate odours at a landfill. Maintaining adequate separation distances to sensitive receptors is therefore another key mitigation measure to avoid odour adverse effects of odour emissions that can arise from time to time.

4.2 Waste acceptance controls

Before any new waste stream is accepted, particularly waste from a new client, landfill management staff will be required to assess the waste quality against the Landfill Waste Acceptance Criteria (LWAC) and evaluate the odour potential of the waste. The procedures that will be in place for managing new wastes and contracts with new clients give landfill management good control over material brought to the landfill for disposal.

Waste will be evaluated on a case by case basis and the LWAC allow WMNZ to determine whether the waste can be accepted on site, based on the ability to manage its impacts. The Landfill will not accept known malodorous waste unless specific pre-acceptance criteria and procedures have been put in place to manage potential odours from these wastes. Potentially malodorous waste, such as biosolids, egg wastes or wool scourings, must be pre-treated by the waste generator to reduce odours prior to delivery. In these examples, pre-treatment might include mixing the waste with lime.

A precautionary approach will be taken when accepting any new potentially malodorous waste streams, including trial disposal of small quantities before entering into longer term contracts.

Where waste is assessed under the LWAC as being excessively odorous, or has been identified as excessively odorous on-site, future loads will not be accepted unless the waste can be pre-treated to reduce odour to acceptable levels.

4.3 Bin exchange area

The majority of waste that is delivered to the site from WMNZ operated transfer stations, including the majority of kerbside collected wastes from the metropolitan Auckland area, will be transported to the site in specially designed bins. These bins will be off-loaded at the bin exchange area before being transferred to the working face by “mules” (small transfer trucks). Other wastes delivered to the site by third parties will be transported directly to the working face, as is current practice at most landfills in New Zealand.

Use of a bin exchange system will provide buffer capacity to manage the rate at which waste is transferred to the working face. This will allow the working face at the landfill to be kept as small as possible. As the working face is a key potential source of odours at the site, the bin exchange system will provide significant benefits to overall site odour management.

The exchange bins will be fully enclosed and will remain closed until they are emptied at the working face. Waste bins will be emptied at the working face by the end of the following landfill working day. Therefore, provided the bins are maintained in good condition and do not have any leaks, they will not be an appreciable source of odours, except in the immediate vicinity (within a few tens of metres) of the bins. This is consistent with observations at the Kate Valley Landfill in Canterbury where all waste deliveries enter the site via a bin exchange area.

Inert construction and demolition waste may be delivered to the site in open top bins and may, at times, be held at the bin exchange area prior to being deposited at the working face. These materials will not generate appreciable odours or dust, however they will be covered to prevent rain ingress.

4.4 Waste handling and tip face management

Odour from the tipping face will be minimised by restricting the size of the active face, during operations and ensuring the placement of a layer of daily cover soil takes place at the end of each day. The thickness of the daily or intermediate cover is sometimes increased in the following days if the odour risk is high.

The size of the working face is determined by operational requirements such as the number of trucks that can tip at the same time and the length of the waste “push”. The working face will typically be no more than 60 x 60 m, although at times may be up to 80 x 80 m.

Stripping back the daily cover in the morning can release odours and can frequently coincide with calm conditions where odour can be transported greater distances with minimal dilution. Odour neutralising sprayers will be started before removing cover to introduce neutraliser into the air before odour is released and odour suppressant will be used on all areas where intermediate cover is being removed.

Preparations for receiving known malodorous waste can include setting aside a reserve of general waste for mixing and burial or preparing specific disposal sites in advance. Careful coordination and timing of waste deliveries and transport is also crucial to minimise the duration of time that odorous waste is exposed to air. With advance notice, landfill staff can ensure adequate personnel and equipment are on hand to quickly bury the waste. Any excavation will be timed so that disposal sites are not prepared too far in advance, exposing potentially odorous material to air. Extra sprayers would also be used including when excavating into old waste.

To minimise odour potential from bio-solids, controls on tipping of bio-solids have been set. The controls for bio-solids tipping include allowing only one load of bio-solids to be tipped at a time and enforcing an in-house limit on the proportion of bio-solids to total waste.

The site’s procedure for managing the active working face will include practices for the management of site personnel, delivery contractors, site machinery and odour control equipment. These practices are essential for ensuring waste is buried in an effective and timely manner to control odour. All operators and leading hands on the landfill will be considered to be “Spotters” and required to take immediate action upon identifying any unacceptable (including odorous) waste brought to the Landfill.

Site personnel will be trained to quickly recognise odorous loads or activities with high potential for odour and to take immediate action. Odour awareness is a part of the staff training programme and site personnel will be empowered to take the necessary actions to minimise or mitigate odour from all aspects of activities on site.

4.5 Odour neutralising sprays

Odour neutralising sprays can be an effective odour management tool if needed, but should not be used as a substitute for measures focussed on reducing odours at source. However, there are some circumstances at the landfill where odour emissions cannot be avoided, such as the relatively brief release of odour that can occur when daily cover is pulled back in the morning under calm or light wind speed conditions. Odour sprays are particularly effective in this sort of situation.

The methods of application and use of odour neutralising sprays have become increasingly efficient, both in terms of the volume of spray used efficiency of spray systems, and selection of chemical agents. Application of odour sprays close to the odour source is more effective than attempting to manage the odour some distance from the source once it has expanded into a larger odour “plume”.

The particular conditions under which odour sprays will be used, will be set out in the Landfill Management Plan.

4.6 Leachate management

The options considered and proposed approach to leachate management are set out in Section 6.4 of the Engineering Report. Leachate will be collected, stored and transferred in enclosed systems, it is not expected to be a source of odour at the site.

It is currently anticipated that once sufficient LFG is available at the Landfill to enable its operation, a low temperature leachate evaporator will be installed on site. Evaporating the water from the leachate reduces the volume of leachate that needs to be disposed back into the landfill by up to 90%. The heat for the evaporator will be provided by burning LFG.

The low temperature leachate evaporator will be installed at the Energy Centre. For the purposes of assessing discharges to air, it has been assumed that the leachate evaporator will be similar in operation to the one installed at Redvale Landfill.

Leachate will be continuously fed into the evaporator vessel. A LFG-fired burner introduces hot gas into the leachate as fine bubbles below the surface (gas sparging) and direct heat transfer occurs between the liquid and hot gas. The leachate is maintained at a temperature of between 85 and 90°C.

The exhaust vapour from the evaporator consists of a mixture of combustion gases from the burner, water vapour and trace quantities of organic compounds that are stripped from the leachate. The low temperatures minimise stripping of contaminants from the leachate.

The exhaust vapour will be fed to the flare in an enclosed pipe, via a demister so that no droplets fall into the flare. Within the flare, organic contaminants transferred with the evaporator exhaust vapour are thermally oxidised. The residence time of the flare is increased slightly when the leachate evaporator is operating because exhaust vapour from the system replaces some of the quench air used in the flare.

Once the leachate evaporator has been installed at the site, the concentrated leachate residue and sludge, which has been reduced to approximately 10 % of its original volume is collected and stored in an enclosed tank prior to disposal in the landfill. As with the raw leachate, because this material is fully contained, it is not expected to be a source of odour.

The impact of the leachate evaporator on discharges to air is minimal due its relatively low operating temperature and because the exhaust vapours are combusted in the flare. Any volatile, or semi-volatile, organic compounds that are stripped from the leachate will be substantially destroyed by combustion in the flare. Metals (apart from possibly mercury) will not be volatilised from the leachate at the operating temperatures (maximum 90°C).

5 Environmental effects of odour emissions

5.1 Approach to assessment

The Ministry for the Environment's Good Practice Guide for Assessing and Managing Odour[2] (Odour GPG) sets out the various techniques for assessing odour effects of a new (proposed) activity, depending on the particular circumstances (Table A2.3 in Appendix 2 of the Odour GPG). Table 5.1 discusses the various odour assessment tools described in the Odour GPG for assessing effects of new activities.

Table 5.1: Consideration of MfE Odour GPG odour assessment tools for this assessment

Assessment tool	Commentary
Community consultation.	WMNZ has undertaken consultation with a range of stakeholders. A summary of the consultation including specific feedback is included in Section 12 of the AEE Report. The potential for odour effects was raised during the consultation process.
Experience and knowledge from other sites of a similar nature, scale and location, including consideration of appropriate separation distances.	WMNZ has extensive experience with the operation of landfills throughout New Zealand, including the Whitford and Redvale Landfills in Auckland. For comparison of scale, the peak rate of LFG collection at Redvale Landfill is expected to be approximately 12,000 m^3/hour, which is higher than the maximum rate of approximately 10,000 m^3/hour predicted for the Auckland Regional Landfill. While there are odour complaints received in relation to the Redvale Landfill, these complaints rarely relate to odours at distances greater than 1 km from the landfill. A more detailed discussion is included in Section 5.2.
Site management and contingency plans, and whether the best practicable option is being applied.	The proposed site management and controls for LFG and odour are set out in detail in Sections 3 and 4. These controls are consistent with those used at WMNZ's other large landfills and are considered to represent best practice for the management of landfills in New Zealand and our experience with landfills internationally, particularly in Australia. Experience at other landfills has shown that off-site odour events are generally related to specific incidents, such as a particularly malodorous load of waste or issues affecting the integrity of the cap resulting in fugitive LFG emissions. There is a variety of specific controls directed at identifying and remedying these non-routine events. The detailed controls and contingency measures will be reflected in the Landfill Gas Management Plan.
Process controls and design, including details of emission controls and engineering risk assessment for system failures.	
Analysis of site-specific meteorology and topographical features.	This is a key component of the assessment as local wind conditions will be strongly influenced by the complex terrain of the site and surrounding area. Overall, the terrain is likely to mitigate the effects of odour as there are no receptors identified as being affected by down-valley drainage flows, which are often the worst conditions for off-site odour effects.

---

[2] Ministry for the Environment. 2016. Good Practice Guide for Assessing and Managing Odour. Wellington

Assessment tool	Commentary
Dynamic dilution olfactometry (DDO) measurements and odour dispersion modelling.	Dispersion modelling has been used as a tool to evaluate the potential for odour effects under normal operating conditions (e.g. in the absence of a particularly malodorous load or failure in the cap integrity). DDO analysis has been used to measure surface odour emission rates from different areas at Redvale Landfill. These values have been used as representative of typical odour emissions from the site. A sensitivity analysis has been undertaken using higher odour emission rates measured at the Melbourne Regional Landfill. The CALMET model has been used to simulate weather conditions at the landfill site. This analysis shows an expected pattern of higher frequency of low wind speed conditions and wind direction shift consistent with terrain. The dispersion modelling of odour emissions is therefore expected to be a reasonable representation of the relative risk of odour at different locations.

5.2 Experience at other landfills

As discussed in Section 2.4 and shown in Appendix A, the separation distances between the edge of the landfill footprint and the closest residential dwellings are in excess of 1 km (the closest dwelling is approximately 1050 m from the edge of the landfill footprint). The closest dwellings to the landfill footprint are located to the south of the eastern end of the landfill footprint, comprising approximately 12 dwellings located between 1 and 1.5 km from the landfill footprint between 696 and 795 SH1 (as noted in Section 2.4, these locations have been identified off aerial maps and some of these receptors may be a shed or outbuilding rather than a dwelling). Dwellings to the west and north of the landfill are more distant, with the closest being approximately 1600 m of the landfill footprint (302 Wilson Rd).

Complaints records from the Redvale Landfill for the period 2004 to August 2018 have been reviewed to characterise the distance at which odour complaints have been received. Redvale Landfill is considered to be a reasonable basis for comparison because it is a similar scale and, because it is also operated by WMNZ, uses similar landfill operating practices and LFG management measures to those proposed.

The vast majority of odour complaints in relation to Redvale Landfill have been received from properties where the dwelling is located within approximately 1 km of the landfill footprint. The farthest distance at which odour complaints have been received is from a dwelling approximately 1500 m north northeast of the landfill. Complaints from this property tend to occur under cold, calm conditions at nighttime or early morning. Under these conditions, odours released at ground level (such as those from a landfill) will tend to remain in a confined plume (i.e. not well dispersed) and drift down-gradient with cold air drainage flows. The location of this property relative to the landfill and local terrain is consistent with these features.

In comparison, the cluster of houses south of the landfill footprint are separated from the landfill by a ridgeline (the elevations on Google Earth shows that the houses are at approximately 70 – 80 m and the ridgeline is at approximately 140 m). Under drainage flow conditions, the houses will be protected from drainage flows by the ridgeline and odours will tend to drift down valley towards the northwest and north (away from the houses).

5.3 Separation distances

Separation distance is an important aspect of the odour assessment because, in general, the potential for odour effects decreases with increasing separation distance from the Landfill. There is no New Zealand guidance on appropriate separation distances from landfills. The Victoria EPA has published a Best Practice Environmental Management document for the siting, design, operation and rehabilitation of landfills (Landfill BPEM[3]). For municipal solid waste landfills, the Landfill BEPM recommends a buffer distance of 500 m between the edge of the landfill footprint to buildings or structures to avoid LFG migration, safety and amenity impacts. This separation distance would apply to residential dwellings to avoid amenity impacts of odour.

The Auckland Unitary Plan Operative in Part (AUP) rule framework adopts the following discretionary activity standards for landfills established after 1 January 2002, under E 14.6.4.1:

(2) The landfill operation must be able to maintain a minimum separation distance of one kilometre between the landfill footprint and nearest dwelling located in the urban area and zoned for residential activities on the 21 October 2010.

(3) The landfill operation must be able to maintain a minimum notional odour boundary of one kilometre through designation or an instrument registered against the land title of any residential property within one kilometre of the landfill footprint for the active life of the landfill. Such designation or instrument must provide a restriction on the owners and occupiers of such land from complaining about any offensive or objectionable odour generated by the landfill in respect of that property.

Where a landfill cannot meet the 1 km separation distance or notional odour boundary, it is a non-complying activity. This separation distance was first introduced in the Auckland Regional Plan: Air, Land and Water and was based on the (then) Auckland Regional Council's experience that odour complaints could be received at distances of up to 1 km from landfills in the region.

Care is required when considering the appropriateness of generic separation distances for landfills because adverse effects can be influenced by scale and site-specific features such as topography and predominant wind conditions (as discussed in the previous sub-section). However, in this case, the separation distance between the footprint of the Landfill and the nearest residential dwelling is approximately 1 km.

5.4 Evaluation of odour dispersion modelling

5.4.1 Odour sources included in modelling

The Air Dispersion Modelling Technical Report is attached as Appendix B to this report. The emission sources considered for inclusion in the dispersion modelling, listed in order of reducing potential to generate odour, are:

- Active daily working face;
- Passive venting through daily and intermediate cover; and
- Passive venting through final cover.

The landfill gas generators and flares are assumed to have close to 100% odour destruction efficiency and emissions of burnt gas have not been considered further.

Based on experience at other landfills, there are not expected to be any appreciable odours through areas of intermediate or final cover. All waste is covered at the end of each working day with a

---

[3] Siting, design, operation and rehabilitation of landfills | EPA Victoria. (2019). Retrieved from https://www.epa.vic.gov.au/our-work/publications/publication/2015/august/788-3.

minimum of 150 mm daily cover. In practice, daily cover is often thicker than 150 mm due to the practicalities of track rolling material over the refuse. In spite of this, the active daily working face is expected to be the most significant routine source of odour emissions at the Landfill. As discussed in Section 4.4, the area of active working face is not expected to exceed 80 x 80 m (6,400 m^2). In order to provide a conservative assessment of potential odour effects, the modelling assessment has used an active cell area of 10,000 m^2 (i.e. 100 x 100 m).

As outlined in Appendix B, measured odour emissions from areas of cover (daily, intermediate and final) are low and similar to odour emissions measured from grassed paddock areas. However, in order to provide appropriately conservative model predictions, the maximum area that may be under daily cover has also been included in the modelling. The maximum area under daily cover has been conservatively set at 20,000 m^2.

5.4.2 Modelling approach

The dispersion modelling study (refer Appendix B) considers two scenarios identified as being potentially the worst case for odour effects, as described in Table 5.2.

Odours from upset conditions or unusual events have not been included in the modelling, as neither the odour emission rate nor the timing (and corresponding meteorological conditions) are known. The effects from these infrequent and short term event have been assessed qualitatively in Section 5.5 taking into account the LFG and odour controls described in Sections 3.3 and 4 that will minimise the risk of these events occurring.

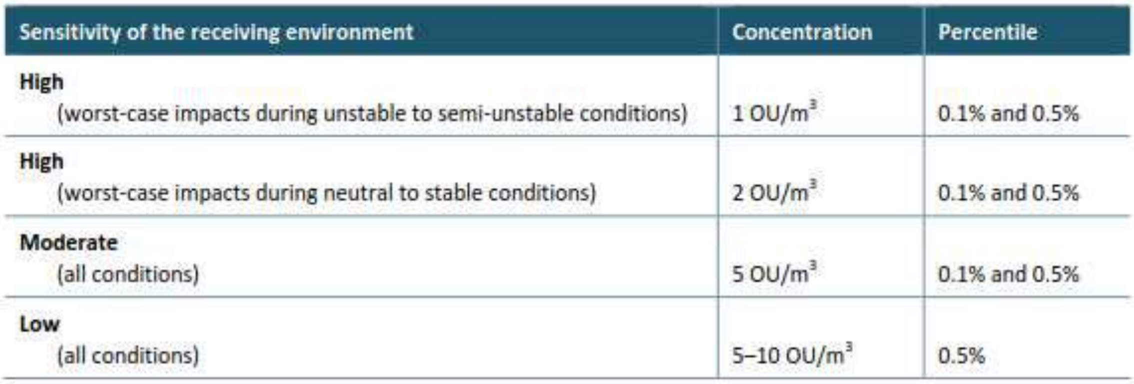
Table 5.2: Odour modelling scenarios

Scenario	Description
Scenario A	Scenario A is intended to represent filling activities at approximately Year 25 (based on an assumed filling rate of 500,000 TPA). This scenario has been chosen to represent the worst-case odour impacts at receptors to the north and west, while filling activities are on the western side of the landfill footprint. The scenario also accounts for elevated terrain (in comparison to the initial phases of filling activities), with placement of fill approximately 40 m above the base elevation of the lining system. Site elevations in this scenario have been represented by Auckland Council LIDAR data, modified for the approximate elevations of the landfill in Year 25.
Scenario B	Scenario B is intended to represent filling activities in the final year of filling, where filling is at the highest elevation and LFG collection is at its highest rate. Site elevations in this scenario have been represented by Auckland Council LIDAR data, modified for the design final cap elevations.

5.4.3 Assessment criteria

The Odour GPG recommends a set of one-hour average odour assessment criteria that can be used to evaluate the results of odour dispersion modelling. The odour assessment criteria are expressed as a combination of odour concentrations and percentile values (i.e. whether the criteria apply to the 99.9th or 99.5th percentile of the hourly model results), as shown in Table 5.3.

Table 5.3: Odour modelling assessment criteria (reproduced from Odour GPG, page 51)



Sensitivity of the receiving environment	Concentration	Percentile
High (worst-case impacts during unstable to semi-unstable conditions)	1 OU/m^3	0.1% and 0.5%
High (worst-case impacts during neutral to stable conditions)	2 OU/m^3	0.1% and 0.5%
Moderate (all conditions)	5 OU/m^3	0.1% and 0.5%
Low (all conditions)	5–10 OU/m^3	0.5%

The appropriate odour assessment criteria are selected based on the sensitivity of the receiving environment. The overall sensitivity of the receiving environment takes into account the presence (or absence of sensitive receptors) and the density of sensitive receptors (which relates to the likelihood of more sensitive individuals being present). For this reason urban areas are more sensitive to odour effects than rural areas, even though rural areas include sensitive receptors.

An odour modelling assessment criterion of 5 OU/m^3 as a 99.9th percentile has typically been adopted for odour assessments of moderately offensive odours (e.g. intensive poultry farming odours) in rural areas. We consider this would be the appropriate criterion to apply in this case.

For highly sensitive receiving environments, different assessment criteria are recommended depending on the meteorological conditions (atmospheric stability) that give rise to the highest model predictions at receptors are also important. Atmospheric stability is important because the assessment criteria are expressed as one-hour averages and, in reality, odour effects can arise from short peaks in odour concentrations within an hour. The ratio of the peak sub-hourly concentration to the hourly mean (the peak-to-mean ratio) will be higher during unstable conditions with greater vertical mixing compared to stable atmospheric conditions. Therefore a lower assessment criterion has been set for unstable conditions to account for the potential for sub-hourly peaks. The worst case meteorological conditions for the impact of the landfill odour emissions at sensitive receptors are stable conditions (Class F).

5.4.4 Odour modelling results

The odour modelling results are summarised in Table 5.4. The predicted odour concentrations are well below (less than 0.2 % of) the suggested odour assessment criterion for a rural environment of 5 OU/m^3 (one-hour average). Predicted odour concentration would be well below this criterion even if odour emissions were an order of magnitude higher than assumed in the dispersion modelling study.

For completeness, we note that the predicted odour concentrations are also well below the lowest recommended odour assessment criterion of 1 OU/m^3 (one-hour average), which would apply in densely populated urban residential areas. Based on this, it is concluded that fugitive odour emissions from the landfill working face and areas under daily cover will not result in any detectable odours at sensitive receptors under normal conditions.

This is consistent with experience at other landfills, where odour complaints are generally related to an identifiable event resulting in unexpected waste-related odours or increased fugitive LFG emissions.

Table 5.4: Odour dispersion modelling results

Scenario	Meteorological modelled year	99.9th percentile predicted odour concentration at sensitive receptor (OU/m³, one-hour average)	Receptor	
			ID	Location
Scenario A	2015	0.06	R9	76 Spindler Road
	2017	0.08	R32	302 Wilson Road
Scenario B	2015	0.06	R28	109 Waiwhiu Road
	2017	0.06	R28	109 Waiwhiu Road

In addition to residential dwellings, the potential for odour effects on users of possible recreational walkways and cycle tracks that may be created as part of the overall proposal have been considered. These may include improved access into Sunnybrook Reserve and along the Hōteo River and Waiwhiu Stream.

Figure 5.1 shows the odour dispersion modelling contours, the landfill footprint (yellow) and the possible location of recreational tracks. The highest predicted concentrations do not exceed 0.5 OU/m^3 and are less than 0.1 OU/m^3 for most of the length of the tracks, if they were to be constructed in these locations. It is therefore considered unlikely that there would be any detectable odours from the landfill at these locations under normal operating conditions.

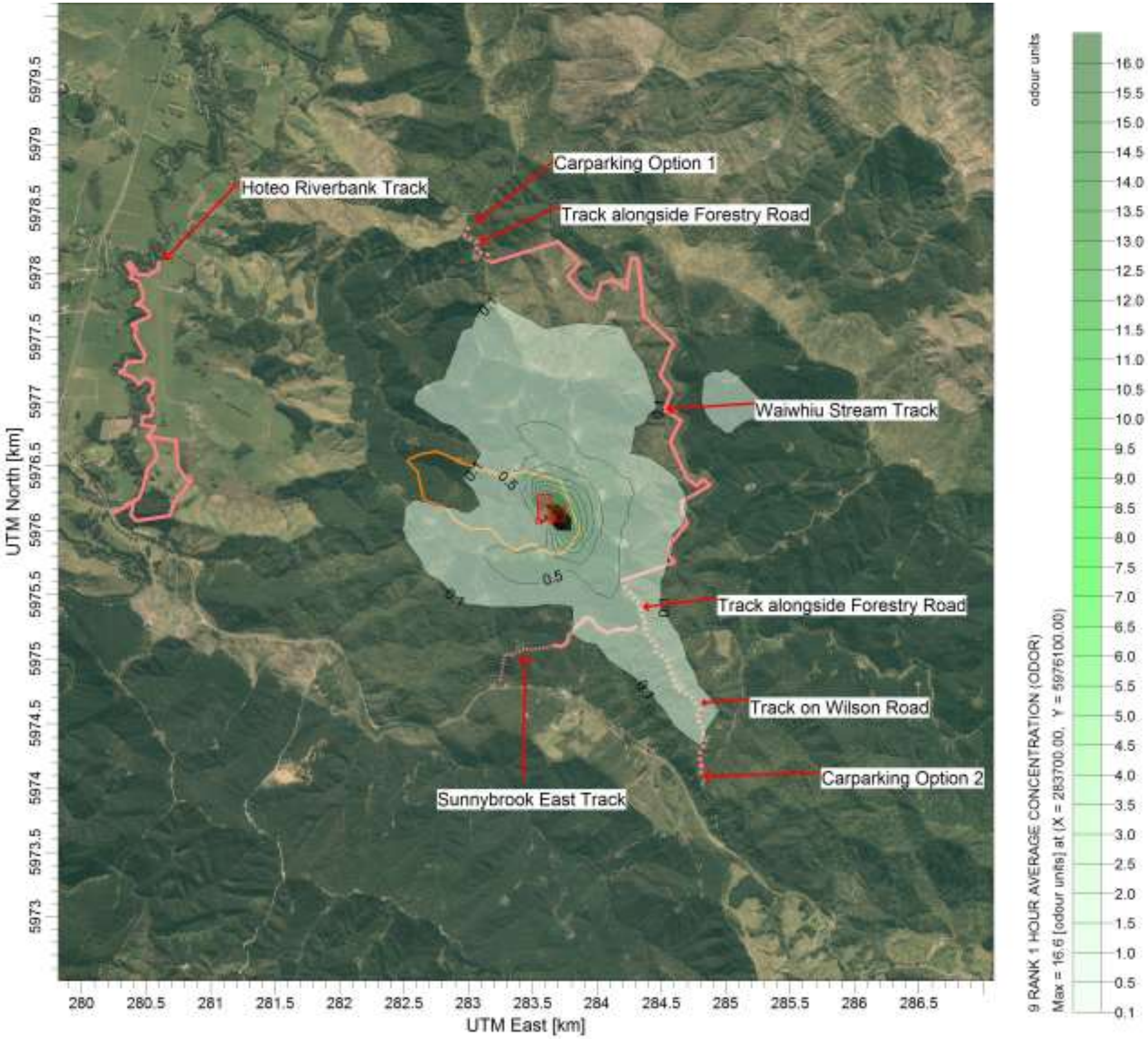


Figure 5.1: Odour concentration contours showing possible locations of walking track (99.9 %ile, 2017)

5.5 Conclusions

The potential for odour nuisance, and the potential for objectionable or offensive effects in particular may be assessed by considering what are termed the FIDOL factors (frequency, intensity, duration, offensiveness/character and location) of locations where odour may be observed.

Waste and LFG odours are intrinsically offensive in character. The sensitivity of the wider receiving environment, which comprises rural farmland and forestry is low. Residential houses within this wider environment have high sensitivity to odour effects.

