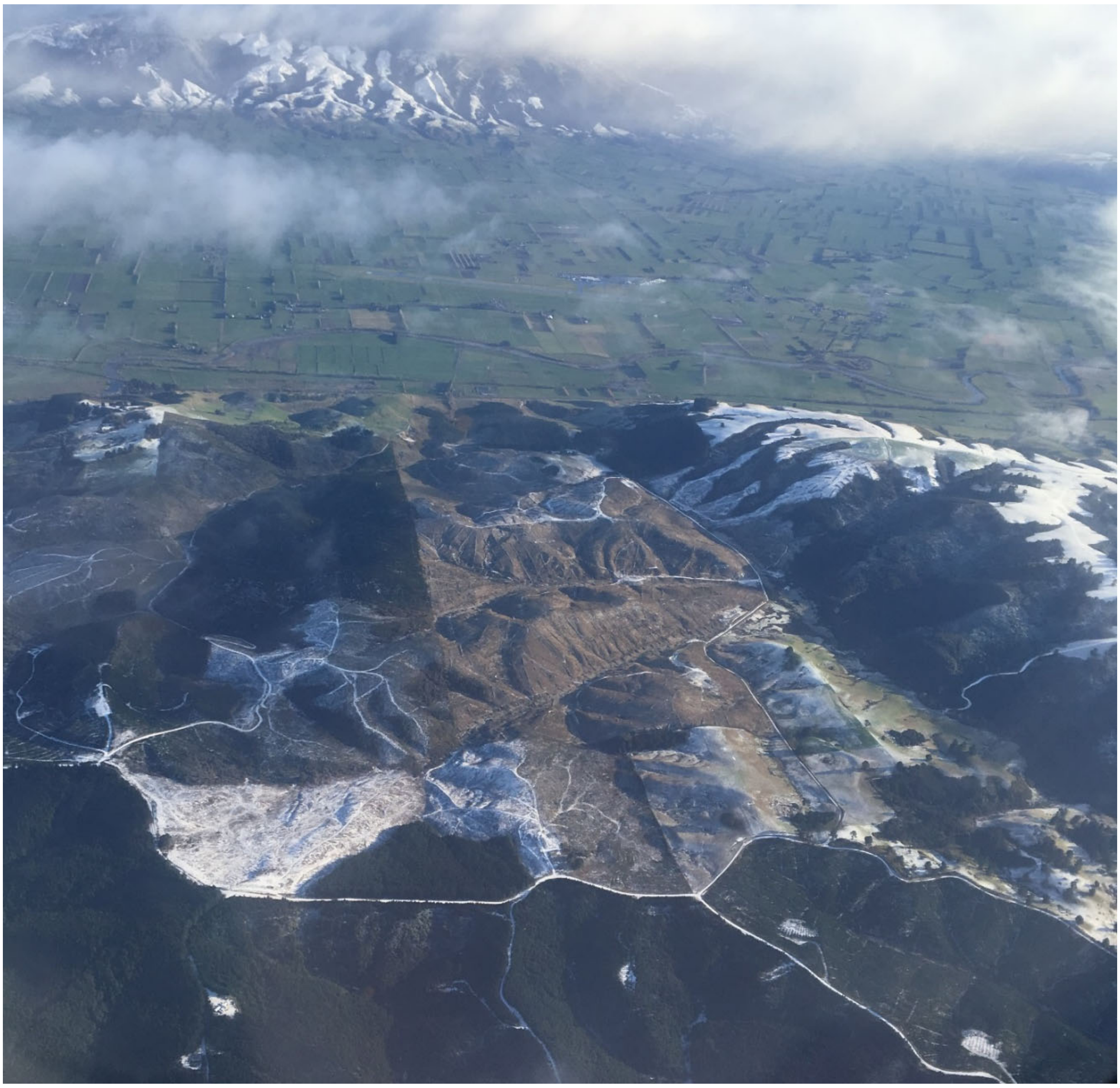
Appendix 10: Air Quality Report



Dunedin City Council

DCC Smooth Hill Consenting
Air Quality Assessment

August 2020
(updated
May 2021)