The frequency, intensity and duration of exposure to odour within the receiving environment is dependent on the strength of emissions and meteorological conditions. These factors have been assessed for normal emissions from the landfill by quantifying the odour emissions and using atmospheric dispersion modelling to predict odour concentrations in the receiving environment. This odour modelling assessment shows that there is no appreciable risk of odour nuisance effects in the surrounding area as a result of normal operational odour emissions at the Landfill.

The risk of abnormal odour emission events occurring is minimised through the use of stringent controls in relation to acceptance and placement of waste as well as the integrity of the landfill cover and gas collection system and efficient operation of the flare and generators. These controls will ensure that there is a very low risk of unplanned odour events that would cause offsite effects.

On the basis that these engineering and management controls are effectively implemented, and given the separation distance available to mitigate effects in the event of unplanned emissions, off-site effects of odour are expected to be less than minor.

6 Environmental effects of LFG combustion emissions

6.1 Methodology

6.1.1 Overview

Combustion of LFG in the flares and generators at the Energy Centre will generate exhaust containing a number of contaminants. These contaminants are principally products of combustion (fine particulate, oxides of nitrogen (NOx), carbon monoxide (CO) and sulphur dioxide (SO_2)) similar to those generated by burning natural gas or other hydrocarbon fuels. These products of combustion have the potential to cause adverse health effects if people are exposed to them at sufficiently high concentrations.

Flares and generators are designed to achieve a high destruction efficiency of organic compounds, specifically methane. The methane destruction efficiency of the flare(s) is expected to be greater than 99.9%, while Jenbacher states a destruction efficiency of 98-98.5% for their generators. Typically, slightly more conservative values are adopted for destruction of non-methane and volatile organic compounds (NMOC and VOCs) in LFG flares and generators. The US EPA AP42 database[4] reports typical destruction efficiencies for NMOC and VOCs of 97.7% for flares and 97.2% for generators. These high destruction efficiencies mean that the emissions of residual unburnt or partially burnt LFG will be minimal. The effects of emissions of these contaminants is assessed separately in the health risk assessment.

Based on anticipated filling rates, the highest rate of LFG generation will occur in the year after landfill closure. The maximum rate of LFG collection and combustion is estimated to be between 7,970 and 10,089 m^3/hr. Based on these estimates, this application provides for the installation of up to 12 electricity generators (each burning 600 m^3/hr LFG). The residual LFG (between 770 and 2,900 m^3/hr, based on lower and upper bound estimates, respectively) would be burnt in the flare.

The impact of emissions of products of combustion on local air quality has been assessed using atmospheric dispersion modelling and comparison with assessment criteria. The details of the atmospheric dispersion modelling study are set out in Appendix B.

It is important to note that the assessment is based on the maximum upper-bound predicted rate of LFG generation which will occur in approximately 30 years' time. The effects over most of the consent duration will be significantly less.

6.1.2 Emission rates

Emission rates of combustion products from the flares (apart from SO_2) have been estimated using published emission factors from the US EPA AP42 database. Emissions of combustion products (apart from SO_2) from the generators have been based on stack testing of the generators at Redvale Landfill and supplier information. For SO_2 emissions, the AP42 document recommends using a mass balance approach based on the estimated sulphur content in the LFG (sulphur from hydrogen sulphide (H_2S) and reduced sulphur compounds). The sulphur content of the LFG is dominated by H_2S and therefore SO_2 emission rates have been estimated based on the average H_2S concentration in LFG at Redvale Landfill over the last approximately 10 years (since 2007).

The PM_{10} particulate matter generated by combustion of LFG will comprise mostly $PM_{2.5}$. Therefore, $PM_{2.5}$ emissions have not been modelled separately but have been assessed by comparing the PM_{10}

---

[4] AP 42, Fifth Edition Compilation of Air Pollutant Emissions Factors, Volume 1: Stationary Point and Area Sources. Draft updated Chapter 2.4 Municipal Solid Waste Landfills. October 2008.

dispersion modelling results with the $PM_{2.5}$ assessment criteria (i.e. effectively assuming all PM_{10} is present as $PM_{2.5}$).

The GE-Jenbacher LFG generators are fitted with a patented lean-mix combustion control system (LeanNOX), which is aimed at minimising NOx emissions. They are designed to meet a NOx emission limit of 500 mg/m^3. Typically, NOx emissions from combustion comprises about 5 to 10 % nitrogen dioxide (NO_2), with the balance comprising the less toxic nitric oxide (NO). The flare NOx emissions have been assumed to comprise 10 % NO_2. However, the lean emission technology used in the generators can produce a higher percentage of NO_2. Emission testing of the generators at Redvale Landfill showed that NO_2 made up between 3 and 20 % of the total NOx. The upper value of 20 % has been used in this assessment, which will give a conservatively high result.

6.1.3 Atmospheric conversion of NO to NO_2

To account for the atmospheric conversion of NO to NO_2, the proxy method, as recommended in the Industry GPG, has been used. This method assumes that the conversion of NO to NO_2 is only limited by the availability of ozone. The dispersion model results are added to a 'Proxy NO_2' concentration that represents the combined background concentration of NO_2 and ozone (as a NO_2 equivalent). The Proxy NO_2 concentrations recommended in the Industry GPG are 95 µg/m^3 (one-hour average) and 75 µg/m^3 (24-hour average).

6.2 Assessment criteria

The ambient air quality assessment criteria used to evaluate the results of dispersion modelling (shown in Table 6.1) are based on:

- Ambient air quality standards set in the NESAQ; and
- Auckland Ambient Air Quality Targets (AAAQT) set in the Auckland Unitary Plan Operative in Part (AUP).

The ambient air quality criteria apply in the open air beyond the site boundary, anywhere where people may be exposed for the relevant averaging period. In practical terms for this assessment, this means that one-hour average criteria apply anywhere beyond the site boundary but longer averaging period criteria (24-hour or annual averages) apply at residential dwellings.

6.3 Dispersion modelling results

The dispersion modelling results are summarised in Table 6.1 (page 31), including consideration of cumulative effects with background concentrations. In accordance with recommended good practice, the maximum predicted one-hour average results are the 99.9th percentile of the yearly model predictions.

In summary, the dispersion modelling results show that:

- The effects of the generator and flare emissions on off-site PM_{10} and $PM_{2.5}$ concentrations are low (at most, 18 % of the guideline value – for 24-hour average $PM_{2.5}$). Taking into account background concentrations, the cumulative effects of the discharges are all predicted to be below the relevant assessment criteria (at most 66 % of the standard/guideline value). The cumulative effects are dominated by the assumed background concentrations;
- The effects of SO_2 and CO emissions are very low and cumulative concentrations are expected to be well within the assessment criteria;
- The predicted worst case concentration of NO_2 at any receptor using the Proxy NO_2 method is 62 % of the one-hour average criterion and 89 % of the 24-hour average assessment criterion. There is no recommended method for assessing annual average NO_2 concentrations using the

Proxy NO_2 Method. However, given that the predicted maximum ground level concentration of NO_2 as an annual average is only 2 % of the guideline value we consider it very unlikely that the emissions would contribute to an exceedance of the annual average Auckland Ambient Air Quality Target.

The dispersion modelling also shows that there will be no exceedances of the ambient air quality standards set in the NESAQ, anywhere beyond the boundary. This is illustrated in Figure 6.1, which shows the cumulative NO_2 concentration contours (NO_2 emissions from the Energy Centre plus Proxy NO_2). The NESAQ ambient air quality standard is 200 µg/m^3 (one-hour average). It can be seen that concentrations predicted to exceed this value (extending out to the contours shaded in yellow), are well within the site boundary (shown in red).

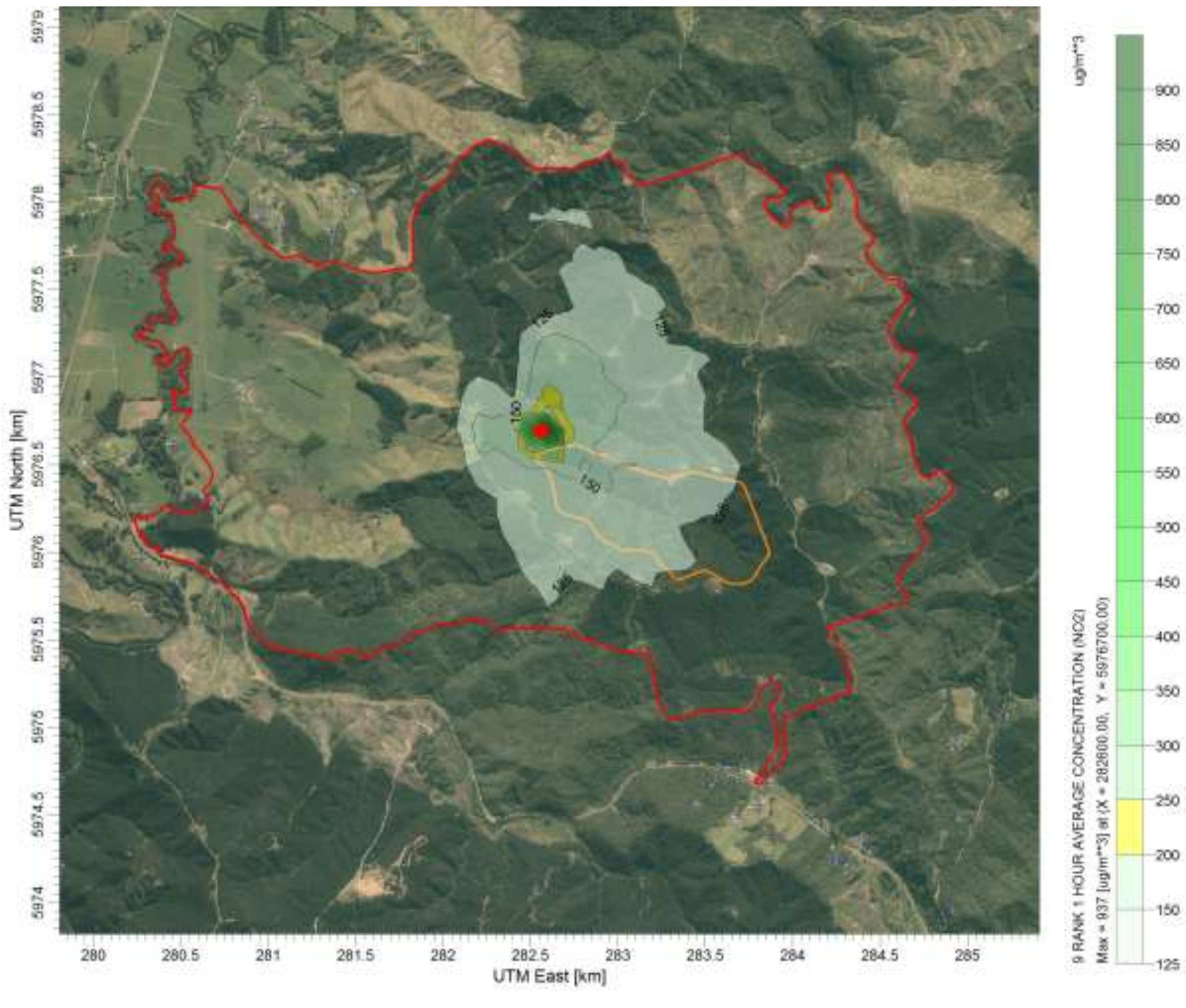


Figure 6.1: One-hour average NO_2 concentration contours (including Proxy NO_2) (99.9 %ile, 2017)

The worst case effects predicted by dispersion modelling correspond with the time of peak LFG collection and combustion. The effects over most of the consent duration will be lower than this.

6.4 Conclusions

The effects of discharges to air of combustion products from burning LFG in the flares and generators at the Energy Centre have been assessed using atmospheric dispersion modelling. Taking into account likely background concentrations, cumulative effects of these discharges from the site are expected to be well within relevant ambient air quality standards and guidelines at residential dwellings and will not cause any exceedances of NESAQ values beyond the boundary.

Table 6.1: Dispersion modelling results

Contaminant	Air quality guideline/standard			Maximum predicted ground level concentration at sensitive receptor	Background concentration	Worst case predicted cumulative concentration at sensitive receptor	Percentage of standard/guideline
	Concentration ($\mu g/m^3$)	Time average	Source	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	%
Fine particulate (PM_{10})	50	24-hour	NESAQ	4.6	28.4	33	66
	20	Annual	AAAQT	0.3	12	12.3	62
Fine particulate ($PM_{2.5}$)	25	24-hour	AAAQT	4.6 [1]	11	15.6	62
	10	Annual	AAAQT	0.3 [1]	4	4.3	4
Carbon monoxide (CO)	30,000	1-hour	AAAQT	704	5,000	5,704	19
	10,000	8-hour	NESAQ	497	2,000	2,497	25
Nitrogen dioxide (NO_2)	200	1-hour	NESAQ	29	95 [4]	124	62
	100	24-hour	AAAQT	14	75 [4]	89	89
	40	Annual	AAAQT	0.9	-	-	-
Sulphur dioxide (SO_2)	350 [2]	1-hour	NESAQ	33	0	33	9
	570 [3]						6
	120	24-hour	AAAQT	16	0	16	14

Notes:

1. Assuming all PM_{10} is present as $PM_{2.5}$
2. Nine allowable exceedences in a 12 month period
3. Never to be exceeded
4. Using NO_2 proxy method - represents combined NO_2 background and ozone available for conversion of NO to NO_2 (see Section 6.1.3)

7 Environmental effects of dust emissions

7.1 Introduction

Dust can be generated at a landfill, particularly during dry, windy conditions, either during construction earthworks, or associated with daily landfilling operations. Each of these is addressed in turn in the following sub-sections.

7.2 Construction dust

Dust will be generated from a range of construction-related activities to establish the landfill and ancillary infrastructure.

The initial establishment works will include the following earthworks activities:

- Earthworks for the construction of the landfill access road;
- The construction of the stockpiles and the clay borrow area (these will be used to place excess material from the earthworks);
- Earthworks associated with the construction of the landfill treatment ponds; and
- Earthworks associated with the bin exchange area platform.

These activities are expected to be limited to a period of three to four years.

Over this time there may also be dust generated from stockpiling of fill or aggregate, and vehicle movements on unpaved surfaces.

The dust generated by earthworks activities mainly comprises large particles that will fall to the ground within approximately 100 m of the source (depending on particle size, particle density and wind speed). Where dust is generated from activities well within the site (greater than approximately 300 m from the site boundary), dust cannot be transported beyond the site boundary and therefore adverse effects would be limited to effects on on-site vegetation or workers.

The construction of the landfill entrance, the initial stages of the landfill access road and the bin exchange area have the greatest potential for offsite dust effects due to their relative proximity to the site boundary. Dust generation will be minimised using standard dust control measures such as controlling vehicle speeds on unpaved areas, applying water to roadways, stockpiles of fine material and open excavation areas, and avoiding locating stockpiles close to the site boundary, to the extent practicable. During the period prior to construction of the stormwater pond, water for dust suppression will be sourced from the on-site bore.

The closest sensitive receptors (houses) to the bin exchange area are approximately 500 m away. With the proposed dust control measures in place, there is not expected to be any discernible dust this distance. Dust emissions from construction will not be at levels that would pose any risk to traffic, such as reduced visibility.

The site access road runs adjacent to a natural management area for part of its length. There is the potential for dust to be deposited on vegetation within this area during construction of the access road (prior to it being paved). Deposited dust (where there is high dust loading) has the potential to impact on vegetation and ecosystems, through:

- Interference with photosynthesis, potentially retarding plant growth and maturity time and the early senescence of leaves;
- Increased incidence of disease from dust accumulation in the crevices of plant surfaces, aiding moisture retention, which can provide a medium for growth of bacteria and fungi; and

- Deposited dust may also indirectly affect vegetation through impacts to beneficial insect species where dust can affect insects' ability to feed, or potentially can affect sensory organs of beneficial insects.

There are a limited number of studies correlating dust loadings with adverse effects, and none specifically relate to New Zealand native plants. However the effects identified above are associated with high dust loadings, sufficient to result in visible coating of the leaves, over a relatively long period of time. Dust loadings of this magnitude are unlikely to occur beyond approximately 10 m of the bush margin adjacent to the construction footprint. The construction of the access road will be of a relatively short duration and dust emissions will be minimised by use of the water cart. Once completed, the access road will be sealed and will not be a significant source of dust. Therefore any effects of dust emissions on vegetation will be reversible and of a short duration.

7.3 Landfilling operations

Landfilling activities with the potential to generate dust include:

- On-going development of landfill cells;
- Stockpiling and removal of soil and clay within Stockpiles 1, 2 and the clay borrow area to provide soil and clay for development of landfill cells and cover;
- Traffic movements on unpaved roads within the landfill;
- Placement of dusty loads of waste at the working face under windy conditions; and
- Placement of interim and long term cover.

A range of management measures will be used to reduce emissions of dust, including regular use of a water cart on unpaved roads during dry conditions and rapid burial of dusty wastes.

Once the initial construction phase has been completed, the site access road will be sealed up to the landfill office buildings (approximately 1200 m from the closest point of State Highway 1). There will be a wheel wash located in this general area to minimise any material being tracked from the landfill internal roads (which will not be sealed) onto the main access road.

The primary source of water for dust suppression, road washing and wheel wash will be the stormwater pond(s).

Similar to the discussion in Section 7.3, the majority of dust particles generated from earthworks activities, vehicle movements on unpaved roads and waste placement will be larger dust particles that will generally fall to the ground within approximately 100 m of the source. It is very unlikely that operational dust emissions would cause any adverse effects beyond the site boundary. As the nearest off-site dwelling (where sensitivity to dust is increased) is approximately 1 km from the landfill footprint and unpaved site roads, there is not expected to be any discernible dust at these locations.

8 Mitigation and monitoring

8.1 Summary of odour control and mitigation measures

Table 8.1 summarises the mitigation measures in place for management of odours from waste and fugitive LFG. These measures will be reflected in the Landfill Management Plan.

Table 8.1: Summary of LFG and odour mitigation measures

Source of odour	Mitigation measures
Active face/tipping of odorous loads	Restricted hours of acceptance of odorous loads Odorous waste not accepted without pre-treatment (e.g. mixing with lime) Special burial Minimise size of active face Mix with fresh waste Immediate covering Odour neutralising sprays Workface covered progressively during day (minimise open area)
Passive venting through flare during power outage	Flame out auto-dial Auto slam-shut valve upon flame out Auto flame re-ignition
Removal of daily/intermediate cover (venting and exposure of old waste)	Early start of sprayers prior to removing cover Exposed waste sprayed with odour neutralising spray Covered quickly with fresh waste
Penetration of cap and excavation in old waste	Work procedure planning in place Restricted work in unfavourable weather conditions Restricted extent of work at any given time Odour neutralising sprays Minimise work duration Immediate covering
Passive venting through daily and intermediate cover	Compact and seal cover Adequate cover thickness Tidy cover layer Horizontal gas drains Earliest practicable connection to passive flare and subsequently to blower
Passive venting through final cover	Adequate cap thickness Walk over inspections Surface emission monitoring and cap maintenance Landfill gas extraction system
Inbound odorous load (still in truck)	Loads covered Encourage timely delivery Gatehouse notified by site radio when load arrived at site Burial ASAP Excavation only on delivery Restricted hours

Source of odour	Mitigation measures
	Notice of delivery Ensure loads are adequately tipped (out of truck) Use of truck wash facilities on site before leaving Reject at gate if unacceptable
Gas flare	Monitoring and alarm/autodial system Adequate capacity Enclosed flare to improve destruction efficiency
LFG collection & extraction	Install network of extraction wells Maintenance and tuning of well vacuums to optimise extraction Control systems that provide early warning of damage to extraction system Destruction of LFG in flares and generators Minimising potential for fugitive LFG emissions through cap.

8.2 Landfill surface emission monitoring

The surface of the Landfill will be regularly monitored to ensure that any areas of fugitive LFG emissions are detected and works or repairs are conducted in a timely manner.

Walkover site inspections will be carried out at least once per week. Walkover inspections involve a visual examination of the entire landfill surface, paying particular attention to identify any:

- Distressed vegetation;
- Visible cracking or drying out of the cap; and
- Discernible LFG odours.

Inspection reports will be prepared, which record any potential odour and/or LFG issues identified.

A Flame Ionisation Detector (FID) will be used to carry out surface emission monitoring over the entire surface of the Landfill at least every three months. These surveys measure fugitive methane emissions, which are used as an indicator of potential odour sources as a result of fugitive LFG.

8.3 Landfill gas monitoring

The LFG composition (methane, carbon dioxide and oxygen in %v/v), temperature (°C) and pressure (mbar) will be monitored on at least a monthly basis at the flare station, at all extraction wellheads, monitoring probes outside the Landfill footprint and other monitoring points where appropriate in the LFG collection system (gas header pipes, leachate pipes). These parameters will be monitored using hand-held landfill gas analysis instruments. Monitoring will be carried out more frequently (typically fortnightly) when the LFG management system is being optimised.

The total LFG flow rate (m^3/hour) will be monitored and recorded continuously at the Energy Centre.

8.4 Weather station

A weather station will be maintained at the site, which records the following weather information as half-hourly averages:

- Wind speed and direction;
- Ambient temperature;
- Barometric pressure; and
- Rain.

8.5 Conditions of consent

A set of proposed conditions of consent is contained in the AEE Report. The recommended conditions relating to discharges to air reflect the engineering and management controls set out in this report and the monitoring described in the previous section.

9 Statutory considerations

9.1 Introduction

This section is not intended to present a comprehensive statutory assessment, but identifies and discusses the requirements of key regulations and planning documents relevant to discharges to air from the proposed site. A full statutory assessment of the proposal is set out in the AEE Report.

9.2 National Environmental Standards for Air Quality

The parts of the regulations of the Resource Management (Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (NESAQ) are applicable to this proposal are:

- Regulations 13 & 14 – Ambient Air Quality Standards; and
- Regulations 26 & 27 – Control of gas and flaring.

For completeness, it is noted that the site is not located in a polluted airshed under Regulation 17 and therefore there is no requirement to offset PM_{10} emissions.

Ambient Air Quality Standards

Ambient air quality standards have been established for a number of contaminants under Regulation 13 and the application of the standards is specified in Regulation 14. These standards have been adopted as assessment criteria and the assessment shows that the emissions from the combustion of FG at the site will not cause a breach of the standards.

Control of gas and flaring

Regulations 26 and 27 of the NESAQ are aimed at controlling emissions of methane (greenhouse gas) from landfills. These regulations set requirements for collection of LFG at large landfills to meet a maximum surface methane concentration of 5000 ppm. The NESAQ also requires the collected gas to be flared, used as a fuel or to generate electricity.

The flare will meet the technical specifications and conditions of operation specified in Regulation 27 (as set out in Section 3.3.5), which are also included as suggested conditions of the air discharge consent. The generators at the site will perform the function of a back-up flare, so a specific back-up flare is not required.

9.3 Auckland Unitary Plan

The discharges to air from the landfill are a non-complying activity under the AUP as the application is for a new landfill[5] (Activity A160 in Table E14.4.1 of the AUP).

Although not strictly relevant to non-complying activities, there is a useful framework provided by the assessment criteria for restricted discretionary activities for discharges to air in Section E14.8.2 of the AUP. An evaluation of the proposal against these criteria is set out in Table 9.1.

---

[5] In order to be a discretionary activity, a landfill must have been issued with resource consent or an application lodged to discharge contaminants into air prior to 1 January 2002.

Table 9.1: Evaluation against assessment criteria for restricted discretionary activities

Assessment criterion	Evaluation
The degree to which Auckland Ambient Air Quality Targets are likely to be met where people are likely to be exposed to the specified contaminants for the relevant averaging period.	The dispersion modelling assessment shows that all relevant New Zealand ambient air quality standards and the Auckland Ambient Air Quality Targets will be readily met, taking into account expected background concentrations.
Whether the amount of separation between the activity discharging contaminants into air and existing or potential activities sensitive to the air discharges is sufficient to mitigate adverse effects on the environment, health and amenity. The extent to which adverse effects are avoided, remedied or mitigated including appropriate emissions control technology and use of management practices.	The separation distance between the edge of the landfill footprint and sensitive receivers is in excess of 1 km. This is considered to be an adequate separation distance to mitigate adverse effects of landfilling activities. The proposed landfill will incorporate best industry practice controls to capture and destroy LFG. The effects of emissions of combustion products from burning LFG are assessed as low on the basis that air quality will meet the relevant ambient air quality guidelines and standards. The proposed management and engineering controls to minimise emissions of odour (from refuse and fugitive LFG) are consistent with industry best practice. With these controls in place, the assessment shows there will be no adverse amenity impacts from odour.
Where applicable, the degree to which offsetting can remedy or mitigate adverse effects considering the proximity of the offset to where the effects of the discharge occur and the effective duration of the offset.	Not applicable
Whether there are practicable location and method options that cause less adverse effects and can still achieve the applicant's objectives	An outline of the site selection process, which included consideration of other possible locations, is set out in Appendix D of the AEE Report. The suite of methods proposed to manage discharges to air are considered to be the best practicable option. There have been no other practicable methods identified that would achieve lesser adverse effects.
The extent to which the odour and dust level meet the expectations for the … Medium air quality – dust and odour area (Rural) …	The effects of emissions of odour and dust from the proposed landfill are considered to be consistent with amenity expectations of the rural zone.
Whether the assessment methods, including monitoring and modelling are appropriate to the scale of the discharge and any potential adverse effects.	The methods used to assess the effects of the proposed landfill include both quantitative (i.e. emissions characterisation and dispersion modelling) and qualitative (i.e. evaluation of the effectiveness of proposed control measures) assessment techniques. The assessment approach is consistent with Ministry of the Environment good practice guidance.

Assessment criterion	Evaluation
Whether discharge into air are minimised as far as practicable, where appropriate through: a Use of clean burning fuels; or b Efficient use of energy; or c Use of best practicable option emissions control and management practices; or d Minimisation of fugitive emissions ; or e Reduction, reuse or recycling of waste materials relating to waste processes.	Landfills do not involve processes that use significant amounts of fuel or energy, other than the use of diesel in machinery and vehicles. Diesel fuel used at the site will meet the land transport fuel specification. The emissions controls and management practices are considered to be the best practicable option and are consistent with best industry practice in New Zealand. Fugitive emissions of odour and dust will be minimised to the extent practicable. The purpose of the landfill is to provide a safe method for disposal of residual wastes that have not been reused or recycled.

10 Conclusions

The discharges to air from landfilling activities principally comprise:

- Combustion products generated by the burning of collected landfill gas in flare(s) and generators;
- Fugitive emissions of landfill gas;
- Odour from the waste itself; and
- Dust emissions from construction activities or dusty wastes.

The landfill will incorporate controls to capture and destroy landfill gas by combustion and to minimise fugitive emissions of odour and dust. In addition, the landfill will be situated within a large landholding, which means there is a large internal buffer (within the landholding) and that separation distances in excess of 1 km can be maintained between the landfill footprint and houses in the wider area. This large separation distance will further mitigate the effects of emissions to air.

The effects of emissions of combustion products from the flare(s) and generators have been assessed using dispersion modelling. The predicted off-site concentrations are well below the relevant ambient air quality standards and regional targets. On this basis, the effects of emissions to air of combustion products are assessed as less than minor

Odour emissions can occur from fugitive emissions of landfill and odorous waste. The effects of emissions of odours have been assessed using a variety of techniques, in accordance with recommended good practice, including dispersion modelling of "routine" odour emissions, consideration of the proposed odour management measures, experience at other similar sites and an overall evaluation using the FIDOL factors. The effects of emissions to air of odour are assessed as less than minor.

The primary method of controlling dust emissions during construction activities will be wet suppression. Given the separation distance, there is not expected to be any discernible dust from either construction or operational activities at dwellings in the wider area. The effects of emissions to air of dust are assessed as negligible.

Overall, subject to the implementation of the design, management and operational measures to control emissions and mitigate their impacts, the effects of discharges to air from the proposed Auckland Regional Landfill are assessed as being less than minor.

11 Applicability

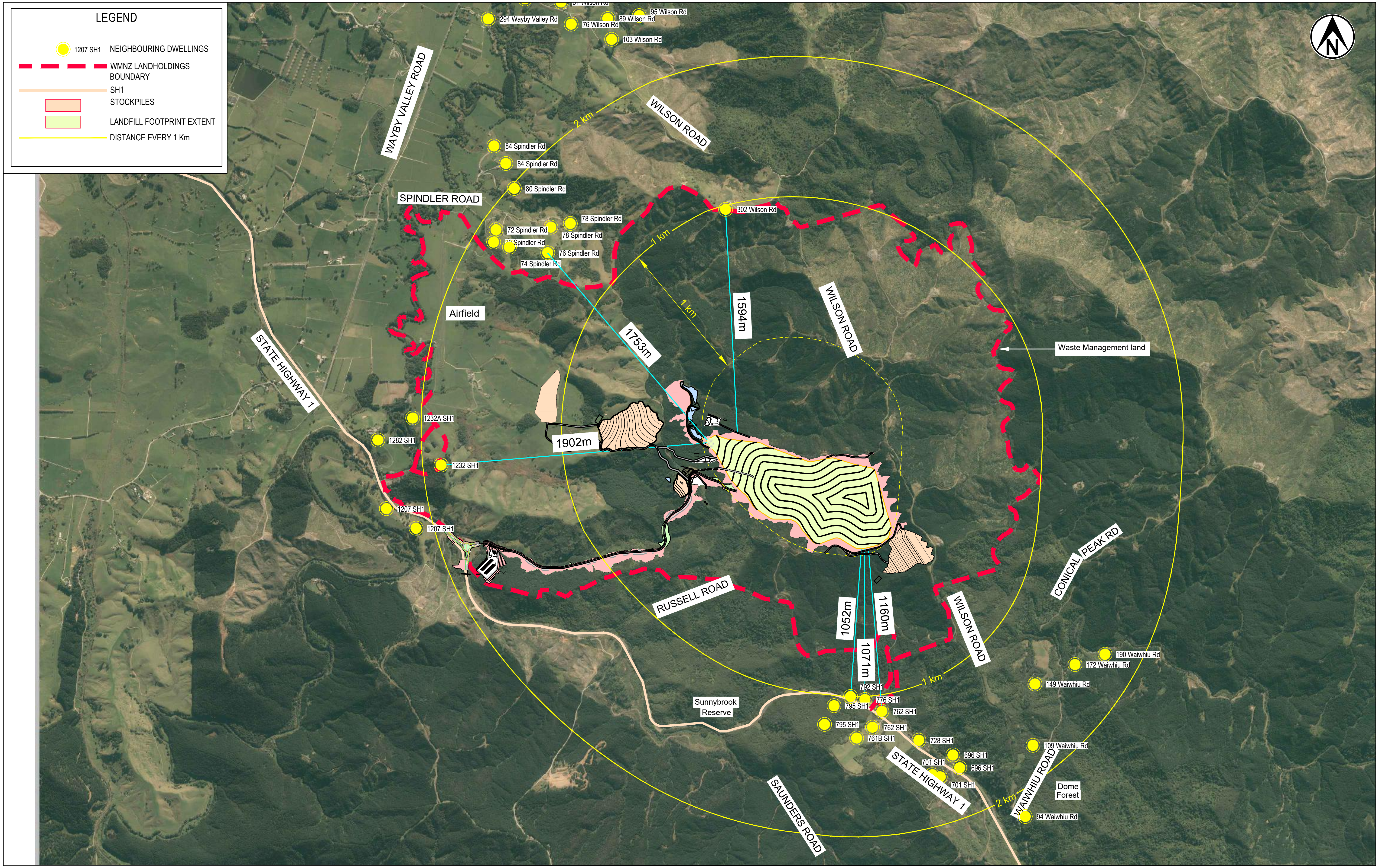
This report has been prepared for the exclusive use of our client Waste Management NZ Ltd, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
	S Eldridge
....	....
Jenny Simpson	Simonne Eldridge
Technical Director – Environmental Engineering	Project Director

JMS
p:\1005069\issued documents\final application for lodgement may 2019\volume 2 - technical reports\technical report d - air quality assessment\appendix d - air discharge report.docx

Appendix A: Landfill footprint and sensitive receptors



SCALE 1:25,000

0 500 1000 1500 (m)

Aerial photo sourced from Auckland Council GIS Website.

Tonkin+Taylor

Exceptional thinking together www.tonkintaylor.co.nz

PROJECT No.	1005069.1200	
DESIGNED	RJB	Feb.19
DRAWN	JABR	Feb.19
CHECKED	ALB	May.19
APPROVED	DATE	

CLIENT **WASTE MANAGEMENT NZ LTD**

PROJECT **AUCKLAND REGIONAL LANDFILL**

TITLE ASSESSMENT OF ENVIRONMENTAL EFFECTS
Distance to residential dwellings

SCALE (A3) 1:25,000 FIG No. Figure 7 REV 1

Appendix B: Air dispersion modelling technical report

REPORT

Tonkin+Taylor

Auckland Regional Landfill

Air Dispersion Modelling Technical Report

Prepared for
Waste Management NZ Ltd
Prepared by
Tonkin & Taylor Ltd
Date
May 2019
Job Number
1005069

Exceptional thinking together
www.tonkintaylor.co.nz

Document Control

Title: Auckland Regional Landfill					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
30/05/2019	1.0	Final	D. Vernall	J. Simpson	J. Simpson

Table of contents

Abbreviations and terms

CALMET	A diagnostic meteorological model which reconstructs the 3D wind and temperature fields starting from meteorological measurements, orography and land use data. The CALMET/CALPUFF modelling system is currently developed by Exponent Inc. USA
CALPUFF	A multi-layer non-steady-state puff dispersion model that simulates the effects of time- and space-varying meteorological conditions on pollution transport, transformation and removal.
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
EWS	Electronic Weather Station
LIDAR	Light Detection and Ranging, is a remote sensing method that uses light measure variable distances to the Earth and create digital elevation models
MM5	A regional mesoscale model used for creating weather forecasts and climate projections
NASA	National Aeronautics and Space Administration, USA
TAPM	The Air Pollution Model, developed by CSIRO Australia

1 Introduction

This report sets out the methodology, inputs and results of an air dispersion modelling study for the proposed Auckland Regional Landfill. This report forms an appendix to the Air Quality Assessment (Technical Report D, Volume 2) and should be read in conjunction with that document.

The contaminants considered in this air dispersion modelling study are:

- Odour from landfilling activities; and
- The following combustion products from the landfill gas engines and flares:
  - Fine particulate matter (PM_{10} and $PM_{2.5}$);
  - Oxides of nitrogen (NOx);
  - Carbon monoxide (CO); and
  - Sulphur dioxide (SO_2).

$PM_{2.5}$ (mass of particles less than 2.5 micron diameter) is a subset of PM_{10} (mass of particles less than 10 micron diameter). This dispersion modelling study predicts ground level concentrations of PM_{10}, which are (conservatively) assumed to also be representative of $PM_{2.5}$ concentrations.

2 Modelling methodology

2.1 Introduction

A 3-dimensional meteorological dataset for two modelling years (2015 and 2017) has been prepared using CALMET (v. 6.5) software, with upper air inputs derived from the TAPM (v. 4.0) prognostic meteorological model. The CALMET model domain consisted of a 40 km x 30 km grid extending coast-to-coast approximately from Kaiwaka to Mahurangi East with a grid resolution of 200 m. CALMET configuration details are provided in Appendix C.

Dispersion modelling of contaminant emissions has been conducted using CALPUFF (v. 7.2.1) software. Predictions have been made over an area of 6 km x 6 km grid of receptors, located at 100 m spacing. A computational grid is established over a 7 km x 7 km grid to allow for plume meander outside the gridded receptor area. CALMET configuration details are provided in Appendix D. In addition to the gridded receptors, discrete receptor points have also been placed at the nearest sensitive receptors (dwellings). The discrete receptors are tabulated in Appendix E and shown in Appendix F.

2.2 Selection of model period

In accordance with good practice, two separate calendar years (2015 and 2017) have been selected to encompass a wider array of meteorological conditions that are likely to be encountered on-site and in the surrounding area.

The selection of 2015 and 2017 was made based on a consideration of the following:

- Availability of valid meteorological data from the nearest meteorological station and other local off-site stations (data availability was best for the period 2014 to 2017, inclusive);
- Comparison of wind-roses and meteorological data for worst-case conditions for odour generation (relatively minor variability between years); and
- Consideration of phases of the El Niño Southern Oscillation. The year 2015 best represented El Niño conditions and 2017 represented La Niña conditions out of the available years.

2.3 Meteorological surface observation input data

Surface meteorological data was input from the following weather stations:

- Mahurangi Forest (approximately 3 km south of the site) – wind speed/direction, temperature, relative humidity and precipitation; and
- Leigh 2 EWS (approximately 20 km east-northeast of the site) – wind speed/direction, temperature, relative humidity, precipitation, solar radiation and atmospheric pressure.

Wind parameters are measured at a height of 10 m above ground at both locations.

2.4 Upper air meteorological input data

The TAPM model was used to simulate three dimensional wind conditions over a final 75 km x 75 km grid of up to 5 km in height over each of the selected model years. This modelling incorporated surface wind data from Mahurangi Forest and Leigh weather stations as well as synoptic meteorological data sourced from CSIRO Australia.

The outputs from TAPM modelling were converted into MM5 format outputs for use as “initial guess” wind field inputs for the CALMET modelling.

2.5 Terrain and land cover

The terrain around the site is complex, as illustrated in Figure 2.1, based on 2006 Auckland Council Rural LIDAR survey data. Terrain data used in the CALMET model consisted of NASA 30 m grid Shuttle Radar Topography Mission elevation data.

Elevations for the sensitive receptors have been derived from a 7.5 minute USGS digital elevation model (DEM) file constructed for the site incorporating the Auckland Council LIDAR data covering the computational area.

Land cover over the CALMET grid was sourced from the Global Land Cover Characterisation database and modified based on information from the New Zealand Land Cover Database (version 4.1) and aerial photographs.

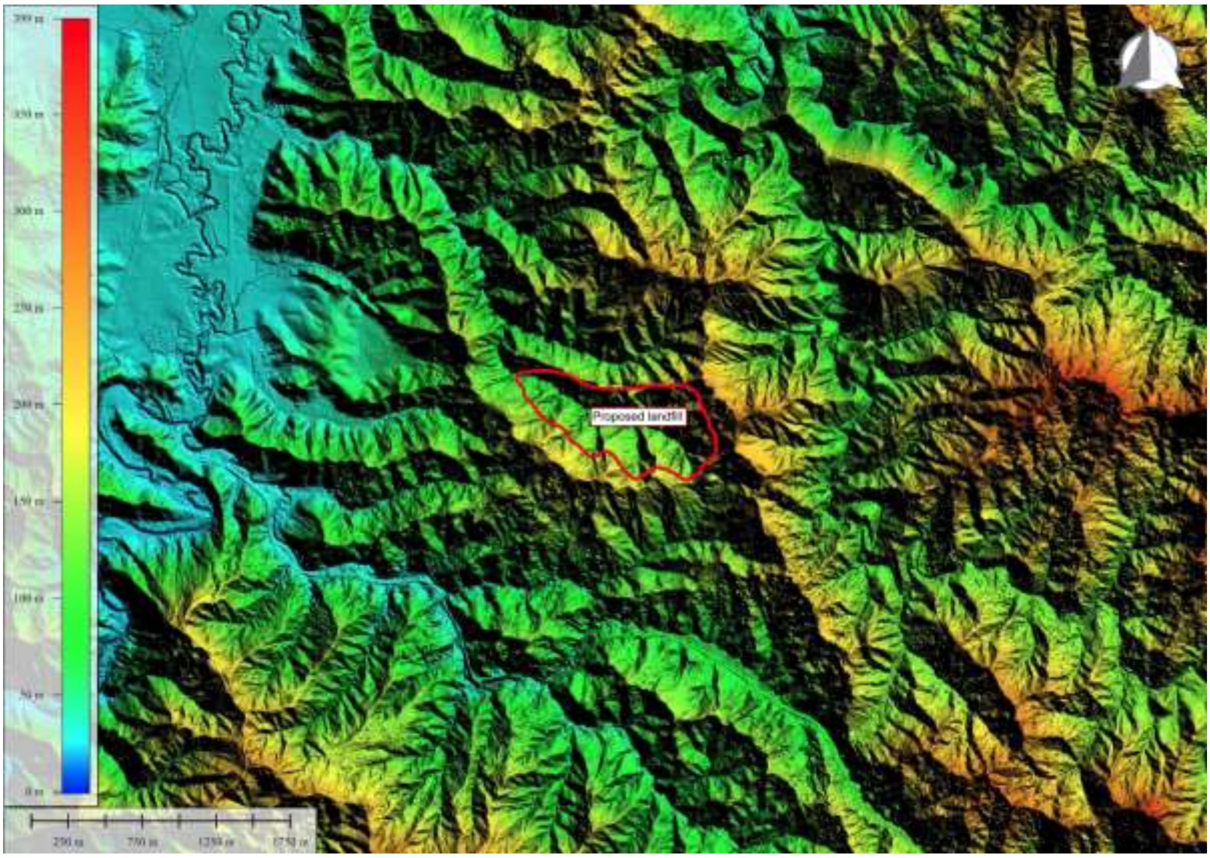


Figure 2.1: Site topography as at 2006 (elevations derived from Auckland Council LIDAR data)

2.6 Evaluation of CALMET generated meteorological dataset

CALMET wind predictions at 10 m elevation at the site have been compared with the wind roses for the nearest weather stations at Leigh and the Mahurangi Forest in Appendix B.

The data from the closest weather station to the site (Mahurangi Forest) reflects the broader wind patterns in the Auckland region with a predominance of south south-west winds, followed by winds from the north north-east. In comparison, the CALMET predicted wind fields for the site show a greater frequency of light wind speeds. The 2015 wind field predictions indicate the predominant wind directions at the site in that modelling year are from the west south-west and southwest. The 2017 wind field predictions show a more even distribution of winds across the different wind directions, which potentially overstates the frequency of winds blowing towards receptors to the southwest and south-southwest on State Highway 1 and Waiwhiu Road.

3 Odour dispersion modelling

3.1 Odour emission rates

The odour emissions from the Auckland Regional Landfill are expected to be similar to those measured at other landfills around New Zealand and Australia. In particular, odour emissions are expected to be similar to Redvale Landfill due to the types of waste acceptance and management methods.

Odour emissions from landfill activities at the Redvale Landfill were measured on 13 and 14 June 2016 and 25 July 2016 (see Table 3.1). In addition to the active cells and cover area, odour emissions were also measured on the surface of the tipping pad, which is the area that the trucks park on at the working face. Three odour samples were collected using a static flux chamber method at locations representative of each of these source types and analysed using dynamic dilution olfactometry.

Table 3.1: Summary of Redvale Landfill odour emission measurements June/July 2016

Sample	Odour emission rate (OU/m^2/s) by sample location				
	Active cell	Tipping pad	Daily cover	Intermediate cover	Final cover
Sample 1	0.37	0.055	0.027	0.017	0.017
Sample 2	0.22	0.019	0.018	0.013	0.030
Sample 3	0.495	0.021	0.020	0.017	0.021
Average*	**0.36**	**0.03**	**0.022**	**0.016**	**0.023**

*Arithmetic mean

Table 3.2 sets out odour emissions measurements from similar odour sources at a variety of Australian landfills for comparison.

Table 3.2: Odour emission measurements from Australian landfills[1]

Location	Measured odour emission rate by source (OU/m^2/s)		
	Active cell	Intermediate cover	Final cover
Melbourne Regional Landfill	3.3*	0.16	0.04**
Wyndham Refuse Disposal Facility	9 -16.7*	-	-
Nambour Landfill	2.6	0.51	-
Summerhill Waste Disposal Facility	0.35	-	-
Lucas Heights Landfill	2.05	0.08	-
Kimbriki	0.08	0.004	-
Eastern Creek	1.97	0.04	0.04
Woodlawn	0.7	-	0.3
Sita NSW Waste Treatment Facility	0.2	0.1	0.047

*Estimated using an ambient sampling transect method rather than direct flux measurement.

** Modelled final cover emissions at the Melbourne Regional Landfill were assumed to be nil with measured emissions equivalent to soil blank measurements.

---

[1] Sourced from Pacific Environment Ltd. 2016. “Melbourne Regional Landfill Air Quality Assessment”

Care is required in comparative interpretation of the odour emission data in Table 3.2 as the odour measurements have not all been made using the same methodology. However, the data generally suggests that working face emissions at Redvale Landfill are lower than measured at some landfills in Australia. Odour emission rates from areas under daily, intermediate and final cover (as well as the tipping pad) were at the same level as measurements from grass paddock areas in Australia[2].

Measured odour emissions from all areas of cover (daily, intermediate and final) at Redvale Landfill were low and similar to odour emissions measured from grassed paddock areas, i.e. background levels of odour. However, in order to obtain an appropriately conservative result from the modelling study, emissions from areas under daily cover have been included in the modelling using the following emission rates:

Active cell working face:	0.36 OU/m^2/s
Areas under daily cover:	0.022 OU/m^2/s

To evaluate the sensitivity of the modelling results to different emission rates, a further analysis has been carried out using the higher active working face emission rate, and the emission rate for areas under intermediate cover, measured at Melbourne Regional Landfill:

3.2 Modelled odour emission scenarios

Active cell working face and daily cover emission sources have been simulated as area sources (representing the surface of the source). For the purposes of this assessment, the area sources have been assumed to be flat (of a single elevation across the source).

In order to determine peak short-term odour levels, odour emissions in both scenarios have been assumed to occur constantly, though this will overstate emissions from the active cell as this area is under daily cover overnight.

Table 3.3 presents the two scenarios chosen for modelling which represent potential worst case scenarios for the effects of odour emissions.

Table 3.3: Summary of modelled odour emission scenarios

Scenario	Description
Scenario A	Scenario A is intended to represent filling activities at approximately Year 25 (based on an assumed filling rate of 500,000 TPA). This scenario has been chosen to represent the worst-case odour impacts at valley receptors to the north and west of the site, when filling activities are at the west of the landfill. The scenario also accounts for elevated terrain (in comparison to the initial phases of filling activities), with placement of fill approximately 40 m above the base elevation of the lining system. Site elevations in this scenario have been represented by Auckland Council LIDAR data, modified for the approximate elevations of the landfill in Year 25.
Scenario B	Scenario B is intended to represent filling activities in the final year of filling, where filling is at the highest elevation and LFG generation is at its highest rate. Site elevations in this scenario have been represented by Auckland Council LIDAR data, modified for the design final cap elevations.

The locations of the modelled sources in each of these scenarios illustrated in Figure 3.1.

---

[2] The odour emission rate measured from the soil blank in Melbourne Regional Landfill testing referred to in Table 3.2 was 0.04 OU/m^2/s – higher than the rates measured in all but one of the 12 samples from these sources

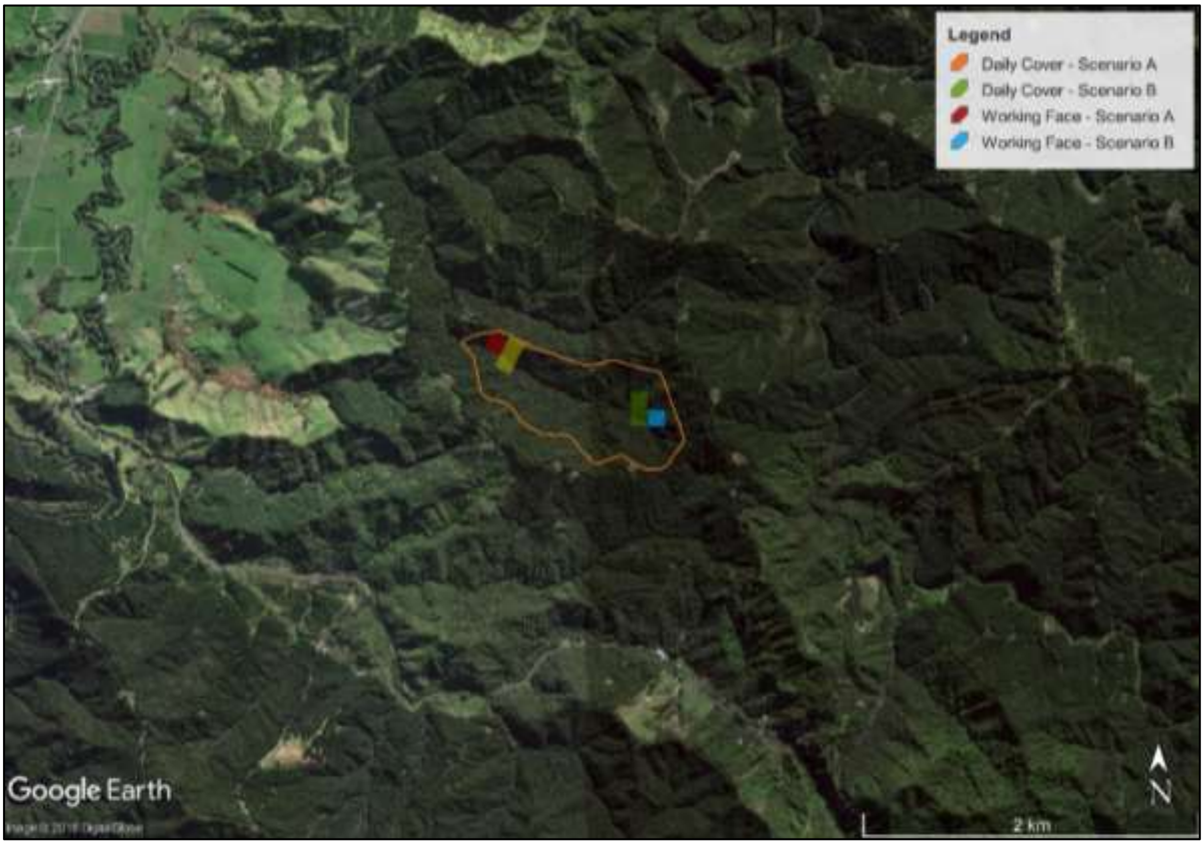


Figure 3.1: Modelled odour emission source locations

The odour dispersion model input parameters are summarised in Table 3.4.

Table 3.4: Source odour discharge parameters

Parameter	Unit	Active cell working face	Daily cover
Source area	m^2	10,000	20,000
Elevation – Scenario A	m	110 m	114 m
Elevation – Scenario B	m	190 m	188 m
Effective height	m	2	0
Initial sigma Z	m	0.5	0.5
Odour emission rate	$OU/m^2/s$*	0.36	0.022
Odour emission rate (sensitivity analysis(	$OU/m^2/s$*	3.3	0.16

*Odour units are described in CALPUFF as European odour units (OU/m^3) therefore the odour emission concentration measurements in units of $OU/m^2/s$ are described in units of OU.m/s in CALPUFF.

3.3 Results

Contour plots illustrating the spatial distribution of peak odour concentrations in these scenarios are provided in Appendix A.

Peak one-hour average odour concentrations at sensitive receptors predicted to result from emissions from current active cell working face and daily cover areas (individually and cumulatively) are detailed in Table 3.5. The peak one hour average odour concentrations from Scenario A and Scenario B are predicted to occur at 76 Spindler Road and 696 State Highway 1, respectively.

Table 3.5: Maximum predicted odour concentrations at any sensitive receptor

Scenario	Meteorological modelled year	Maximum predicted odour concentration (OU/m^3)*		
		Working face (0.36 OU/m^2/s)	Daily cover (0.022 OU/m^2/s)	Cumulative impacts
Scenario A	2015	0.056	0.0060	0.062
	2017	0.071	0.0080	0.079
Scenario B	2015	0.049	0.0061	0.055
	2017	0.051	0.0071	0.058

*99.9th percentile one-hour average

3.4 Sensitivity analysis to differing odour emission rates

A sensitivity analysis of CALPUFF odour predictions has been carried out though variation of the odour emissions from the active cell and daily cover areas to levels measured at the Melbourne Regional Landfill in 2015 (as described in Table 3.2).

The maximum ground level odour concentrations from based on this variation are presented in Table 3.6.

Table 3.6: Maximum predicted odour concentration at any sensitive receptor using emission rates measured at the Melbourne Regional Landfill

Scenario	Meteorological year	Maximum predicted odour concentration (OU/m^3)*		
		Working face (3.3 OU/m^2/s)	Daily cover (0.16 OU/m^2/s)	Cumulative impacts
Scenario A	2015	0.51	0.044	0.56
	2017	0.65	0.058	0.67
Scenario B	2015	0.45	0.044	0.49
	2017	0.48	0.051	0.52

*99.9th percentile one-hour average

4 Dispersion modelling of combustion emissions

4.1 Emission rates of combustion products

4.1.1 Generator emissions

It has been assumed that the generators will be the same as the Jenbacher GE nominal 1 MW generators installed at the Redvale Landfill. Stack testing for PM_{10}, NO_X and CO has been carried out on the generators at Redvale Landfill in December 2006, April 2013 and May 2016. Each stack testing round has measured the emissions from three different generators (i.e. over this period nine different generators have been tested). The highest measured emission rates of contaminants from each round of stack testing are shown in Table 4.1.

Given the limited amount of generators stack testing data it was considered appropriate to generally adopt slightly higher values than the stack testing for the modelling assessment. The Jenbacher GE generators are specified to achieve a NO_x emission concentration below 500 mg/m^3. For this reason a 500 mg/m^3 emission rate has been adopted. Typically, NO_x emissions from combustion comprise about 5 to 10 % nitrogen dioxide (NO_2). However, the lean emission technology used in generators can produce a higher percentage of NO_2. Emission testing of the generators at Redvale Landfill showed that NO_2 made up between 3 and 20 % of the total NO_x. The upper value of 20 % has been used in this assessment, which will give a conservatively high result.