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Abbreviations

Abbreviation	Term
AEE	Assessment of Effects on the Environment
ACGD	Auckland Council's guidance document on background concentrations
AWS	Automatic Weather Station (operated by MetService)
2GP	Dunedin City 2nd Generation District Plan
CCL	Compacted Clay Liner
CO	Carbon monoxide
DCC	Dunedin City Council
ENSO	El Niño-Southern Oscillation
EPA Victoria	Environment Protection Authority Victoria
FIDOL	Frequency, Intensity, Duration, Offensiveness and Location
FML	Flexible Membrane Liner
GPG	Good practice guide
H_2S	Hydrogen sulphide
IAQM Odour	Institute of Air Quality Management's (IAQM) guidance document on the assessment of odour for planning, July 2018
LandGEM	Landfill Gas Emissions Model
LFG	Landfill Gas
LMP	Landfill Management Plan
MetService	Meteorological Service of New Zealand Limited
MfE	Ministry for the Environment
MfE, ADM	Ministry for the Environment, Good Practice Guide for Atmospheric Dispersion Modelling
MfE Dust	Ministry for the Environment, Good Practice Guide for Assessing and Managing Dust
MfE ID	Ministry for the Environment, Good Practice Guide for Assessing Discharges to Air from Industry
MfE Odour	Ministry for the Environment, Good Practice Guide for Assessing and Managing Odour in New Zealand, 2016
NESAQ	National Environmental Standards for Air Quality
NASA	National Aeronautics and Space Administration
NIWA	National Institute of Water and Atmospheric Research
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen
NZAAQG	Ministry for the Environment, Ambient Air Quality Guidelines
NZTM	New Zealand Transverse Mercator

Abbreviation	Term
ORC	Otago Regional Council
OU	Odour unit
PM_{10}	Particulate matter with an aerodynamic diameter less than 10 micrometres in size.
$PM_{2.5}$	Particulate matter with an aerodynamic diameter less than 2.5 micrometres in size.
RAQT	Regional Air Quality Targets
RL	Relative Level
RMA	Resource Management Act 1991
SR	Sensitive Receptor
SO_2	Sulphur dioxide
SRTM	Shuttle Radar Topography Mission
TAPM	The Air Pollution Model
UTM	Universal Transverse Mercator
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
VOC	Volatile organic compounds
WHO AQG	World Health Organisation air quality guideline
WMMP	Waste Management Minimisation Plan 2013
t/per annum	Rate of filling: Tonnes per annum
m^3/LFG/year	Cubic meters of landfill gas per year
m^3/LFG/h	Cubic meters of landfill gas per hour
m asl	Metres above sea level
%	Percent
dscm	Dry standard cubic metres
ppm	Unit of concentration: parts per million
mg/m^3	Unit of concentration: milligrams per cubic metre
Km/hr	Unit of speed: kilometres per hour
km	Length scale or distance (as ‘kilometres’)
m	Length scale or distance (as ‘metres’)
m^3	Unit of volume: cubic metres
°C	Unit of temperature: degrees centigrade

1. Introduction

1.1 Background

The Dunedin City Council (Council) collects residential waste and manages the disposal of both residential and most commercial waste generated from the Dunedin City area and environs.

The Council has embarked on the Waste Futures Project to develop an improved comprehensive waste management and diverted material system for Dunedin, including future kerbside collection and waste disposal options. As part of the project, Council has confirmed the need to develop a new landfill to replace Council's current Green Island Landfill, which is envisaged to reach full capacity in the next few years. Final closure could be around 2028 depending on the closure strategy adopted by the Council.~~come to the end of its functional life sometime between 2023 and 2028.~~

Council commenced siting studies for a new landfill location in the late 1980s and early 1990 and selected the Smooth Hill site in south-west Dunedin as the preferred location. At that time, the site was designated in the Dunedin District Plan, signalling and enabling its future use as a landfill site. Council also secured an agreement with the then landowner, Fulton Hogan Ltd, to purchase the land and the Council took ownership of the land in September 2020. Since the 1990's the Council extended the life of Green Island Landfill and further development of the Smooth Hill site has been on hold.

As part of the Waste Future's Project, Council has reconfirmed the technical suitability of Smooth Hill for the disposal of waste and has developed a concept design landfill and associated road upgrades. The concept design (the subject of this report) for the landfill has been developed by GHD with technical input from Boffa Miskell and represents contemporary good practice landfill design that meets adopted New Zealand landfill design standards.

The Council lodged applications for resource consents for Smooth Hill landfill with both the Otago Regional Council and Dunedin City Council in August 2020. The applications included an earlier version of this report.