Table 4.1: Contaminant emission rates from the generators

Contaminant	Stack concentration (mg/m^3, STP, dry basis)				Emission rate (g/s per generator)			
	Highest measured in stack testing			Adopted value	Highest measured in stack testing			Adopted value
	Dec 2006	April 2013	May 2016		Dec 2006	April 2013	May 2016	
PM_{10}	21.5	19.5	8	30	0.020	0.018	0.009	0.03
NO_x	537	438	348	500	0.51	0.36	0.35	0.50
CO	1806	1315	1392	2500	1.71	1.22	1.48	2.49

4.1.2 Flare emissions

For convenience, the flare emissions have been modelled as a single source. The emission rates of PM_{10}, NO_x and CO from the flares have been estimated using published emission factors from United States Environmental Protection Agency (USEPA) AP-42: Compilation of Air Emission Factors (Chapter 2.4, Municipal Solid Waste Landfills).

The current final version of AP-42 Chapter 2.4 was published in November 1998. A draft version of Chapter 2.4 of AP-42 was released in October 2008. Emission factors from the more recent draft have been used in dispersion modelling. The emission factors for all three species have been assigned with an 'A' rating ("Excellent") indicating a high level of reliability.

The AP-42 emission factors are expressed as the mass emission of contaminant per m^3 methane in the unburnt LFG, as shown in below. For information purposes, the emission factors have also been expressed in terms of mg/m^3, assuming a CH_4 content of 50%. The total mass emission rate of each contaminant from the flares is obtained by multiplying the emission factor by the flow rate of methane (in LFG) being burnt). The emissions of NO_x from the flare have been assumed to comprise 10 % NO_2.

Table 4.2: Contaminant emission factors for the flares

Species	Emission factor expressed as mg emitted per m^3 CH_4 in LFG burnt	Emission factor expressed as mg emitted per m^3 LFG burnt
PM_{10}	238	119
NO_x	631	316
CO	737	368.5

4.1.3 Sulphur dioxide emissions from flares and generators

SO_2 emission rates have been estimated on a mass balance basis, assuming that all sulphur in the LFG is converted to SO_2. The main source of sulphur in LFG is hydrogen sulphide (H_2S). The mass contribution of sulphur from other reduced sulphur species, such as mercaptans, is negligible compared to H_2S.

The equation for 100% stoichiometric conversion of H_2S to SO_2 during combustion is:

$$2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O$$

It has been assumed that H2S concentrations in LFG at the Auckland Regional Landfill will be similar to the existing Redvale Landfill. WMNZ have measured concentrations of H_2S at the inlet gas to the LFG engines at the Redvale Landfill between 1999 and 2015, as presented in Figure 4.1.

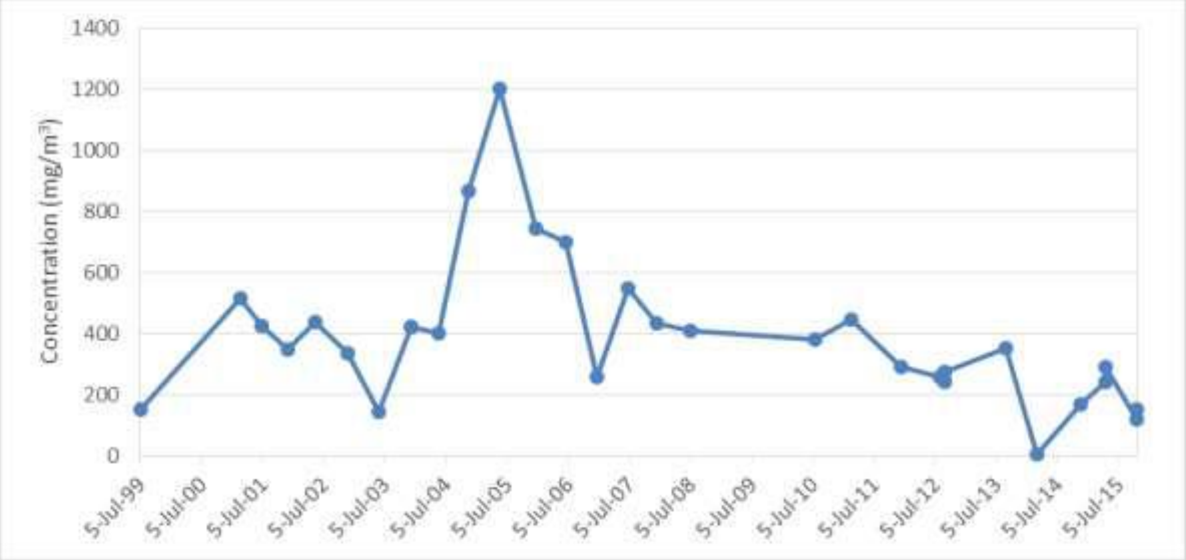


Figure 4.1: Hydrogen sulphide concentrations measured from the inlet gas at Redvale Landfill

With the exception of measurements between November 2004 and June 2006, H_2S concentrations have been relatively stable. The relatively high H_2S concentrations measured between November 2004 and June 2006 are considered likely to be due to the acceptance of large quantities of certain waste into the Redvale landfill (e.g. gypsum board in construction and demolition waste). These high concentrations are not considered to be representative of typical, or long term, emissions.

The average concentration of H_2S in LFG over the period 2007 to 2015 was 307 mg/m^3 (excluding the low measurement in March 2014). This is equivalent to 577 mg of SO_2 being generated for each cubic metre of LFG combusted. Each generator will burn approximately 600 m^3/hour of LFG which equates to an emission rate of 0.10 g/s SO_2 per generator.

4.2 Modelled combustion emission scenarios

LFG generation modelling has been undertaken for the proposed landfilling to estimate the potential volume of LFG likely to be generated (described in Appendix B of the Air Quality Assessment (Technical Report D, Volume 2)). This modelling has been used to inform the projected requirements for LFG generators and residual LFG flaring.

The highest rate of LFG generation (and collection) typically occurs in the year after landfill closure. The maximum rate of LFG collection for the proposed landfill is estimated to be between 7,970 and 10,089 m^3/hr. Dispersion modelling has been undertaken based on the upper-bound predicted rate of LFG collection.

The application provides for the installation of up to 12 electricity generators (each burning 600 m^3/hr LFG). The residual LFG (up to 2,900 m^3/hr, based on the upper-bound estimate) would be burnt in the flare.

The terrain data used for the combustion emission modelling is the same as odour emissions Scenario B described in Table 3.3 (refer Section 3.2). Emission source details for the modelled combustion scenario are presented in Table 4.3. Emission rates for pollutants for the flare and generators are described in Section 4.1.

Table 4.3: Modelled combustion discharge parameters

Parameter	Unit	Flare	Generators (G1 – G12)
Stack height	m	9.16	10
Stack diameter	m	2	0.3
Exit velocity	m/s	5.22	42.0
Exit temperature	°C	750	450

The generator and flares will be located at the Energy Centre, in the location shown in Figure 4.2.

Figure 4.2: Energy centre location

4.3 Results

Maximum ground level concentrations of contaminants at sensitive receptors are presented in the tables below. Contour plots illustrating the spatial distribution of contaminant concentrations in these scenarios are provided in Appendix A.

The highest concentrations of contaminants at any sensitive receptor (dwelling) are predicted to occur at the nearest dwelling to the proposed energy centre north of the site at 302 Wilson Road.

Table 4.4: Predicted maximum ground level concentrations for PM_{10}

Meteorological year	Averaging period	
	24-hour average (µg/m^3)	Annual average (µg/m^3)
2015	2.6	0.3
2017	4.6	0.3
Maximum ground level concentration	4.6	0.3

Note: also assumed to be representative of $PM_{2.5}$ concentrations

Table 4.5: Predicted maximum ground level concentrations for NO_2

Meteorological year	Averaging period		
	One-hour average (µg/m^3)	24-hour average (µg/m^3)	Annual average (µg/m^3)
2015	26	8.0	0.7
2017	29	14	0.9
Maximum ground level concentration	29	14	0.9

Table 4.6: Predicted maximum ground level concentrations for SO_2

Meteorological year	Averaging period	
	One-hour average (µg/m^3)-	24-hour average (µg/m^3)
2015	30	9.3
2017	33	16
Maximum ground level concentration	33	16

Table 4.7: Predicted maximum ground level concentrations for CO

Meteorological year	Averaging period	
	One-hour average (µg/m^3)	Eight-hour average (µg/m^3)
2015	650	364
2017	704	497
Maximum ground level concentration	704	497

5 Applicability

This report has been prepared for the exclusive use of our client Waste Management NZ Ltd, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

Report prepared by:

....

Dylan Vernall

Environmental Scientist

Authorised for Tonkin & Taylor Ltd by:

S Eldridge

....

Simonne Eldridge

Project Director

Report reviewed by:

....

Jenny Simpson

Technical Director – Environmental Engineering

DV
p:\1005069\issued documents\final application for lodgement may 2019\volume 2 - technical reports\technical report d - air quality assessment\appendices\appendix b - dispersion modelling report final 220519.docx

Appendix A: Concentration contour plots

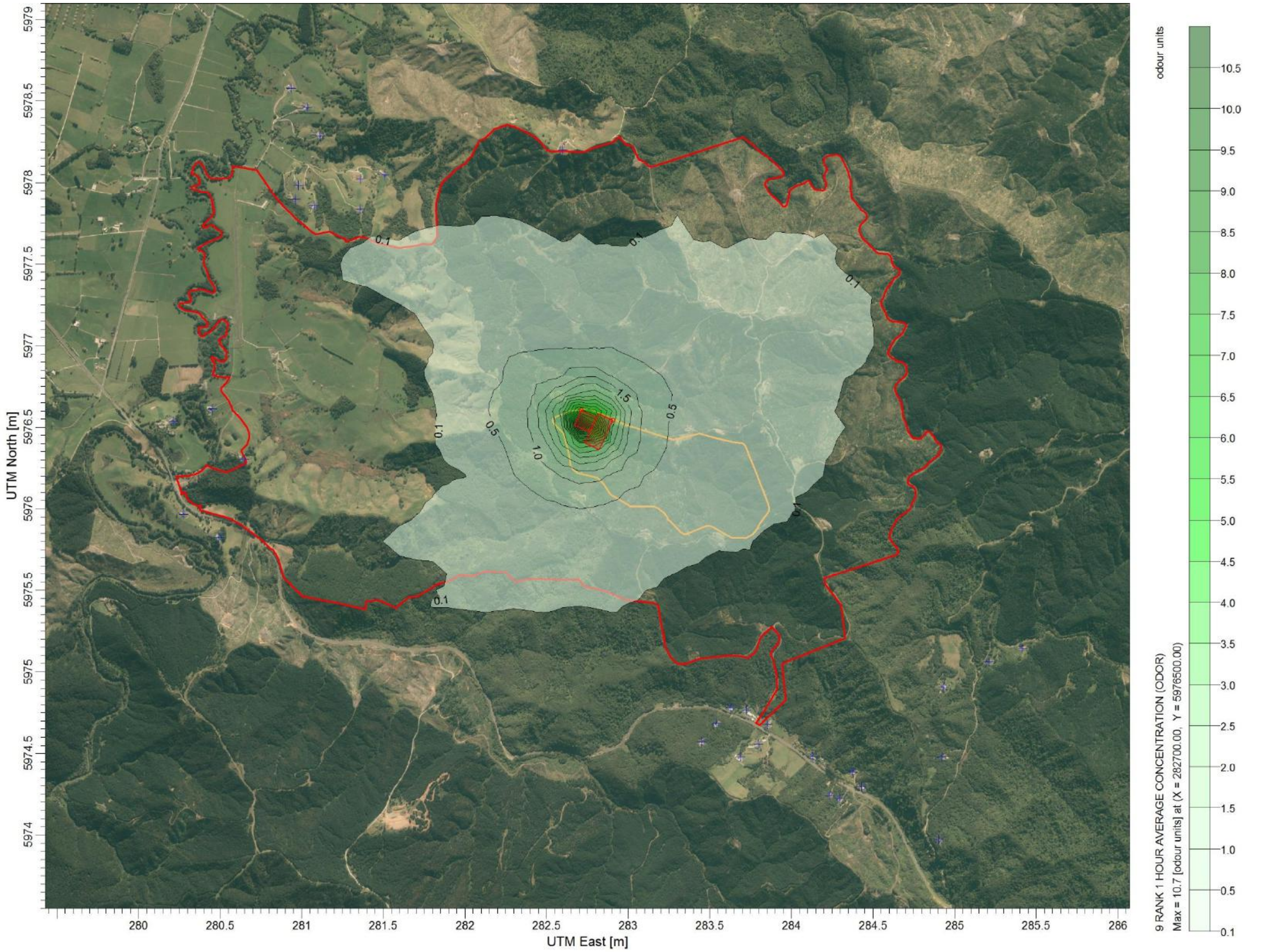


Figure Appendix.A.1: Odour, Scenario A, 2015 model year, odour modelled at emission rates measured at Redvale Landfill. 99.9th percentile 1-hour average odour concentration. WMNZ's landholding boundary is outlined in red. The extent of the proposed landfill is outlined in orange.

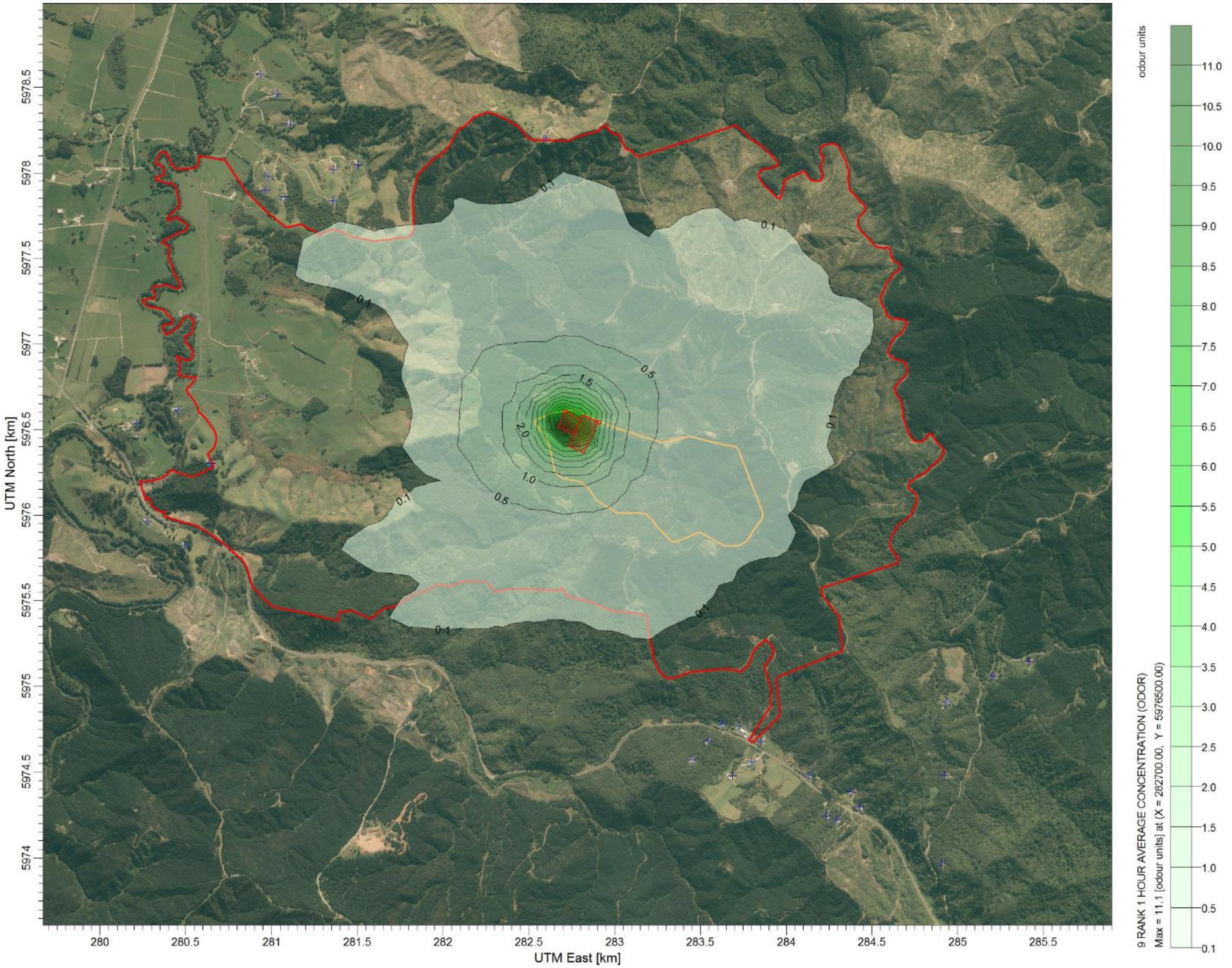


Figure Appendix.A.2: Odour, Scenario A, 2017 model year, modelled at emission rates measured at Redvale Landfill. 99.9th percentile 1-hour average odour concentration. WMNZ's landholding boundary is outlined in red. The extent of the proposed landfill is outlined in orange.

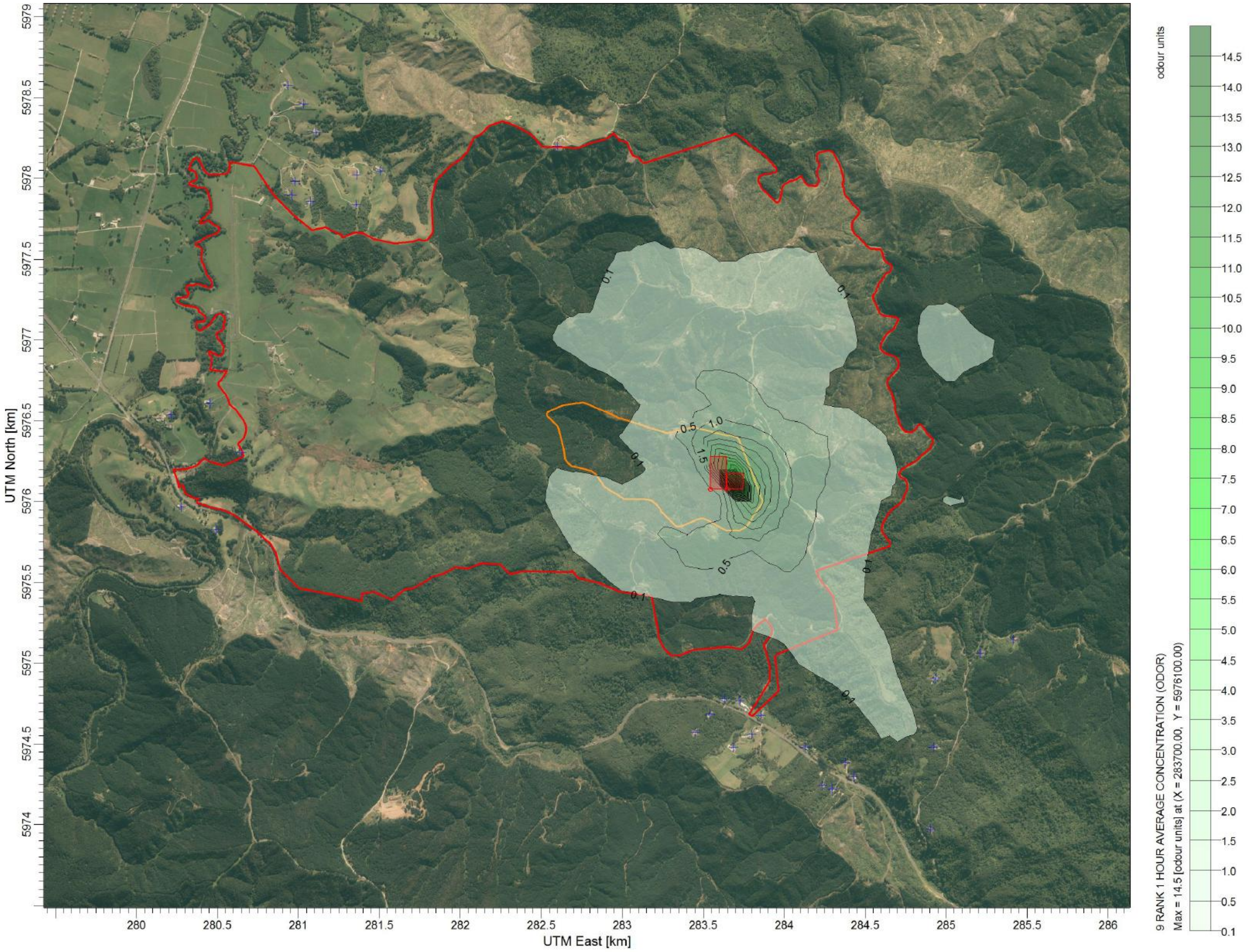


Figure Appendix.A.3: Odour, Scenario B, 2015 model year, modelled at emission rates measured at Redvale Landfill. 99.9th percentile 1-hour average odour concentration. WMNZ's landholding boundary is outlined in red. The extent of the proposed landfill is outlined in orange.

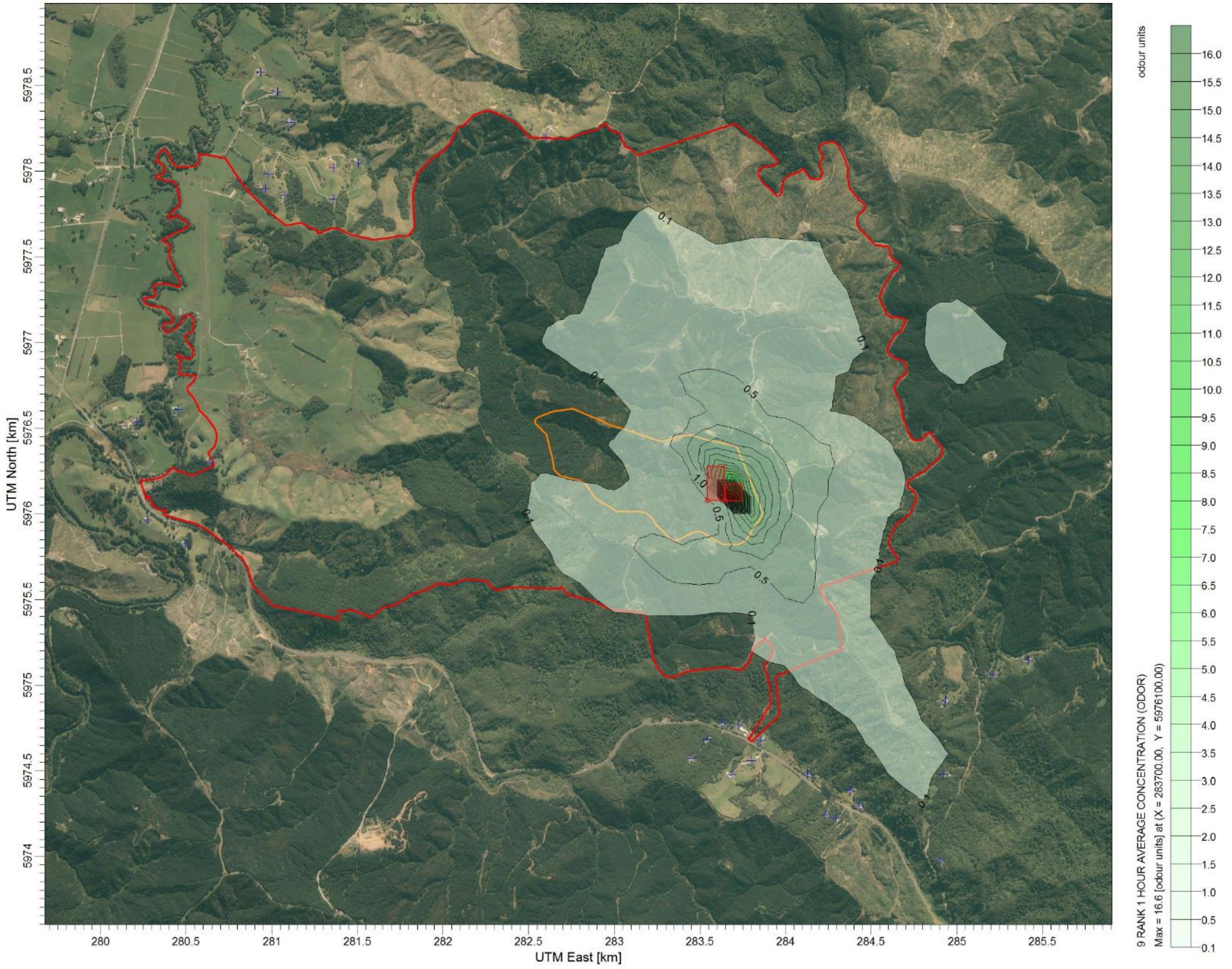


Figure Appendix.A.4: Odour, Scenario B, 2017 model year, modelled at emission rates measured at Redvale Landfill. 99.9th percentile 1-hour average odour concentration. WMNZ's landholding boundary is outlined in red. The extent of the proposed landfill is outlined in orange.

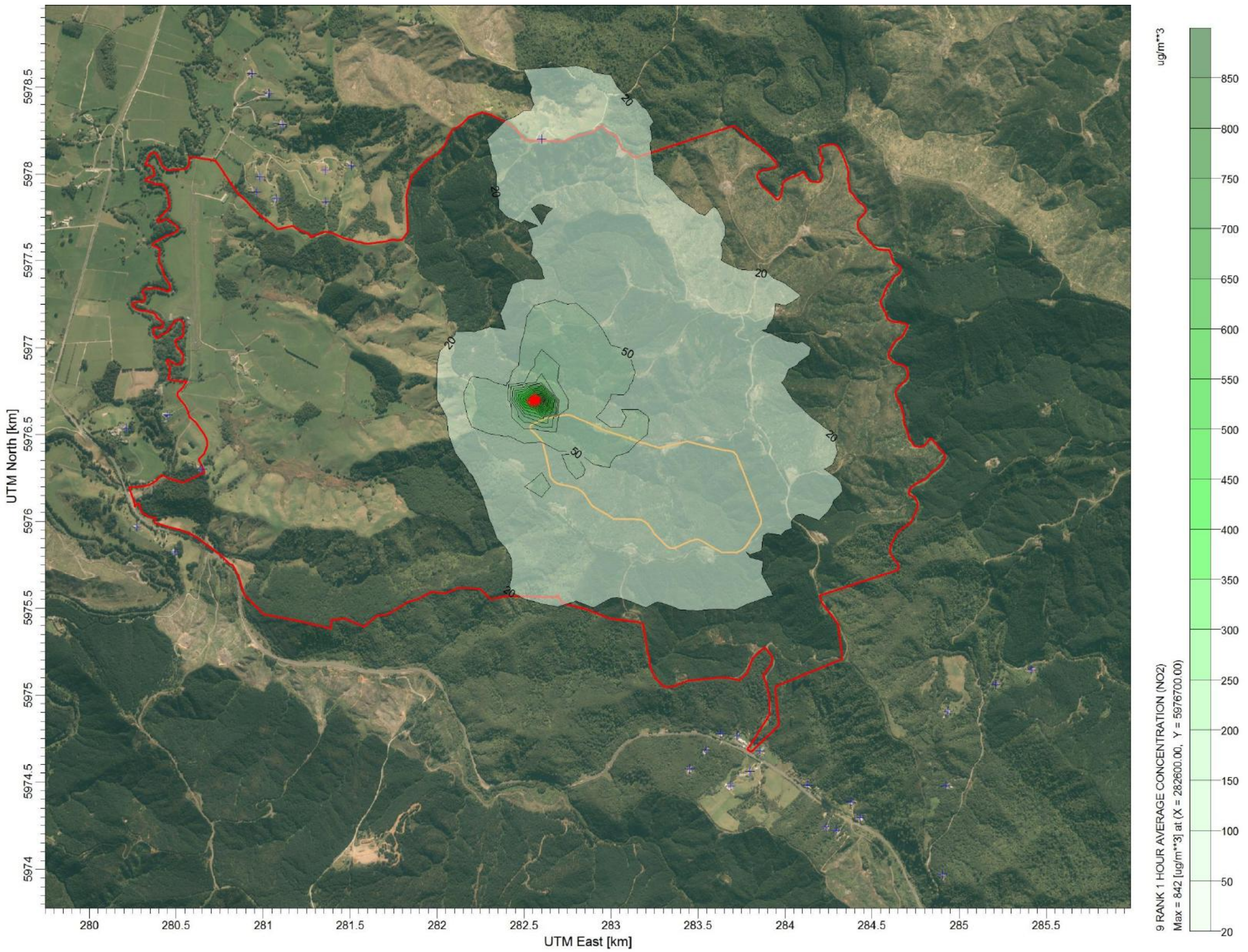


Figure Appendix.A.5: NO$_2$, 2015 model year. 99.9th percentile 1-hour average concentration, no background. WMNZ's landholding boundary is outlined in red. The extent of the proposed landfill is outlined in orange.

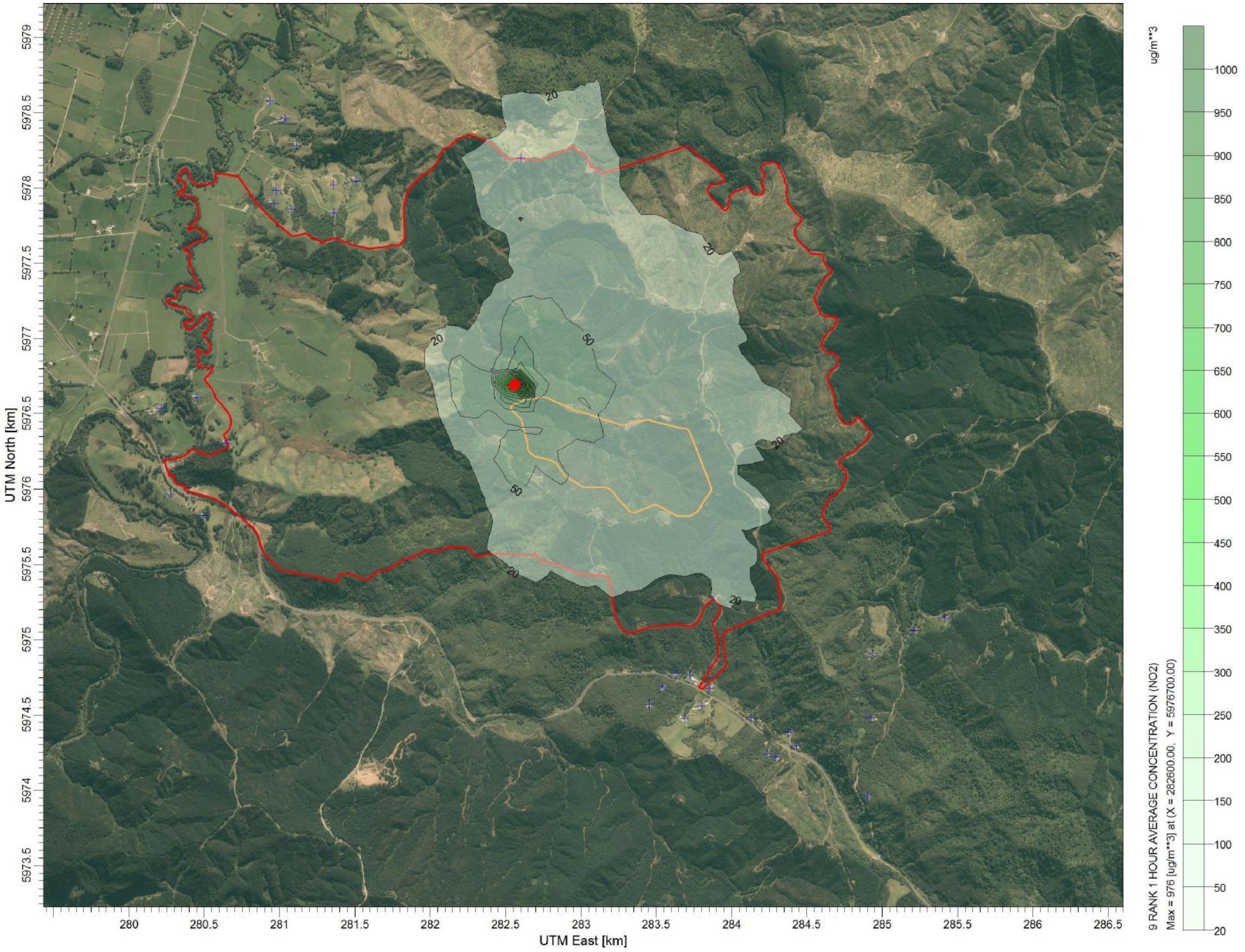


Figure Appendix.A.6: NO$_2$, 2017 model year. 99.9th percentile 1-hour average concentration, no background. WMNZ's landholding boundary is outlined in red. The extent of the proposed landfill is outlined in orange.

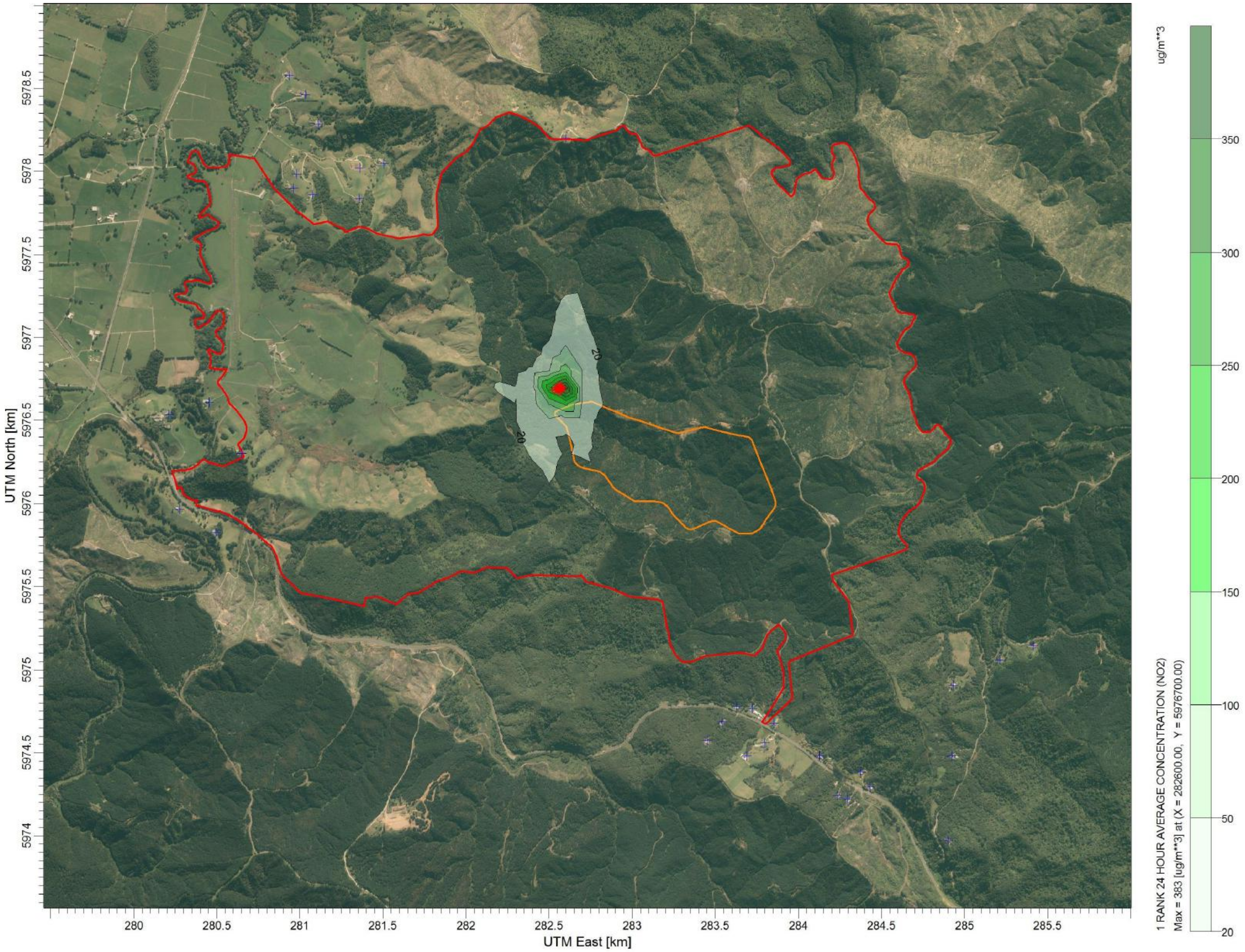


Figure Appendix.A.7: NO_2, 2015 model year. 24-hour average concentration, no background. WMNZ's landholding boundary is outlined in red. The extent of the proposed landfill is outlined in orange.

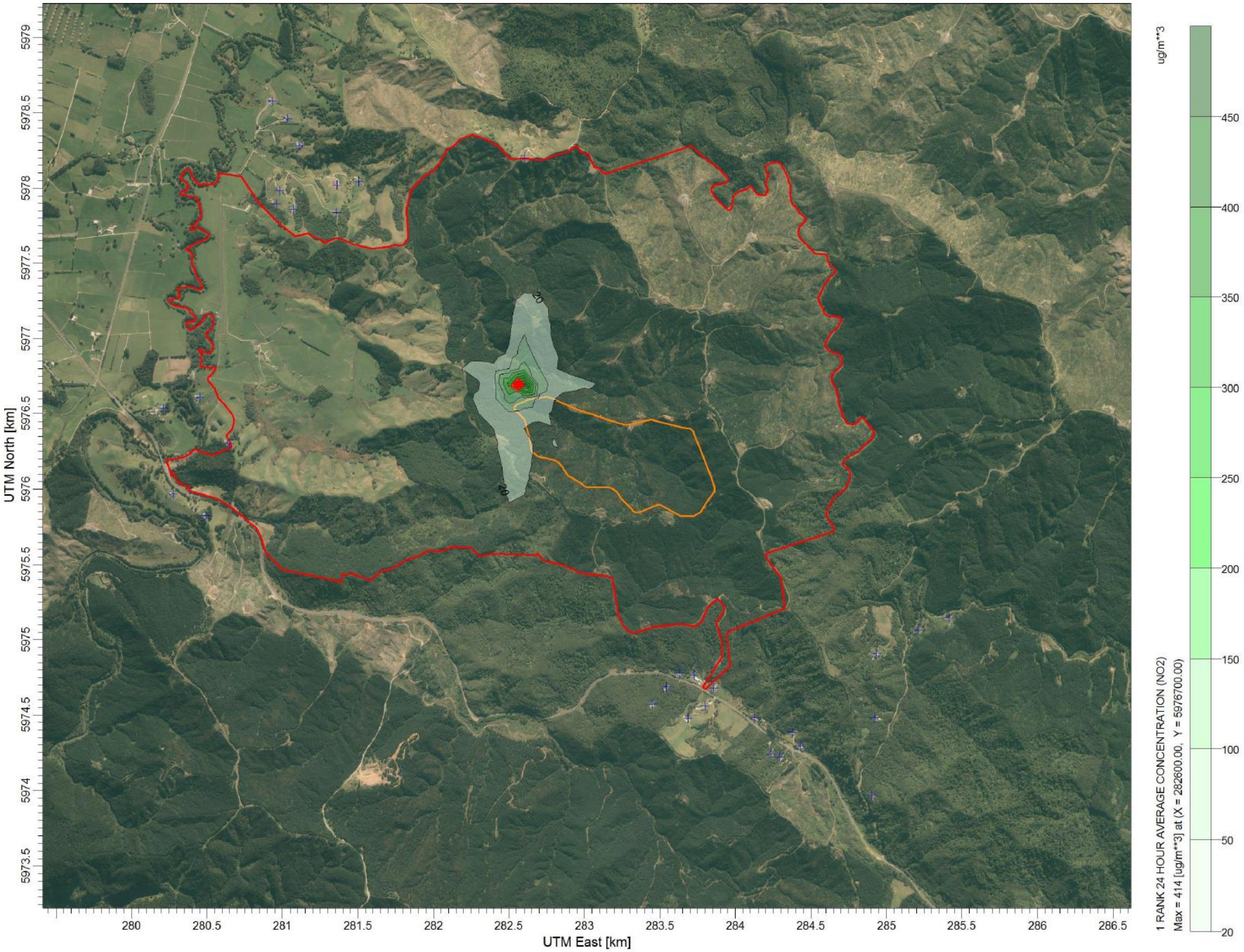


Figure Appendix.A.8: NO_2, 2017 model year. 24-hour average concentration, no background. WMNZ's landholding boundary is outlined in red. The extent of the proposed landfill is outlined in orange.

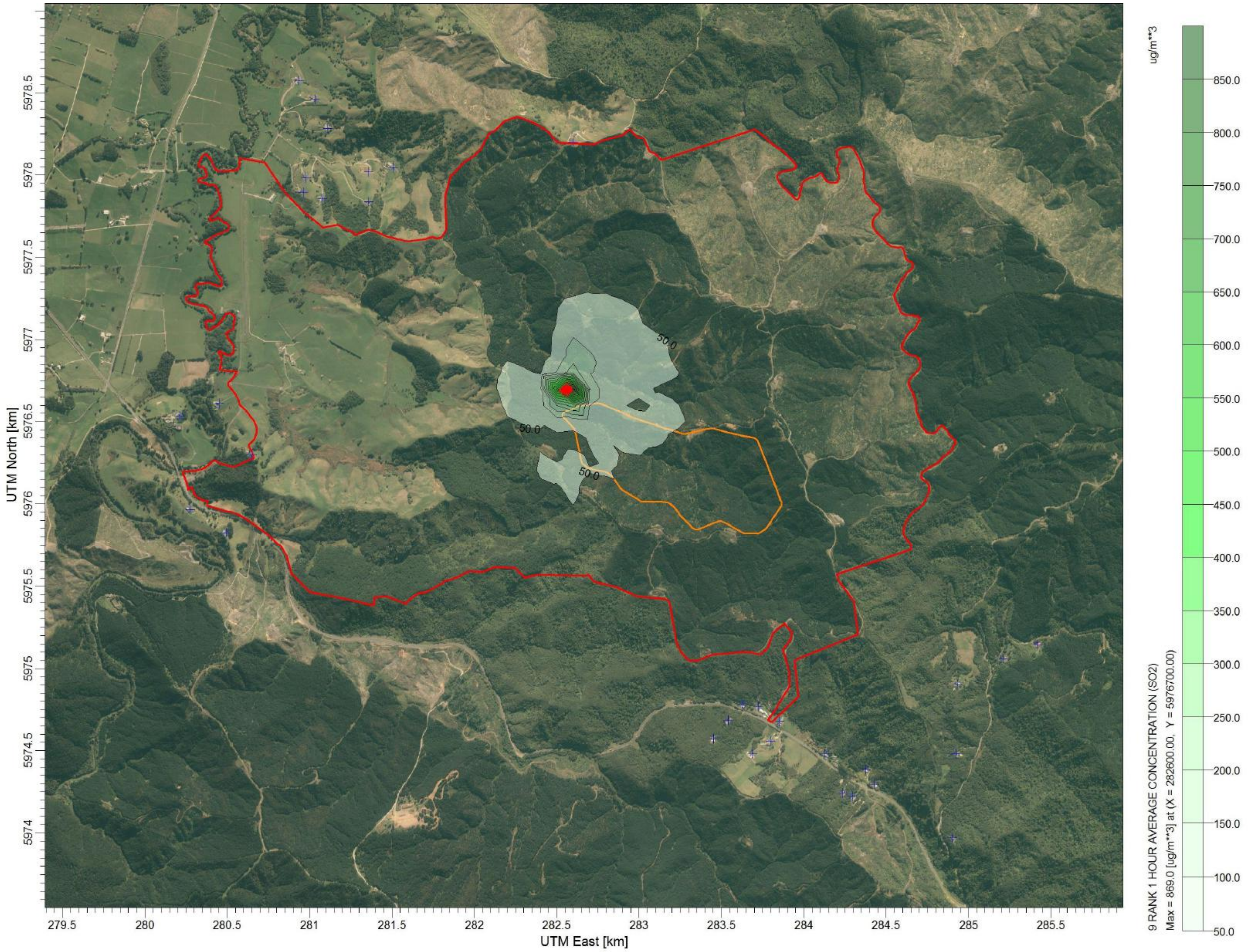


Figure Appendix.A.9: SO_2, 2015 model year. 99.9th percentile 1-hour average concentration. WMNZ's landholding boundary is outlined in red. The extent of the proposed landfill is outlined in orange.

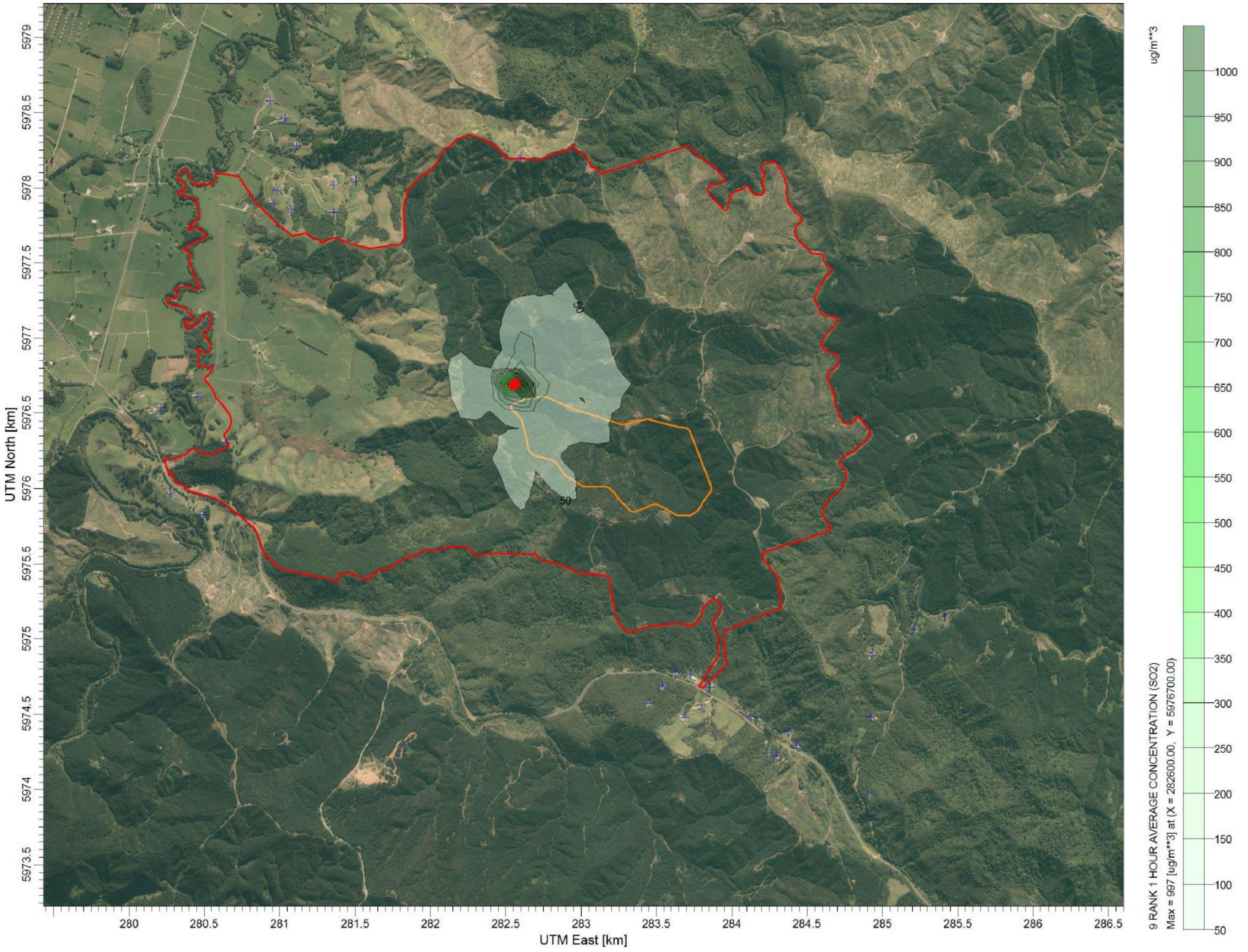


Figure Appendix.A.10: SO_2, 2017 model year. 99.9th percentile 1-hour average concentration. WMNZ's landholding boundary is outlined in red. The extent of the proposed landfill is outlined in orange.

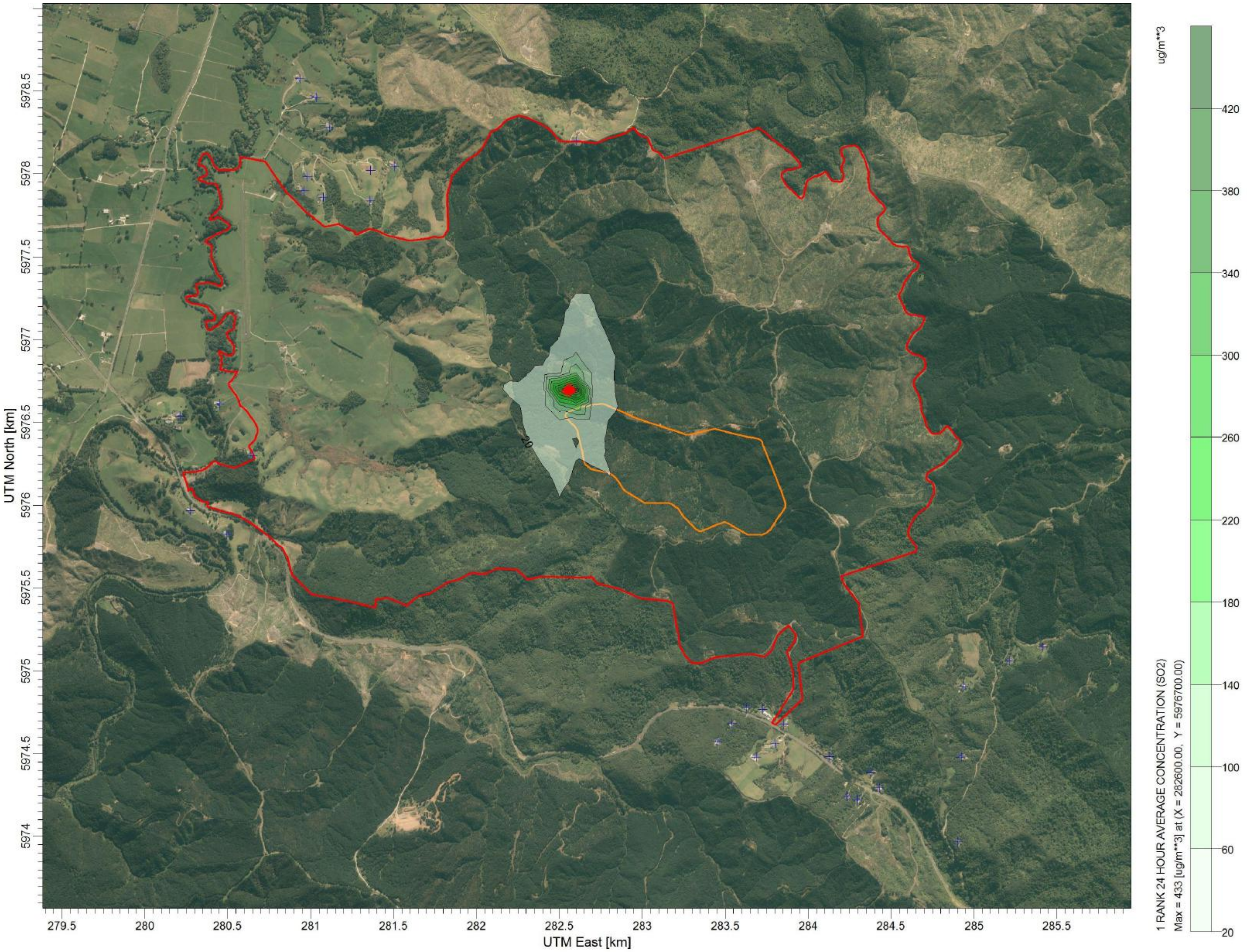


Figure Appendix.A.11: SO$_2$, 2015 model year. 24-hour average concentration. WMNZ's landholding boundary is outlined in red. The extent of the proposed landfill is outlined in orange.

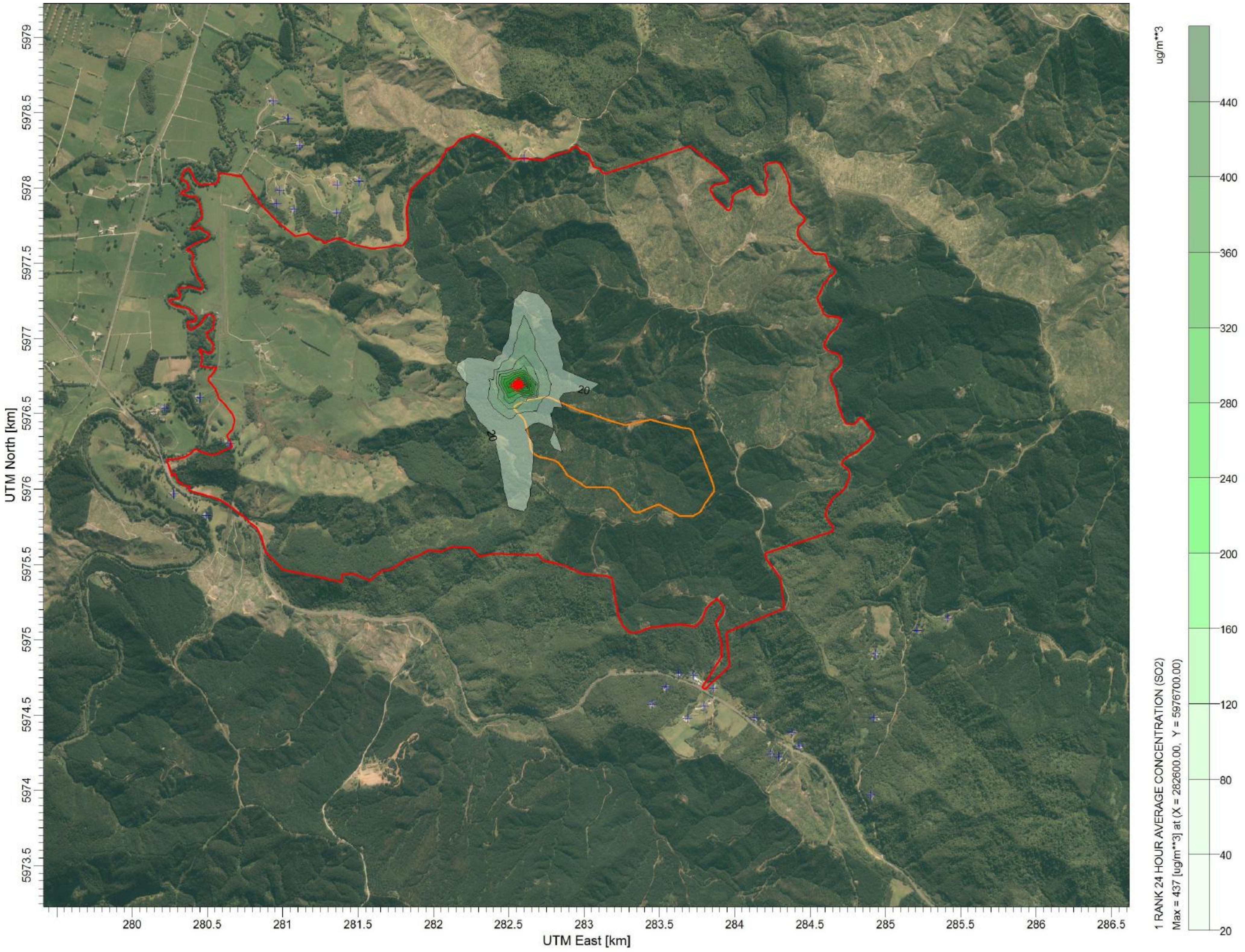


Figure Appendix.A.12: SO_2, 2017 model year. 24-hour average concentration. WMNZ's landholding boundary is outlined in red. The extent of the proposed landfill is outlined in orange.

Appendix B: Meteorological analysis

B.1 Model year selection

B.1.1 Data availability

The following table illustrates the availability of meteorological data from the nearest meteorological stations over the period 2013-2017.

Table B.1: Availability of meteorological data 2013-2017

Location	Approximate distance from site	Parameter	2013	2014	2015	2016	2017
Mahurangi Forest	3.0 km	Wind	Partial	Available	Available	Available	Available
		Temperature	Partial	Available	Available	Available	Available
		Relative humidity	Partial	Available	Available	Available	Available
		Precipitation	Partial	Available	Available	Available	Available
Warkworth EWS	13.4 km	Wind	Available	Available	Partial	-	-
		Temperature	Available	Available	Available	Available	Available
		Relative humidity	Available	Available	Available	Available	Available
		Solar radiation	Available	Available	Available	Available	Available
Leigh 2 EWS	20.5 km	Wind	Available	Available	Available	Available	Available
		Temperature	Available	Available	Available	Available	Available
		Relative humidity	Available	Available	Available	Available	Available
		Precipitation	Available	Available	Available	Available	Available
		Solar radiation	Available	Available	Available	Available	Available
		Station pressure	Available	Available	Available	Available	Available

The nearest meteorological station is the Mahurangi Forest weather station, located approximately 3 km away. As this is the most proximate meteorological station to the site, additional weighting has been provided to observations from this location in the selection of model years. Climate data from the Mahurangi Forest meteorological station is available from August 2013, with full years' meteorological data available for years 2014 to 2017.

The next proximate meteorological station is located at Warkworth, however wind data was discontinued at this site from February 2015, therefore only the years 2013 and 2014 are available for this site. As only one full year is available in commonality with the Mahurangi Forest meteorological station, data from the Warkworth station has not been used in dispersion modelling

The Leigh 2 meteorological station is located approximately 20 km from the site, and has monitoring data available for the years 2013 to 2017

Overall the availability of full calendar years of climate data from local meteorological stations is greatest in the period 2014-2017 and the further investigation of model years has focussed on this period.

B.1.2 Southern Oscillation Index

The Southern Oscillation Index (SOI) measures how abnormal pressure difference between Tahiti and Darwin is. Negative values of this index correspond to El Niño conditions, while positive SOI values correspond with La Niña conditions. Figure B.1 presents SOI values for the period January 2014 to December 2017, inclusive.

The years 2015 and 2017 best represent differing El Niño and La Niña cycles, respectively. Generally SOI values in 2015 are negative (indicating El Niño conditions), and SOI values in 2017 positive (indicating La Niña conditions).

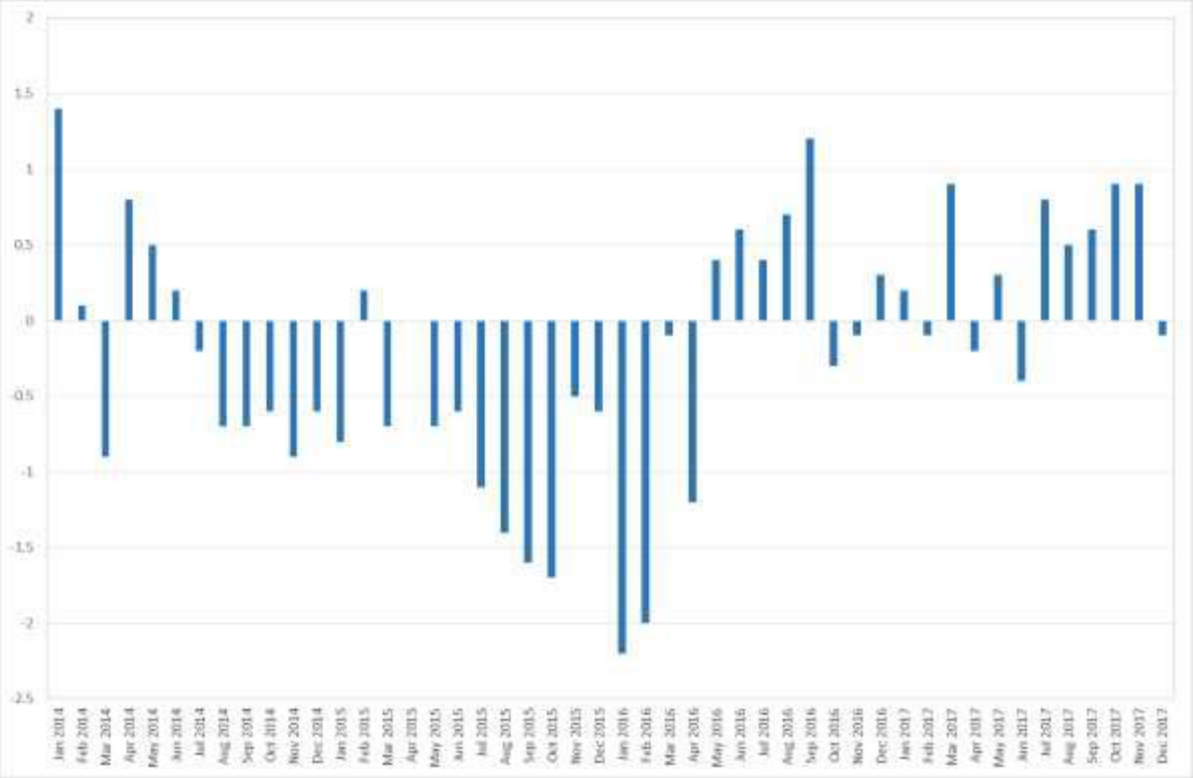


Figure B.1: Southern Oscillation Index values for years 2014 to 2017

B.1.3 Wind comparison

Wind rose frequency analyses of one-hour average wind speed and direction observations at local weather stations in the calendar years 2014 - 2017 are illustrated in Figure B.2.

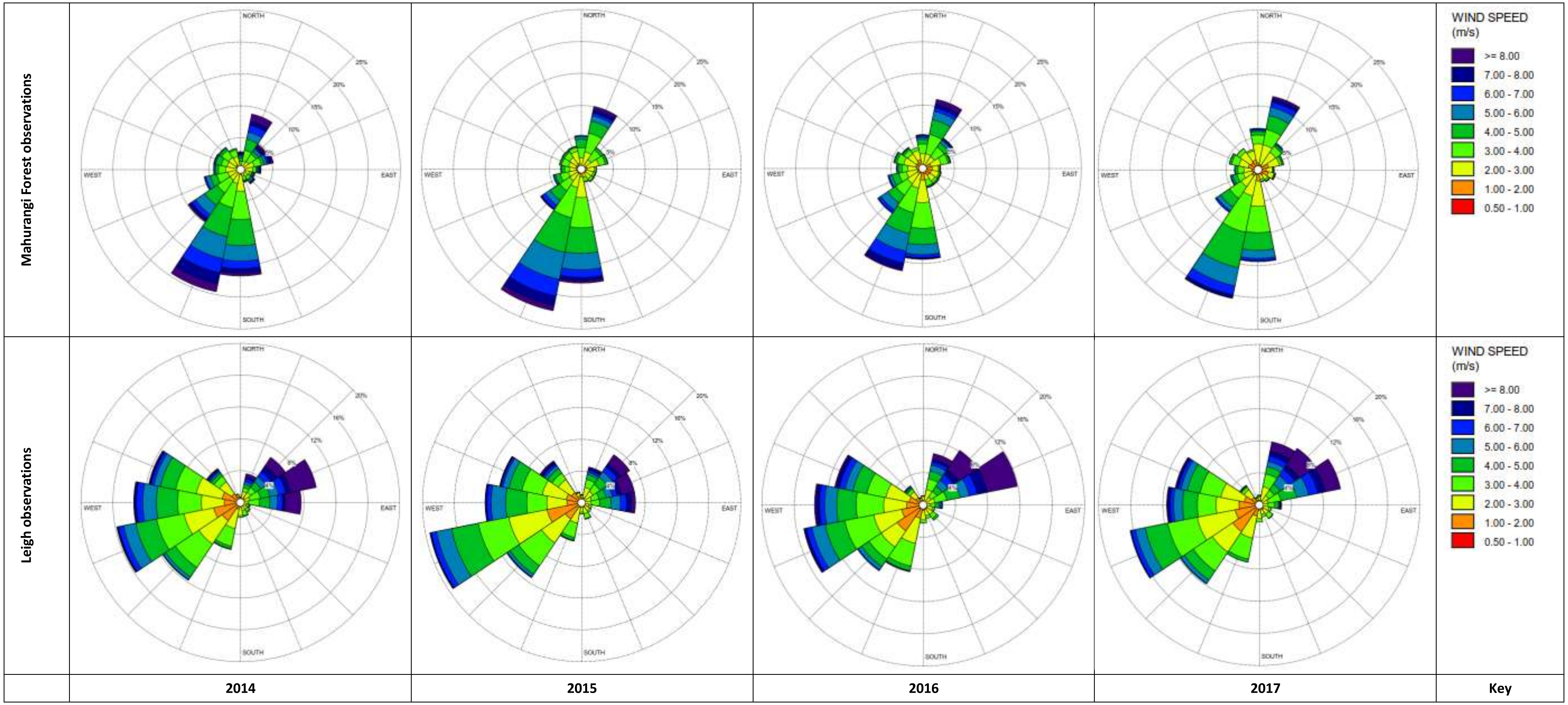


Figure B.2: Annual observed wind speed-direction frequency rose analyses – Mahurangi Forest and Leigh weather stations, blowing-from, one-hour average data, 2014 – 2017.

B.2 Comparison of CALMET predictions with observed meteorological data

Wind rose frequency analyses of wind speeds and directions predicted at the site (approximate location) by the CALMET model for 2015 and 2017 are compared with equivalent analyses of observational wind data from the Mahurangi Forest and Leigh weather stations in Figure B.3.

Wind speeds and directions at the site are expected to be different to those measured at Mahurangi Forest and Leigh weather stations due to topographical variations between the locations of the two meteorological stations and the site.

Wind directions predicted at the site generally differ to those observed at the Mahurangi Forest location, located approximately 3 km from the site. In particular, winds show a lower prevalence towards the south, south-southwest and north-northeast wind directions. The predicted 2017 wind field may overstate winds blowing from the northwest and north-northwest towards receptors to the southwest and south-southwest on State Highway 1 and Waiwhiu Road.

The predicted wind directions at the site for the 2015 meteorological year show a higher proportion of winds blowing from the southwest and south-southwest wind directions in comparison to the 2017 year. The higher predicted prevalence of southwest and south-southwest winds in 2015 is likely to be caused by the higher proportion of strong winds (>3 m/s) in 2015 compared to the 2017 year, particularly during night time hours (7 pm to 6 am)[3]. At these higher wind speeds, winds are less prone to terrain effects that will shift the wind direction towards the valley orientation under lighter winds.

With regards to winds conductive to odour propagation (typically light winds less than 3 m/s), a higher proportion of winds less than 3 m/s are predicted at the site in comparison to the Mahurangi Forest observations. For the 2015 and 2017 modelled years, 44% and 60% of winds (respectively) are predicted to be less than 3 m/s at the site, compared to 37% and 50% of winds (respectively) observed at the Mahurangi Forest Weather station. Wind predictions at the site show an increased prevalence of light winds from the north-northwest and south-southeast in comparison to the Mahurangi Forest weather station which is likely influenced by the ridge running in this direction to the east of the site.

Trends in monthly average wind speeds and temperatures predicted and observed on-site and observed at the nearest meteorological stations are illustrated in Figures B.4 to B.7.

Wind speeds observed at both the Mahurangi Forest and Leigh stations are relatively consistent throughout the year. Predicted wind speeds both modelled years show higher wind speeds during the winter months than the summer months. In particular the 2017 predictions show lower wind speeds than both the Leigh and Mahurangi Forest observations. Predicted monthly average temperature was similar to those observed at the Mahurangi Forest meteorological station, with Leigh temperatures being slightly higher.

Overall, the wind speeds predicted at the site are more likely to be conductive to odour, particularly in directions to the north-northwest and south-southeast in the directions of the nearest sensitive dwellings. The 2017 meteorological year is predicted to have wind conditions which are more conductive to odour transport towards the nearest sensitive receptors, however may overstate winds towards receptors to the southwest and south-southwest on State Highway 1 and Waiwhiu Road.

---

[3] At the Mahurangi Forest weather station, between 7pm and 6am, winds greater than 3 m/s occur 59% and 44% of the time in 2015 and 2017, respectively

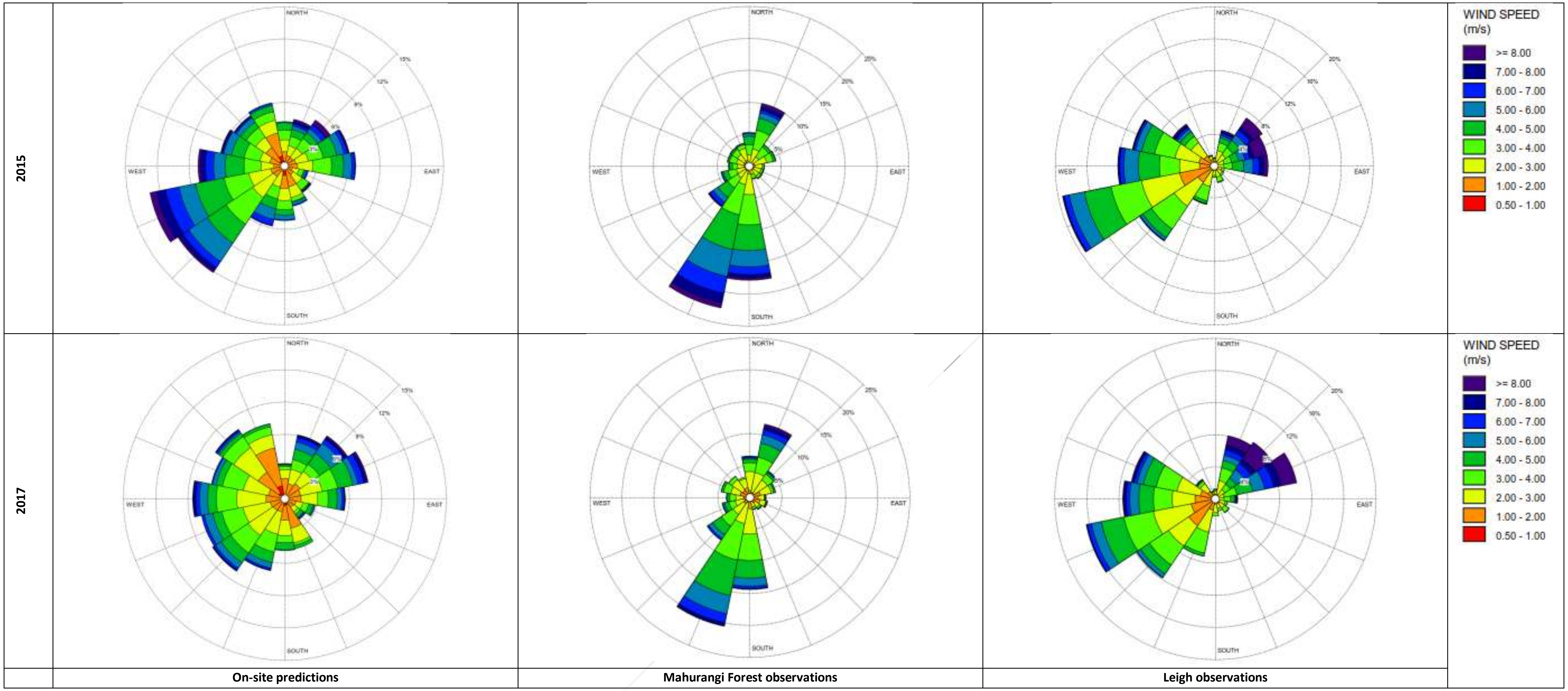


Figure B.3: Comparative wind speed-direction frequency rose analyses – on-site CALMET predictions and on-site observations, blowing-from, one-hour average data, 2015 and 2017.

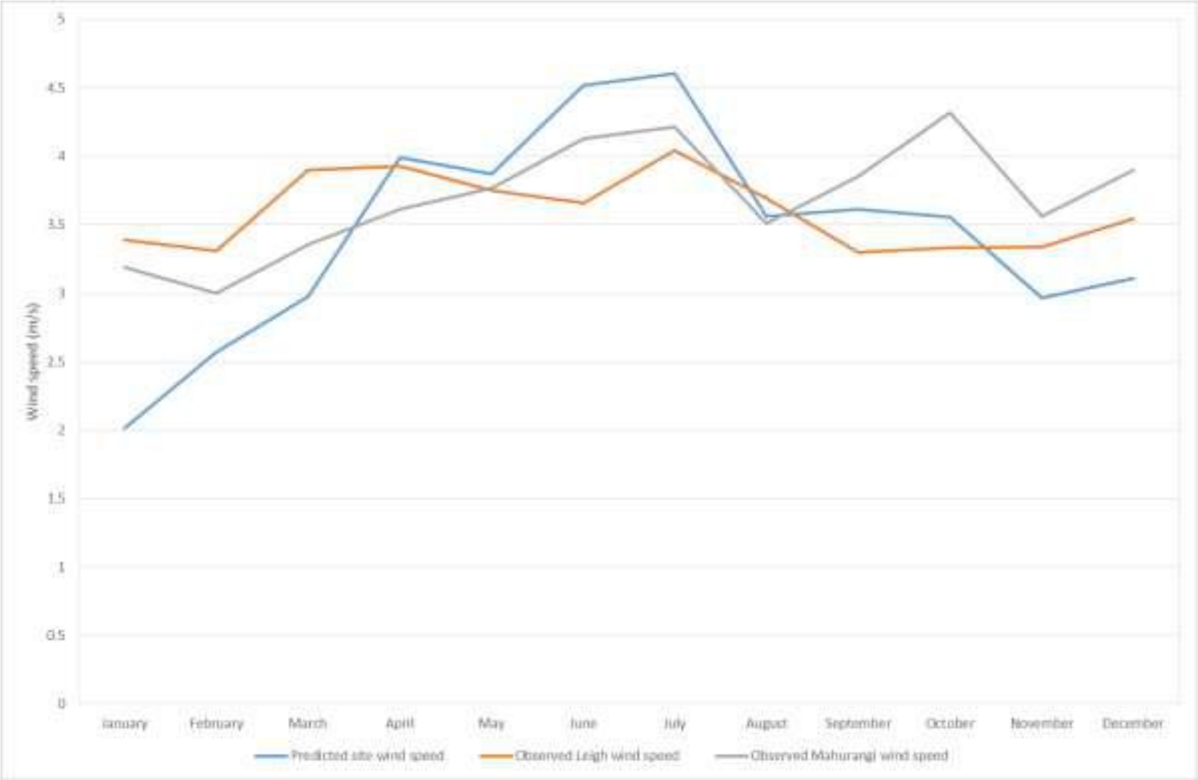


Figure B.4: Comparison of predicted and observed monthly average wind speeds, 2015

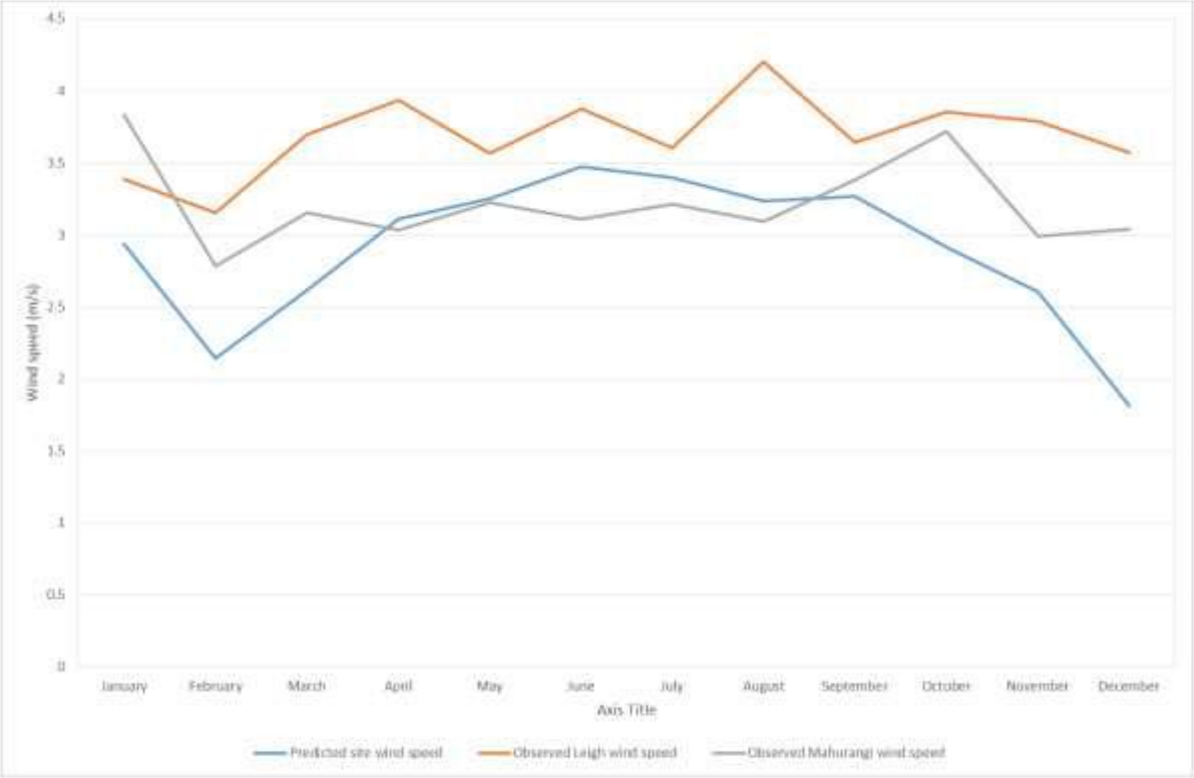


Figure B.5: Comparison of predicted and observed monthly average wind speeds, 2017

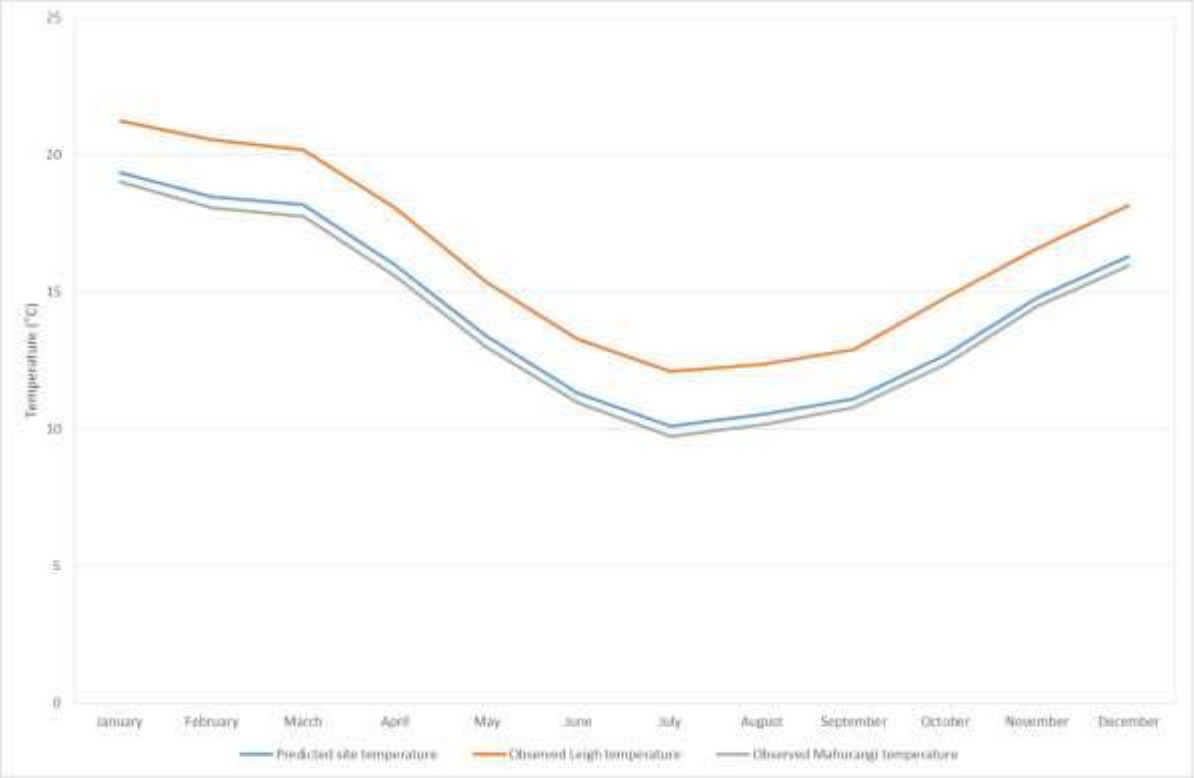


Figure B.6: Comparison of predicted and observed monthly average temperatures, 2015

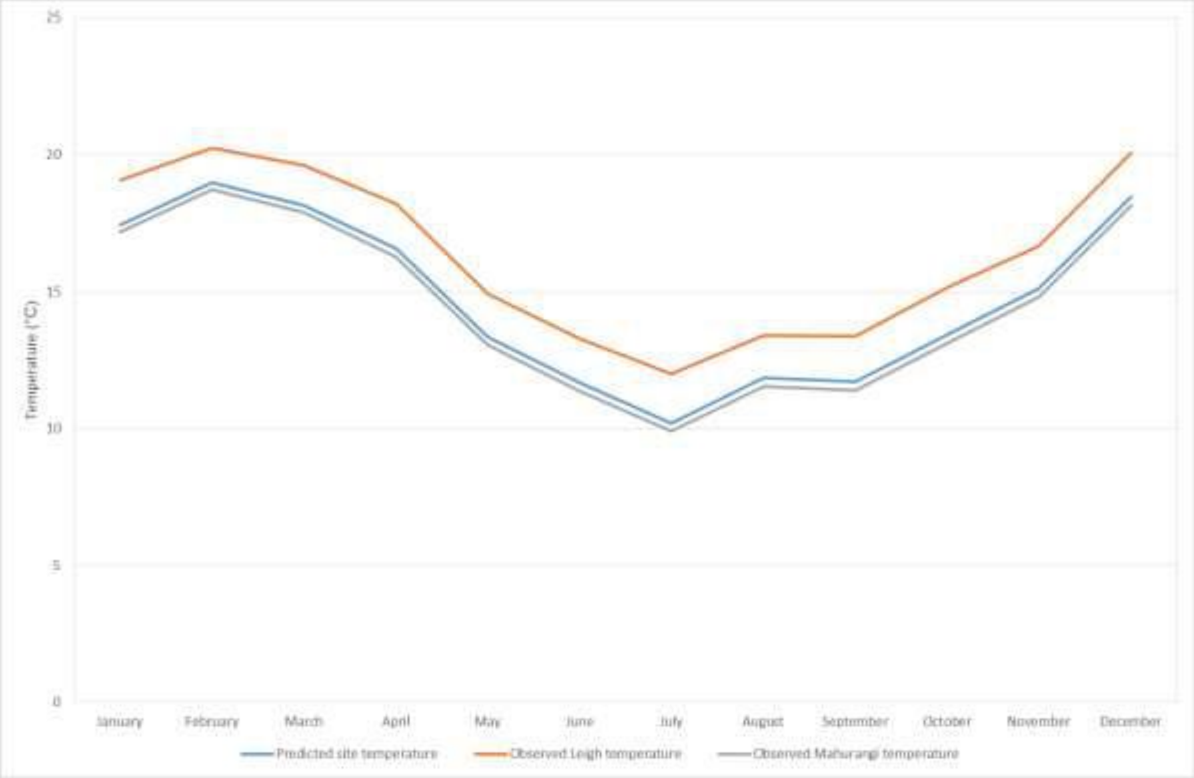


Figure B.7: Comparison of predicted and observed monthly average temperatures, 2017

Appendix C: Summary of CALMET configuration

CALMET Parameters

Polaris - 2015 Meterological Run
Version 4

INPUT GROUP: 0 -- Input and Output File Names

Parameter	Description	Value
GEODAT	Input file of geophysical data (GEO.DAT)	GEO.DAT
SRFDAT	Input file of hourly surface meteorological data (SURF.DAT)	SURF.DAT
METLST	Output file name of CALMET list file (CALMET.LST)	CALMET.LST
METDAT	Output file name of generated gridded met files (CALMET.DAT)	CALMET.DAT
LCFILES	Lower case file names (T = lower case, F = upper case)	F
NUSTA	Number of upper air stations	0
NOWSTA	Number of overwater stations	0
NM3D	Number of prognostic meteorological data files (3D.DAT)	1
NIGF	Number of IGF-CALMET.DAT files used as initial guess	0

INPUT GROUP: 1 -- General Run Control Parameters

Parameter	Description	Value
IBYR	Starting year	2015
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	1
IBSEC	Starting second	0
IEYR	Ending year	2015
IEMO	Ending month	12
IEDY	Ending day	31
IEHR	Ending hour	23
IESEC	Ending second	0
ABTZ	Base time zone	UTC+1200
NSECDT	Length of modeling time-step (seconds)	3600
IRTYPE	Output run type (0 = wind fields only, 1 = CALPUFF/CALGRID)	1
LCALGRD	Compute CALGRID data fields (T = true, F = false)	T
ITEST	Flag to stop run after setup phase (1 = stop, 2 = run)	2
MREG	Regulatory checks (0 = no checks, 1 = US EPA LRT checks)	0

INPUT GROUP: 2 -- Map Projection and Grid Control Parameters

Parameter	Description	Value
PMAP	Map projection system	UTM
FEAST	False easting at projection origin (km)	0.0
FNORTH	False northing at projection origin (km)	0.0

INPUT GROUP: 2 -- Map Projection and Grid Control Parameters		
Parameter	**Description**	**Value**
IUTMZN	UTM zone (1 to 60)	60
UTMHEM	Hemisphere of UTM projection (N = northern, S = southern)	S
XLAT1	1st standard parallel latitude (decimal degrees)	30S
XLAT2	2nd standard parallel latitude (decimal degrees)	60S
DATUM	Datum-Region for the coordinates	WGS-84
NX	Meteorological grid - number of X grid cells	200
NY	Meteorological grid - number of Y grid cells	150
DGRIDKM	Meteorological grid spacing (km)	0.2
XORIGKM	Meteorological grid - X coordinate for SW corner (km)	264.3000
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	5961.3000
NZ	Meteorological grid - number of vertical layers	10
ZFACE	Meteorological grid - vertical cell face heights (m)	0.00,20.00,40.00,80.00,160.00,320.00,640.00,1200.00,2000.00,3000.00,4000.00

INPUT GROUP: 3 -- Output Options		
Parameter	**Description**	**Value**
LSAVE	Save met fields in unformatted output file (T = true, F = false)	T
IFORMO	Type of output file (1 = CALPUFF/CALGRID, 2 = MESOPUFF II)	1
LPRINT	Print met fields (F = false, T = true)	F
IPRINF	Print interval for output wind fields (hours)	1
STABILITY	Print gridded PGT stability classes? (0 = no, 1 = yes)	0
USTAR	Print gridded friction velocities? (0 = no, 1 = yes)	0
MONIN	Print gridded Monin-Obukhov lengths? (0 = no, 1 = yes)	0
MIXHT	Print gridded mixing heights? (0 = no, 1 = yes)	0
WSTAR	Print gridded convective velocity scales? (0 = no, 1 = yes)	0
PRECIP	Print gridded hourly precipitation rates? (0 = no, 1 = yes)	0
SENSHEAT	Print gridded sensible heat fluxes? (0 = no, 1 = yes)	0
CONVZI	Print gridded convective mixing heights? (0 = no, 1 = yes)	0
LDB	Test/debug option: print input met data and internal variables (F = false, T = true)	F
NN1	Test/debug option: first time step to print	1
NN2	Test/debug option: last time step to print	1
LDBCST	Test/debug option: print distance to land internal variables (F = false, T = true)	F
IOUTD	Test/debug option: print control variables for writing winds? (0 = no, 1 = yes)	0
NZPRN2	Test/debug option: number of levels to print starting at the surface	1
IPR0	Test/debug option: print interpolated winds? (0 = no, 1 = yes)	0
IPR1	Test/debug option: print terrain adjusted surface wind? (0 = no, 1 = yes)	0

INPUT GROUP: 3 -- Output Options		
Parameter	**Description**	**Value**
IPR2	Test/debug option: print smoothed wind and initial divergence fields? (0 = no, 1 = yes)	0
IPR3	Test/debug option: print final wind speed and direction? (0 = no, 1 = yes)	0
IPR4	Test/debug option: print final divergence fields? (0 = no, 1 = yes)	0
IPR5	Test/debug option: print winds after kinematic effects? (0 = no, 1 = yes)	0
IPR6	Test/debug option: print winds after Froude number adjustment? (0 = no, 1 = yes)	0
IPR7	Test/debug option: print winds after slope flow? (0 = no, 1 = yes)	0
IPR8	Test/debug option: print final winds? (0 = no, 1 = yes)	0

INPUT GROUP: 4 -- Meteorological Data Options		
Parameter	**Description**	**Value**
NOOBS	Observation mode (0 = stations only, 1 = surface/overwater stations with prognostic upper air, 2 = prognostic data only)	1
NSSTA	Number of surface stations	2
NPSTA	Number of precipitation stations	-1
ICLDOUT	Output the CLOUD.DAT file? (0 = no, 1 = yes)	0
MCLOUD	Method to compute cloud fields (1 = from surface obs, 2 = from CLOUD.DAT, 3 = from prognostic (Teixera), 4 = from prognostic (MM5toGrads)	3
IFORMS	Surface met data file format (1 = unformatted, 2 = formatted)	2
IFORMP	Precipitation data file format (1 = unformatted, 2 = formatted)	2
IFORMC	Cloud data file format (1 = unformatted, 2 = formatted)	1

INPUT GROUP: 5 -- Wind Field Options and Parameters		
Parameter	**Description**	**Value**
IWFCOD	Wind field model option (1 = objective analysis, 2 = diagnostic)	1
IFRADJ	Adjust winds using Froude number effects? (0 = no, 1 = yes)	1
IKINE	Adjust winds using kinematic effects? (0 = no, 1 = yes)	0
IOBR	Adjust winds using O'Brien velocity procedure? (0 = no, 1 = yes)	0
ISLOPE	Compute slope flow effects? (0 = no, 1 = yes)	1
IEXTRP	Extrapolation of surface winds to upper layers method (1 = none, 2 = power law, 3 = user input, 4 = similarity theory, - = same except layer 1 data at upper air stations are ignored)	-4
ICALM	Extrapolate surface winds even if calm? (0 = no, 1 = yes)	0
BIAS	Weighting factors for surface and upper air stations (NZ values)	0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
RMIN2	Minimum upper air station radius of influence for surface extrapolation exclusion (km)	-1
IPROG	Use prognostic winds as input to diagnostic wind model (0 = no, 13 = use winds from 3D.DAT as Step 1 field, 14 = use winds from 3D.DAT as initial guess field, 15 = use winds from 3D.DAT file as observations)	14
ISTEPPGS	Prognostic data time step (seconds)	3600

INPUT GROUP: 5 -- Wind Field Options and Parameters		
Parameter	**Description**	**Value**
IGFMET	Use coarse CALMET fields as initial guess? (0 = no, 1 = yes)	0
LVARY	Use varying radius of influence (F = false, T = true)	F
RMAX1	Maximum radius of influence in the surface layer (km)	2
RMAX2	Maximum radius of influence over land aloft (km)	10
RMAX3	Maximum radius of influence over water (km)	0
RMIN	Minimum radius of influence used in wind field interpolation (km)	0.1
TERRAD	Radius of influence of terrain features (km)	4
R1	Relative weight at surface of step 1 fields and observations (km)	1.5
R2	Relative weight aloft of step 1 field and observations (km)	15
RPROG	Weighting factors of prognostic wind field data (km)	0
DIVLIM	Maximum acceptable divergence	5E-006
NITER	Maximum number of iterations in the divergence minimization procedure	50
NSMTH	Number of passes in the smoothing procedure (NZ values)	2,9*4
NINTR2	Maximum number of stations used in each layer for interpolation (NZ values)	10*99
CRITFN	Critical Froude number	1
ALPHA	Empirical factor triggering kinematic effects	0.1
NBAR	Number of barriers to interpolation of the wind fields	0
KBAR	Barrier - level up to which barriers apply (1 to NZ)	10
IDIOPT1	Surface temperature (0 = compute from obs/prognostic, 1 = read from DIAG.DAT)	0
ISURFT	Surface station to use for surface temperature (between 1 and NSSTA)	-1
IDIOPT2	Temperature lapse rate used in the computation of terrain-induced circulations (0 = compute from obs/prognostic, 1 = read from DIAG.DAT)	0
IUPT	Upper air station to use for the domain-scale lapse rate (between 1 and NUSTA)	-1
ZUPT	Depth through which the domain-scale lapse rate is computed (m)	200
IDIOPT3	Initial guess field winds (0 = compute from obs/prognostic, 1 = read from DIAG.DAT)	0
IUPWND	Upper air station to use for domain-scale winds	-1
ZUPWND	Bottom and top of layer through which the domain-scale winds are computed (m)	1.0, 1.00
IDIOPT4	Read observed surface wind components (0 = from SURF.DAT, 1 = from DIAG.DAT)	0
IDIOPT5	Read observed upper wind components (0 = from UPn.DAT, 1 = from DIAG.DAT)	0
LLBREZE	Use Lake Breeze module (T = true, F = false)	F
NBOX	Lake Breeze - number of regions	0

INPUT GROUP: 6 -- Mixing Height, Temperature and Precipitation Parameters		
Parameter	**Description**	**Value**
CONSTB	Mixing height constant: neutral, mechanical equation	1.41

INPUT GROUP: 6 -- Mixing Height, Temperature and Precipitation Parameters		
Parameter	**Description**	**Value**
CONSTE	Mixing height constant: convective equation	0.15
CONSTN	Mixing height constant: stable equation	2400
CONSTW	Mixing height constant: overwater equation	0.16
FCORIOL	Absolute value of Coriolis parameter (1/s)	0.0001
IAVEZI	Spatial mixing height averaging? (0 = no, 1 = yes)	1
MNMDAV	Maximum search radius in averaging process (grid cells)	1
HAFANG	Half-angle of upwind looking cone for averaging (degrees)	30
ILEVZI	Layer of winds used in upwind averaging (between 1 and NZ)	1
IMIXH	Convective mixing height method (1 = Maul-Carson, 2 = Batchvarova-Gryning, - for land cells only, + for land and water cells)	1
THRESHL	Overland threshold boundary flux (W/m**3)	0
THRESHW	Overwater threshold boundary flux (W/m**3)	0.05
ITWPROG	Overwater lapse rate and deltaT options (0 = from SEA.DAT, 1 = use prognostic lapse rates and SEA.DAT deltaT, 2 = from prognostic)	0
ILUOC3D	Land use category in 3D.DAT	16
DPTMIN	Minimum potential temperature lapse rate (K/m)	0.001
DZZI	Depth of computing capping lapse rate (m)	200
ZIMIN	Minimum overland mixing height (m)	50
ZIMAX	Maximum overland mixing height (m)	3000
ZIMINW	Minimum overwater mixing height (m)	50
ZIMAXW	Maximum overwater mixing height (m)	3000
ICOARE	Overwater surface fluxes method	10
DSHELF	Coastal/shallow water length scale (km)	0
IWARM	COARE warm layer computation (0 = off, 1 = on)	0
ICOOL	COARE cool skin layer computation (0 = off, 1 = on)	0
IRHPROG	Relative humidity read option (0 = from SURF.DAT, 1 = from 3D.DAT)	0
ITPROG	3D temperature read option (0 = stations, 1 = surface from station and upper air from prognostic, 2 = prognostic)	1
IRAD	Temperature interpolation type (1 = 1/R, 2 = 1/R**2)	1
TRADKM	Temperature interpolation radius of influence (km)	500
NUMTS	Maximum number of stations to include in temperature interpolation	5
IAVET	Conduct spatial averaging of temperatures? (0 = no, 1 = yes)	1
TGDEFB	Default overwater mixed layer lapse rate (K/m)	-0.0098
TGDEFA	Default overwater capping lapse rate (K/m)	-0.0045
JWAT1	Beginning land use category for temperature interpolation over water	999
JWAT2	Ending land use category for temperature interpolation over water	999
NFLAGP	Precipitation interpolation method (1 = 1/R, 2 = 1/R**2, 3 = EXP/R**2)	2
SIGMAP	Precipitation interpolation radius of influence (km)	100.
CUTP	Minimum precipitation rate cutoff (mm/hr)	0.01

Appendix D: Summary of CALPUFF configuration

CALPUFF Parameters

1005069.1150 - Polaris
2015 - Scenario B
v4 Met

INPUT GROUP: 0 -- Input and Output File Names

Parameter	Description	Value
PUFLST	CALPUFF output list file (CALPUFF.LST)	CALPUFF.LST
CONDAT	CALPUFF output concentration file (CONC.DAT)	CONC.DAT
DFDAT	CALPUFF output dry deposition flux file (DFLX.DAT)	DFLX.DAT
WFDAT	CALPUFF output wet deposition flux file (WFLX.DAT)	WFLX.DAT
LCFILES	Lower case file names (T = lower case, F = upper case)	F
NMETDOM	Number of CALMET.DAT domains	1
NMETDAT	Number of CALMET.DAT input files	12
NPTDAT	Number of PTEMARB.DAT input files	0
NARDAT	Number of BAEMARB.DAT input files	0
NVOLDAT	Number of VOLEMARB.DAT input files	0
NFLDAT	Number of FLEMARB.DAT input files	0
NRDDAT	Number of RDEMARB.DAT input files	0
NLNDAT	Number of LNEMARB.DAT input files	0
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-01-01-01-0000-2015-02-01-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-02-01-00-0000-2015-03-04-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-03-04-00-0000-2015-04-03-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-04-03-00-0000-2015-05-03-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-05-03-00-0000-2015-06-03-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-06-03-00-0000-2015-07-03-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-07-03-00-0000-2015-08-02-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-08-02-00-0000-2015-09-02-00-0000.DAT

INPUT GROUP: 0 -- Input and Output File Names		
Parameter	**Description**	**Value**
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-09-02-00-0000-2015-10-02-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-10-02-00-0000-2015-11-01-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-11-01-00-0000-2015-12-02-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-12-02-00-0000-2015-12-31-23-0000.DAT

INPUT GROUP: 1 -- General Run Control Parameters		
Parameter	**Description**	**Value**
METRUN	Run all periods in met data file? (0 = no, 1 = yes)	0
IBYR	Starting year	2015
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	1
IBMIN	Starting minute	0
IBSEC	Starting second	0
IEYR	Ending year	2015
IEMO	Ending month	12
IEDY	Ending day	31
IEHR	Ending hour	22
IEMIN	Ending minute	0
IESEC	Ending second	0
ABTZ	Base time zone	UTC+1200
NSECDT	Length of modeling time-step (seconds)	3600
NSPEC	Number of chemical species modeled	1
NSE	Number of chemical species to be emitted	1
ITEST	Stop run after SETUP phase (1 = stop, 2 = run)	2
MRESTART	Control option to read and/or write model restart data	0
NRESPD	Number of periods in restart output cycle	0
METFM	Meteorological data format (1 = CALMET, 2 = ISC, 3 = AUSPLUME, 4 = CTDM, 5 = AERMET)	1
MPRFFM	Meteorological profile data format (1 = CTDM, 2 = AERMET)	1
AVET	Averaging time (minutes)	60
PGTIME	PG Averaging time (minutes)	60
IOUTU	Output units for binary output files (1 = mass, 2 = odour, 3 = radiation)	2

INPUT GROUP: 2 -- Technical Options

Parameter	Description	Value
MGAUSS	Near field vertical distribution (0 = uniform, 1 = Gaussian)	1
MCTADJ	Terrain adjustment method (0 = none, 1 = ISC-type, 2 = CALPUFF-type, 3 = partial plume path)	3
MCTSG	Model subgrid-scale complex terrain? (0 = no, 1 = yes)	0
MSLUG	Near-field puffs modeled as elongated slugs? (0 = no, 1 = yes)	0
MTRANS	Model transitional plume rise? (0 = no, 1 = yes)	1
MTIP	Apply stack tip downwash to point sources? (0 = no, 1 = yes)	1
MRISE	Plume rise module for point sources (1 = Briggs, 2 = numerical)	1
MTIP_FL	Apply stack tip downwash to flare sources? (0 = no, 1 = yes)	0
MRISE_FL	Plume rise module for flare sources (1 = Briggs, 2 = numerical)	2
MBDW	Building downwash method (1 = ISC, 2 = PRIME)	1
MSHEAR	Treat vertical wind shear? (0 = no, 1 = yes)	0
MSPLIT	Puff splitting allowed? (0 = no, 1 = yes)	0
MCHEM	Chemical transformation method (0 = not modeled, 1 = MESOPUFF II, 2 = User-specified, 3 = RIVAD/ARM3, 4 = MESOPUFF II for OH, 5 = half-life, 6 = RIVAD w/ISORROPIA, 7 = RIVAD w/ISORROPIA CalTech SOA)	0
MAQCHEM	Model aqueous phase transformation? (0 = no, 1 = yes)	0
MLWC	Liquid water content flag	1
MWET	Model wet removal? (0 = no, 1 = yes)	0
MDRY	Model dry deposition? (0 = no, 1 = yes)	0
MTILT	Model gravitational settling (plume tilt)? (0 = no, 1 = yes)	0
MDISP	Dispersion coefficient calculation method (1= PROFILE.DAT, 2 = Internally, 3 = PG/MP, 4 = MESOPUFF II, 5 = CTDM)	2
MTURBVW	Turbulence characterization method (only if MDISP = 1 or 5)	3
MDISP2	Missing dispersion coefficients method (only if MDISP = 1 or 5)	3
MTAULY	Sigma-y Lagrangian timescale method	0
MTAUADV	Advective-decay timescale for turbulence (seconds)	0
MCTURB	Turbulence method (1 = CALPUFF, 2 = AERMOD)	1
MROUGH	PG sigma-y and sigma-z surface roughness adjustment? (0 = no, 1 = yes)	0
MPARTL	Model partial plume penetration for point sources? (0 = no, 1 = yes)	1
MPARTLBA	Model partial plume penetration for buoyant area sources? (0 = no, 1 = yes)	0
MTINV	Strength of temperature inversion provided in PROFILE.DAT? (0 = no - compute from default gradients, 1 = yes)	0
MPDF	PDF used for dispersion under convective conditions? (0 = no, 1 = yes)	1
MSGTIBL	Sub-grid TIBL module for shoreline? (0 = no, 1 = yes)	0
MBCON	Boundary conditions modeled? (0 = no, 1 = use BCON.DAT, 2 = use CONC.DAT)	0
MSOURCE	Save individual source contributions? (0 = no, 1 = yes)	0
MFOG	Enable FOG model output? (0 = no, 1 = yes - PLUME mode, 2 = yes - RECEPTOR mode)	0
MREG	Regulatory checks (0 = no checks, 1 = USE PA LRT checks)	0

INPUT GROUP: 3 -- Species List		
Parameter	**Description**	**Value**
CSPEC	Species included in model run	ODOR

INPUT GROUP: 4 -- Map Projection and Grid Control Parameters		
Parameter	**Description**	**Value**
PMAP	Map projection system	UTM
FEAST	False easting at projection origin (km)	0.0
FNORTH	False northing at projection origin (km)	0.0
IUTMZN	UTM zone (1 to 60)	60
UTMHEM	Hemisphere (N = northern, S = southern)	S
RLAT0	Latitude of projection origin (decimal degrees)	0.00N
RLON0	Longitude of projection origin (decimal degrees)	0.00E
XLAT1	1st standard parallel latitude (decimal degrees)	30S
XLAT2	2nd standard parallel latitude (decimal degrees)	60S
DATUM	Datum-region for the coordinates	WGS-84
NX	Meteorological grid - number of X grid cells	200
NY	Meteorological grid - number of Y grid cells	150
NZ	Meteorological grid - number of vertical layers	10
DGRIDKM	Meteorological grid spacing (km)	0.2
ZFACE	Meteorological grid - vertical cell face heights (m)	0.0, 20.0, 40.0, 80.0, 160.0, 320.0, 640.0, 1200.0, 2000.0, 3000.0, 4000.0
XORIGKM	Meteorological grid - X coordinate for SW corner (km)	264.3000
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	5961.3000
IBCOMP	Computational grid - X index of lower left corner	75
JBCOMP	Computational grid - Y index of lower left corner	55
IECOMP	Computational grid - X index of upper right corner	115
JECOMP	Computational grid - Y index of upper right corner	95
LSAMP	Use sampling grid (gridded receptors) (T = true, F = false)	T
IBSAMP	Sampling grid - X index of lower left corner	80
JBSAMP	Sampling grid - Y index of lower left corner	60
IESAMP	Sampling grid - X index of upper right corner	110
JESAMP	Sampling grid - Y index of upper right corner	90
MESHDN	Sampling grid - nesting factor	2

INPUT GROUP: 5 -- Output Options		
Parameter	**Description**	**Value**
ICON	Output concentrations to CONC.DAT? (0 = no, 1 = yes)	1
IDRY	Output dry deposition fluxes to DFLX.DAT? (0 = no, 1 = yes)	0
IWET	Output wet deposition fluxes to WFLX.DAT? (0 = no, 1 = yes)	0

INPUT GROUP: 5 -- Output Options		
Parameter	**Description**	**Value**
IT2D	Output 2D temperature data? (0 = no, 1 = yes)	0
IRHO	Output 2D density data? (0 = no, 1 = yes)	0
IVIS	Output relative humidity data? (0 = no, 1 = yes)	0
LCOMPRS	Use data compression in output file (T = true, F = false)	T
IQAPLOT	Create QA output files suitable for plotting? (0 = no, 1 = yes)	1
IPFTRAK	Output puff tracking data? (0 = no, 1 = yes use timestep, 2 = yes use sampling step)	0
IMFLX	Output mass flux across specific boundaries? (0 = no, 1 = yes)	0
IMBAL	Output mass balance for each species? (0 = no, 1 = yes)	0
INRISE	Output plume rise data? (0 = no, 1 = yes)	0
ICPRT	Print concentrations? (0 = no, 1 = yes)	0
IDPRT	Print dry deposition fluxes? (0 = no, 1 = yes)	0
IWPRT	Print wet deposition fluxes? (0 = no, 1 = yes)	0
ICFRQ	Concentration print interval (timesteps)	1
IDFRQ	Dry deposition flux print interval (timesteps)	1
IWFRQ	Wet deposition flux print interval (timesteps)	1
IPRTU	Units for line printer output (e.g., 3 = ug/m**3 - ug/m**2/s, 5 = odor units)	5
IMESG	Message tracking run progress on screen (0 = no, 1 and 2 = yes)	2
LDEBUG	Enable debug output? (0 = no, 1 = yes)	F
IPFDEB	First puff to track in debug output	1
NPFDEB	Number of puffs to track in debug output	1000
NN1	Starting meteorological period in debug output	1
NN2	Ending meteorological period in debug output	10

INPUT GROUP: 6 -- Subgrid Scale Complex Terrain Inputs		
Parameter	**Description**	**Value**
NHILL	Number of terrain features	0
NCTREC	Number of special complex terrain receptors	0
MHILL	Terrain and CTSG receptor data format (1= CTDM, 2 = OPTHILL)	2
XHILL2M	Horizontal dimension conversion factor to meters	1.0
ZHILL2M	Vertical dimension conversion factor to meters	1.0
XCTDMKM	X origin of CTDM system relative to CALPUFF system (km)	0.0
YCTDMKM	Y origin of CTDM system relative to CALPUFF system (km)	0.0

INPUT GROUP: 9 -- Miscellaneous Dry Deposition Parameters		
Parameter	**Description**	**Value**
RCUTR	Reference cuticle resistance (s/cm)	30
RGR	Reference ground resistance (s/cm)	10
REACTR	Reference pollutant reactivity	8

INPUT GROUP: 9 -- Miscellaneous Dry Deposition Parameters		
Parameter	**Description**	**Value**
NINT	Number of particle size intervals for effective particle deposition velocity	9
IVEG	Vegetation state in unirrigated areas (1 = active and unstressed, 2 = active and stressed, 3 = inactive)	1

INPUT GROUP: 11 -- Chemistry Parameters		
Parameter	**Description**	**Value**
MOZ	Ozone background input option (0 = monthly, 1 = hourly from OZONE.DAT)	1
BCKO3	Monthly ozone concentrations (ppb)	80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00
MNH3	Ammonia background input option (0 = monthly, 1 = from NH3Z.DAT)	0
MAVGNH3	Ammonia vertical averaging option (0 = no average, 1 = average over vertical extent of puff)	1
BCKNH3	Monthly ammonia concentrations (ppb)	10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00
RNITE1	Nighttime SO2 loss rate (%/hr)	0.2
RNITE2	Nighttime NOx loss rate (%/hr)	2
RNITE3	Nighttime HNO3 loss rate (%/hr)	2
MH2O2	H2O2 background input option (0 = monthly, 1 = hourly from H2O2.DAT)	1
BCKH2O2	Monthly H2O2 concentrations (ppb)	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00
RH_ISRP	Minimum relative humidity for ISORROPIA	50.0
SO4_ISRP	Minimum SO4 for ISORROPIA	0.4
BCKPMF	SOA background fine particulate (ug/m**3)	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00
OFRAC	SOA organic fine particulate fraction	0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15
VCNX	SOA VOC/NOX ratio	50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00
NDECAY	Half-life decay blocks	0

INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
SYTDEP	Horizontal puff size for time-dependent sigma equations (m)	550
MHFTSZ	Use Heffter equation for sigma-z? (0 = no, 1 = yes)	0
JSUP	PG stability class above mixed layer	5
CONK1	Vertical dispersion constant - stable conditions	0.01

INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
CONK2	Vertical dispersion constant - neutral/unstable conditions	0.1
TBD	Downwash scheme transition point option (<0 = Huber-Snyder, 1.5 = Schulman-Scire, 0.5 = ISC)	0.5
IURB1	Beginning land use category for which urban dispersion is assumed	10
IURB2	Ending land use category for which urban dispersion is assumed	19
ILANDUIN	Land use category for modeling domain	20
Z0IN	Roughness length for modeling domain (m)	.25
XLAIIN	Leaf area index for modeling domain	3.0
ELEVIN	Elevation above sea level (m)	.0
XLATIN	Meteorological station latitude (deg)	-999.0
XLONIN	Meteorological station longitude (deg)	-999.0
ANEMHT	Anemometer height (m)	10.0
ISIGMAV	Lateral turbulence format (0 = read sigma-theta, 1 = read sigma-v)	1
IMIXCTDM	Mixing heights read option (0 = predicted, 1 = observed)	0
XMXLEN	Slug length (met grid units)	1
XSAMLEN	Maximum travel distance of a puff/slug (met grid units)	1
MXNEW	Maximum number of slugs/puffs release from one source during one time step	99
MXSAM	Maximum number of sampling steps for one puff/slug during one time step	99
NCOUNT	Number of iterations used when computing the transport wind for a sampling step that includes gradual rise	2
SYMIN	Minimum sigma-y for a new puff/slug (m)	1
SZMIN	Minimum sigma-z for a new puff/slug (m)	1
SZCAP_M	Maximum sigma-z allowed to avoid numerical problem in calculating virtual time or distance (m)	5000000
SVMIN	Minimum turbulence velocities sigma-v (m/s)	0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.37, 0.37, 0.37, 0.37, 0.37, 0.37
SWMIN	Minimum turbulence velocities sigma-w (m/s)	0.2, 0.12, 0.08, 0.06, 0.03, 0.016, 0.2, 0.12, 0.08, 0.06, 0.03, 0.016
CDIV	Divergence criterion for dw/dz across puff (1/s)	0, 0
NLUTIBL	TIBL module search radius (met grid cells)	4
WSCALM	Minimum wind speed allowed for non-calm conditions (m/s)	0.5
XMAXZI	Maximum mixing height (m)	3000
XMINZI	Minimum mixing height (m)	50
TKCAT	Emissions scale-factors temperature categories (K)	265., 270., 275., 280., 285., 290., 295., 300., 305., 310., 315.
PLX0	Wind speed profile exponent for stability classes 1 to 6	0.07, 0.07, 0.1, 0.15, 0.35, 0.55
PTG0	Potential temperature gradient for stable classes E and F (deg K/m)	0.02, 0.035

INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
PPC	Plume path coefficient for stability classes 1 to 6	0.5, 0.5, 0.5, 0.5, 0.35, 0.35
SL2PF	Slug-to-puff transition criterion factor (sigma-y/slug length)	10
FCLIP	Hard-clipping factor for slugs (0.0 = no extrapolation)	0
NSPLIT	Number of puffs created from vertical splitting	3
IRESPLIT	Hour for puff re-split	0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
ZISPLIT	Minimum mixing height for splitting (m)	100
ROLDMAX	Mixing height ratio for splitting	0.25
NSPLITH	Number of puffs created from horizontal splitting	5
SYSPLITH	Minimum sigma-y (met grid cells)	1
SHSPLITH	Minimum puff elongation rate (SYSPLITH/hr)	2
CNSPLITH	Minimum concentration (g/m**3)	0
EPSSLUG	Fractional convergence criterion for numerical SLUG sampling integration	0.0001
EPSAREA	Fractional convergence criterion for numerical AREA source integration	1E-006
DSRISE	Trajectory step-length for numerical rise integration (m)	1.0
HTMINBC	Minimum boundary condition puff height (m)	500
RSAMPBC	Receptor search radius for boundary condition puffs (km)	10
MDEPBC	Near-surface depletion adjustment to concentration (0 = no, 1 = yes)	1

INPUT GROUP: 13 -- Point Source Parameters		
Parameter	**Description**	**Value**
NPT1	Number of point sources	0
IPTU	Units used for point source emissions (e.g., 1 = g/s)	1
NSPT1	Number of source-species combinations with variable emission scaling factors	0
NPT2	Number of point sources in PTEMARB.DAT file(s)	0

INPUT GROUP: 14 -- Area Source Parameters		
Parameter	**Description**	**Value**
NAR1	Number of polygon area sources	2
IARU	Units used for area source emissions (e.g., 1 = g/m**2/s)	5
NSAR1	Number of source-species combinations with variable emission scaling factors	0
NAR2	Number of buoyant polygon area sources in BAEMARB.DAT file(s)	0

INPUT GROUP: 15 -- Line Source Parameters		
Parameter	**Description**	**Value**
NLN2	Number of buoyant line sources in LNEMARB.DAT file	0
NLINES	Number of buoyant line sources	0

INPUT GROUP: 15 -- Line Source Parameters		
Parameter	**Description**	**Value**
ILNU	Units used for line source emissions (e.g., 1 = g/s)	1
NSLN1	Number of source-species combinations with variable emission scaling factors	0
NLRISE	Number of distances at which transitional rise is computed	6

INPUT GROUP: 16 -- Volume Source Parameters		
Parameter	**Description**	**Value**
NVL1	Number of volume sources	0
IVLU	Units used for volume source emissions (e.g., 1 = g/s)	1
NSVL1	Number of source-species combinations with variable emission scaling factors	0
NVL2	Number of volume sources in VOLEMARB.DAT file(s)	0

INPUT GROUP: 17 -- FLARE Source Control Parameters (variable emissions file)		
Parameter	**Description**	**Value**
NFL2	Number of flare sources defined in FLEMARB.DAT file(s)	0

INPUT GROUP: 18 -- Road Emissions Parameters		
Parameter	**Description**	**Value**
NRD1	Number of road-links sources	0
NRD2	Number of road-links in RDEMARB.DAT file	0
NSFRDS	Number of road-links and species combinations with variable emission-rate scale-factors	0

INPUT GROUP: 19 -- Emission Rate Scale-Factor Tables		
Parameter	**Description**	**Value**
NSFTAB	Number of emission scale-factor tables	0

INPUT GROUP: 20 -- Non-gridded (Discrete) Receptor Information		
Parameter	**Description**	**Value**
NREC	Number of discrete receptors (non-gridded receptors)	31
NRGRP	Number of receptor group names	0

Appendix E: Receptor locations tabulated

Table E.1: Discrete receptor locations

Receptor ID	X (UTM, m)	Y (UTM, m)	Base elevation (m)	Receptor description
R1	280935.41	5978576.13	37.18	84 Spindler Road
R2	281033.37	5978462.55	47.31	84 Spindler Road
R3	281111.58	5978284.23	51.82	80 Spindler Road
R4	281505.45	5978046.23	57.54	78 Spindler Road
R5	281360.22	5978020.72	59.49	78 Spindler Road
R6	280980.08	5977983.24	48.86	72 Spindler Road
R7	280961.34	5977897.35	54.83	70 Spindler Road
R8	281076.90	5977859.09	66.29	74 Spindler Road
R9	281358.94	5977837.85	88.40	76 Spindler Road
R10	280452.11	5976611.39	26.94	1232 SH1
R11	280213.07	5976535.86	32.13	1282 SH1
R12	280649.92	5976300.93	52.31	1232 SH1
R13	280275.15	5975966.50	36.96	1207 SH1
R14	280493.31	5975826.29	35.56	1207 SH1
R15	283452.38	5974571.97	103.95	795 SH1
R16	283541.99	5974685.27	87.75	795 SH1
R17	283629.29	5974778.60	81.38	792 SH1
R18	283724.57	5974766.81	82.55	776 SH1
R19	283854.06	5974678.30	82.29	762 SH1
R20	283797.78	5974559.75	80.96	761A SH1
R21	283687.42	5974478.89	104.58	761B SH1
R22	284128.99	5974482.00	86.18	728 SH1
R23	284234.86	5974242.28	103.27	701 SH1
R24	284293.84	5974222.62	98.58	701 SH1
R25	284377.03	5974385.20	96.36	696 SH1
R26	284429.20	5974294.46	97.86	696 SH1
R27	284903.08	5973971.71	152.65	94 Waiwhiu Road
R28	284923.01	5974480.19	158.66	109 Waiwhiu Road
R29	284934.83	5974906.34	148.56	149 Waiwhiu Road
R30	285211.26	5975061.27	131.76	172 Waiwhiu Road
R31	285415.69	5975144.84	133.89	190 Waiwhiu Road
R32	282600.00	5978200.00	171.20	302 Wilson Road

Appendix F: Receptor location plan

- **Receptor location plan – overview**
- **Receptor location plan – southeast of proposed landfill**
- **Receptor location plan – west of proposed landfill**

Figure Appendix F.1: Receptor location plan - overview

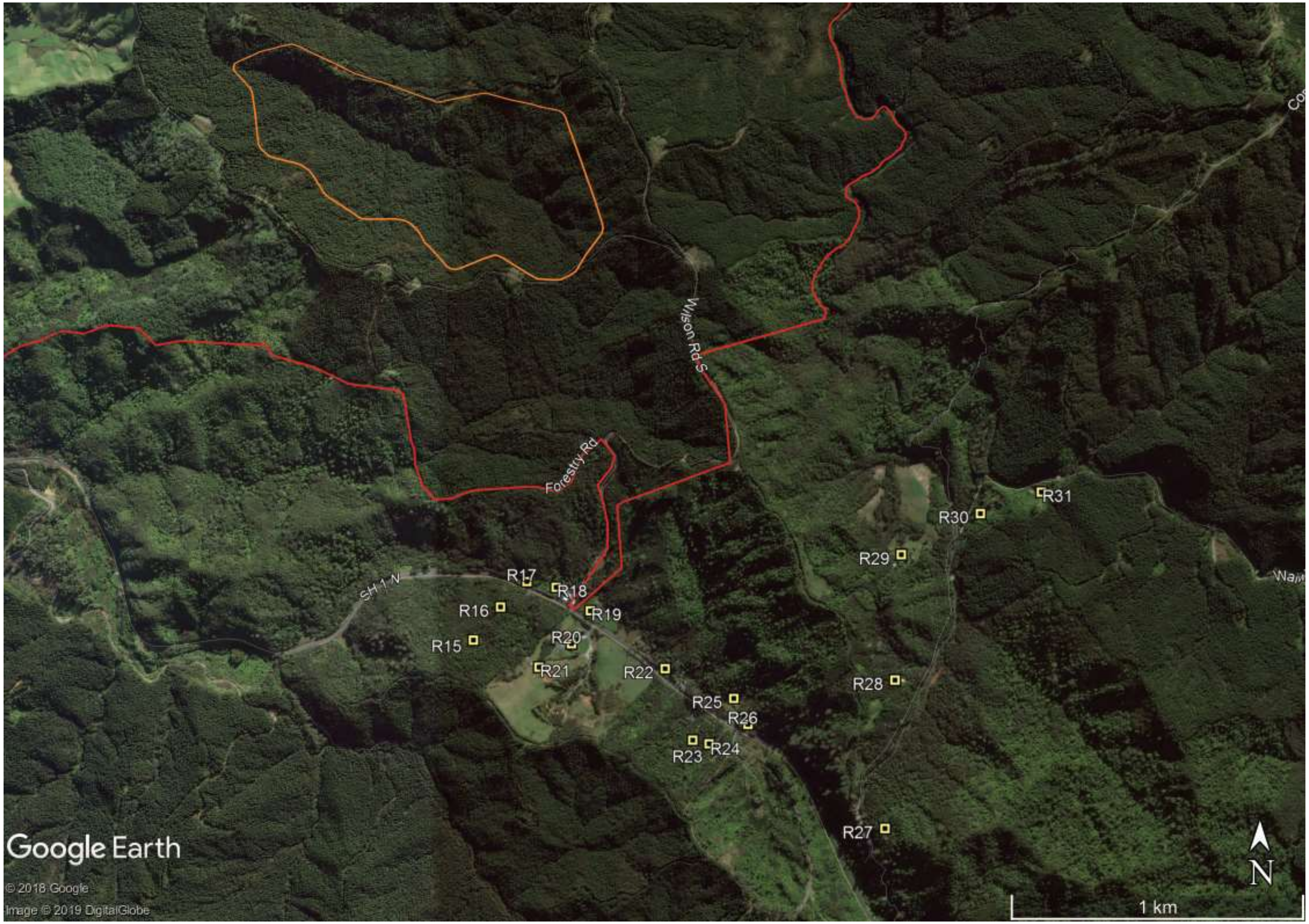


Figure Appendix F.2: Receptor location plan - southeast

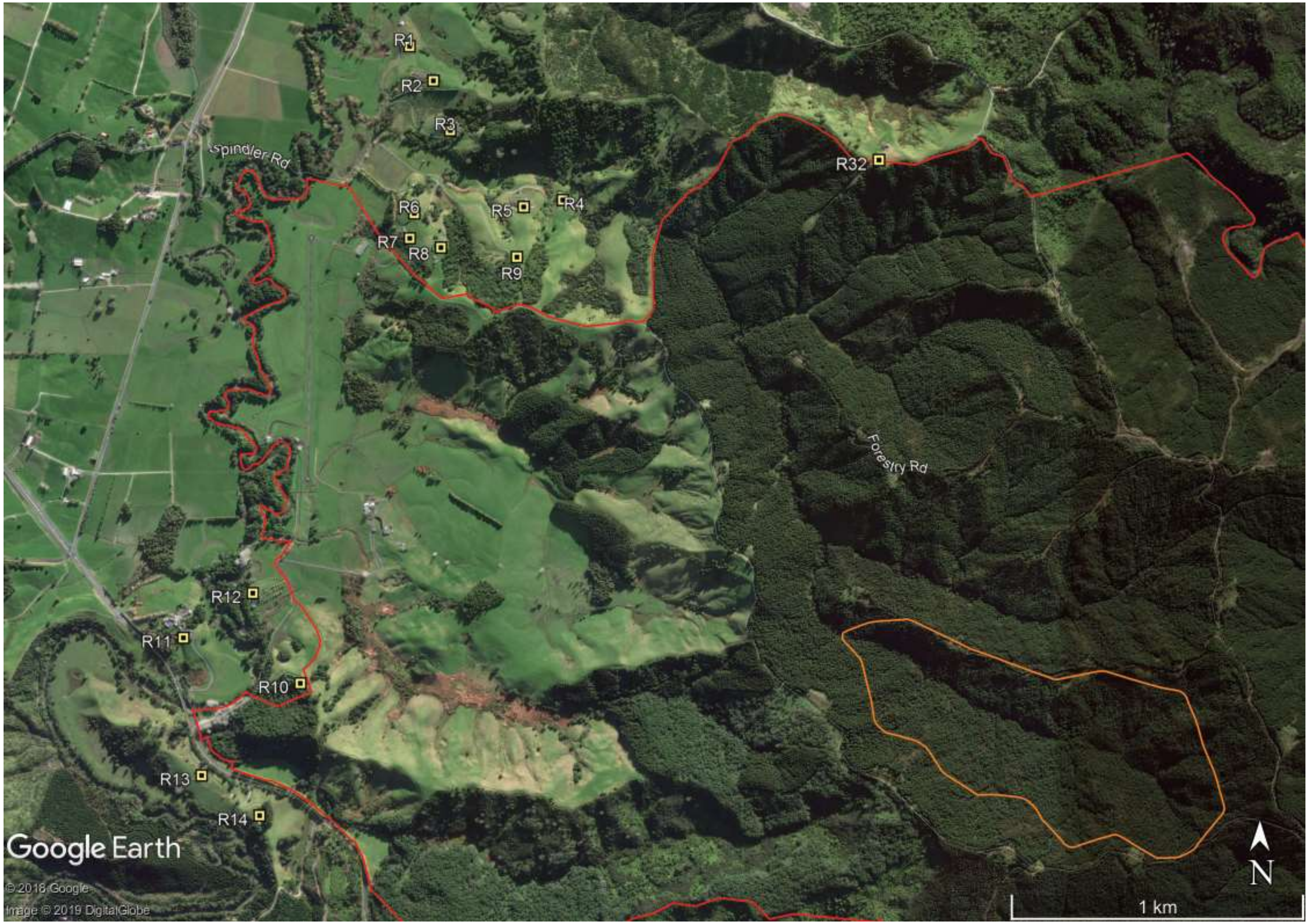


Figure Appendix F.3: Receptor location plan - west

www.tonkintaylor.co.nz

Appendix C: Landfill Gas generation rate estimates

C1 Overview

The rate at which landfill gas (LFG) is generated declines with time and this is often represented as an exponential decay. The rate of the decay over time is strongly influenced by temperature, moisture content, availability of nutrients and pH.

The most widely used LFG prediction model is the first order model. The simplest approach is the single stage first order decay such as the Scholl Canyon Model, which assumes that waste degradation parameters are constant over the analysis period.

The model assumes that the gas production rate is at its peak upon initial waste placement, after a lag time during which anaerobic conditions are established in the landfill. The gas production rate is then assumed to decrease exponentially (i.e. first order decay) as the organic fraction of the landfill waste decreases. The total methane generation from the entire landfill is generally assumed to be at its peak upon the landfill closure if a constant annual acceptance rate is assumed.

The model calculates methane production rates, and these are converted to total LFG using the average methane concentration of 50%.

The Scholl Canyon equation is as follows:

$$Q_{Methane} = L_0R(e^{-kc} - e^{-kt})$$

Where:

$Q_{Methane}$ = Methane generation rate at time t (cubic metres per year)

L_0 = Methane generation potential (cubic metres per tonne of waste)

R = Average annual waste acceptance rate during the active life (tonnes per year)

k = Methane generation rate constant (1/year)

c = Time since closure (c=0 when the landfill is active) (years)

t = Time since initial waste placement (years)

The annual waste acceptance rate (R) has been set at 500,000 tonnes. The selection of values used of the key parameters of L_o and k are discussed in more detail below.

C2 Methane generation potential (Lo)

The theoretical maximum yield of landfill gas from a tonne of municipal solid waste is dependent upon its composition. However, an estimate based upon balanced stoichiometric equations for a mixture of paper waste and food waste probably provides an upper limit of the potential yield. In practice, the gas yield is considerably less than this.

Some researchers have reported “obtainable Lo” which accounts for the nutrient availability, pH, and moisture content within the landfill. The researchers point out that “obtainable Lo” is less than the theoretical Lo. Even though waste may have a high cellulose content, if the landfill conditions are not hospitable to the methanogens, the potential methane generation capacity of the waste may never be reached. The “obtainable Lo” is approximated from overall biodegradability of "typical" composite waste or individual waste components, assuming a conversion efficiency based on landfill conditions.

The maximum “obtainable Lo” for typical waste streams is 170 m^3/tonne for a 100% organic waste stream. Therefore it is possible to estimate the appropriate Lo value on the basis of assumptions around the percentage of organic material in the incoming waste.

Schedule 3 of the Climate Change (Unique Emissions Factors) Regulations 2009 provides guidance on the default waste composition for New Zealand and corresponding Lo values. Based on this data a default Lo value of 79 m^3/tonne can be calculated and has been selected as the lower bound value in this assessment. This value is equivalent to an organic fraction of approximately 46%. In order to test the sensitivity of the assessment an upper bound value of 100 m^3/tonne (equivalent to a 60 % organic fraction) has also been adopted.

Upper bound L_o: 100 m^3/tonne (equivalent to 60 % organic fraction)

Lower bound L_o: 79 m^3/tonne

C3 Methane generation rate constant (k)

The methane generation rate constant, k, describes how quickly the methane generation rate decreases, once it reaches the peak rate after waste has been placed. The higher the value of k, the faster the methane generation rate from each sub-mass decreases over time.

The value of k is a function of:

- Waste moisture content;
- Availability of nutrients;
- Ph;
- Temperature; and
- Nature of the waste (whether it degrades rapidly or slowly).

The higher the value of k, the greater the predicted peak LFG generation rate and the more quickly the LFG production will decrease once the landfill is closed.

Schedule 3 of the Climate Change (Unique Emissions Factors) Regulations 2009 provides guidance on the default waste composition for New Zealand and corresponding k values. Based on this data a default Lo value of 0.063 $year^{-1}$ can be calculated and has been selected as the k value in this assessment.

C4 Landfill gas emission predictions

Upper bound and lower bound estimates have been made of landfill gas generation rates, using the upper and lower bound values of Lo as shown in Figure Appendix C.1. The peak rate of LFG generation, which will occur around the year of landfill closure, is estimated to be between 8,800 and 11,100 m^3/hour.

The dispersion modelling has assumed a maximum of 12 electricity generators will be installed at the Landfill, and has used the upper bound estimate to calculate the maximum rate of flaring of residual LFG. This is likely to over-estimate the rate of flaring.

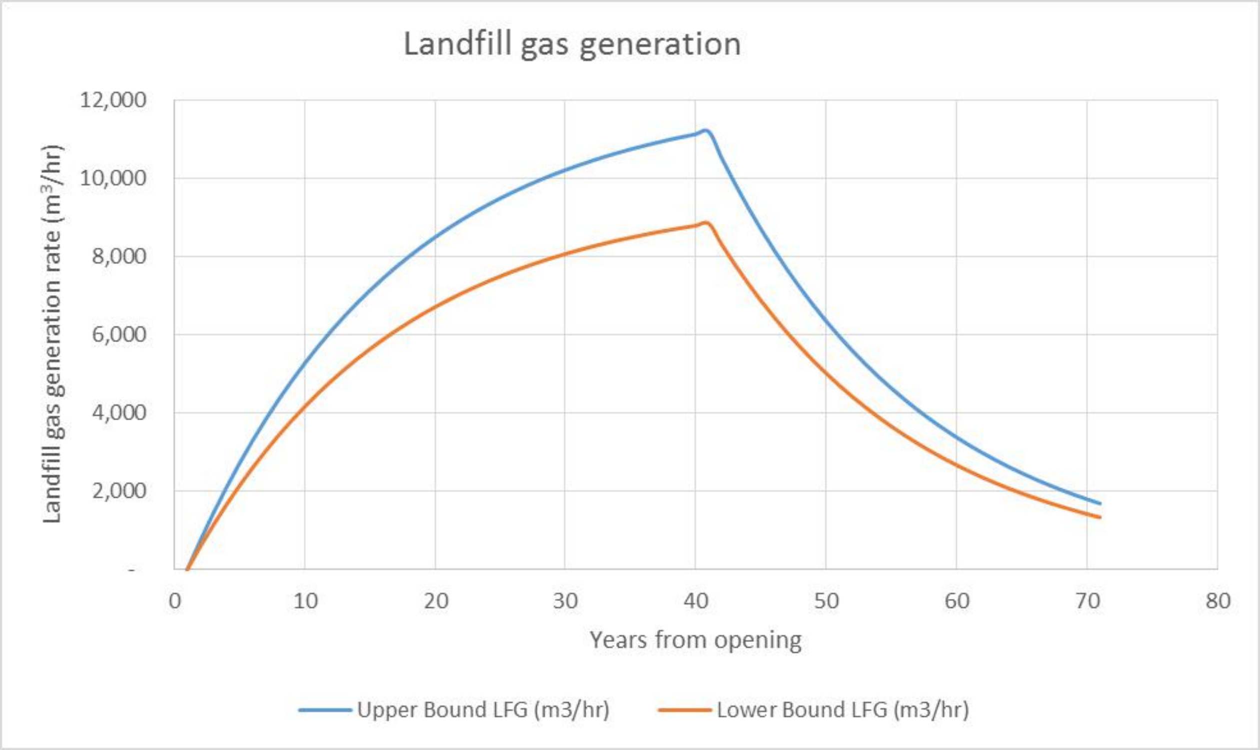


Figure Appendix C.1: Predicted rates of LFG generation

www.tonkintaylor.co.nz