This report has now been updated to reflect both the changes in the design and in response to specific s92 questions. The key changes to the design are summarised below:

- The landfill size has been reduced. The revised landfill lies within the footprint of Stage 1 and Stage 2 of the original design, with the western Stages 3, 4 and 5 no longer included (for comparison see Drawings C102 and C104). In overall terms:
  - the footprint of the landfill is reduced from 44.5 ha to 18.6 ha
  - landfill (gross) capacity is reduced from approximately 7.9-million m^3 to 3.3-million m^3
  - net waste capacity is reduced from 6.2-million m^3 to 2.9-million m^3
  - the predicted landfill life has reduced from 55-years to 40-years
- Practical adjustments to the general construction of the landfill, including:
  - Landfill staging and construction sequencing, to a more typical 'bottom-up' filling methodology, which improves the intermediate and overall landform stability of the new design (Drawing C202 and C210 to C214)
  - Leachate containment and collection systems adjusted to reflect the revised construction sequencing
  - Construction phase systems for stormwater diversion, treatment and control
  - Relocation of the attenuation basin to the west of the revised landfill footprint rather than immediately downstream of the landfill toe.

1.2 Project overview

The proposal includes the following key components:

- ~~The staged construction, operation, and aftercare of a Class 1 landfill within the existing designated site to accept municipal solid waste. The landfill will have a capacity of approximately 6 million cubic metres (equivalent of 5 million tonnes), and expected life (at current Dunedin disposal rates) of approximately 55 years.~~ The landfill will receive waste only from commercial waste companies or bulk loads
- Infrastructure to safely collect, manage, and dispose of landfill leachate, gas, groundwater, and stormwater to avoid consequential adverse effects on the receiving environment
- Facilities supporting the operation of the landfill, including staff and maintenance facilities
- Environmental monitoring systems
- Landscape and ecological mitigation, including planting
- Upgrades to McLaren Gully Road including its intersection with State Highway 1, and Big Stone Road, to facilitate vehicle access to the site
- Construction and operation of a new landfill access from Big Stone Road

1.3 Purpose of this report

GHD has been engaged by Dunedin City Council to prepare an air quality assessment of the potential effects associated with air discharges from Smooth Hill Landfill to support a resource consent application to the Otago Regional Council (ORC) for an air discharge consent. The scope of works for the assessment is outlined in section 1.4 below.

1.4 Scope of works

GHD has undertaken an air quality assessment which includes the following scope of works:

- Meteorological modelling to determine the likely onsite weather conditions
- ~~Qualitative a~~Assessment of landfill odour, including qualitative assessment and atmospheric dispersion modelling
- Qualitative assessment of construction and operational dust
- Atmospheric dispersion modelling of combustion emissions associated with the landfill gas flare(s)
- Provide recommendations for appropriate mitigation measures to control odour and dust
- The assessment undertaken in this report has been carried out in accordance with the following guidance documents:
- MfE Good Practice Guide for Assessing and Managing Dust1 (GPG Dust)
- MfE Good Practice Guide for Assessing Discharges to Air from Industry2 (GPG ID)
- MfE Good Practice Guide for Atmospheric Dispersion Modelling (GPG ADM)3
- MfE Good Practice Guide for Assessing and Managing Odour (GPG Odour)4

[1] Ministry for the Environment Good Practice Guide for Assessing and Managing Dust, November 2016

[2] Ministry for the Environment Good Practice Guide for Assessing Discharges to Air from Industry, November 2016

[3] Ministry for the Environment Good Practice Guide for Atmospheric Dispersion Modelling, June 2004

[4] Ministry for the Environment Good Practice Guide for Assessing and Managing Odour, November 2016

- Air Quality Management's (IAQM) guidance document on the assessment of odour for planning5 (IAQM Odour)

1.5 Assumptions

The following assumptions have been used in preparing this report:

- Meteorological data has been provided by MetService has been assumed to be accurate and free of errors
- Information on the design of the landfill is based on GHD's Smooth Hill Design Report[6] and Landfill Gas Report[7], dated May 2021~~0~~

[5] Institute of Air Quality Management's (IAQM) guidance document on the assessment of odour for planning, July 2018

[6] GHD, Waste Futures Phase 2 – Work stream 3 Smooth Hill Landfill, Landfill Concept Design report, May 2021

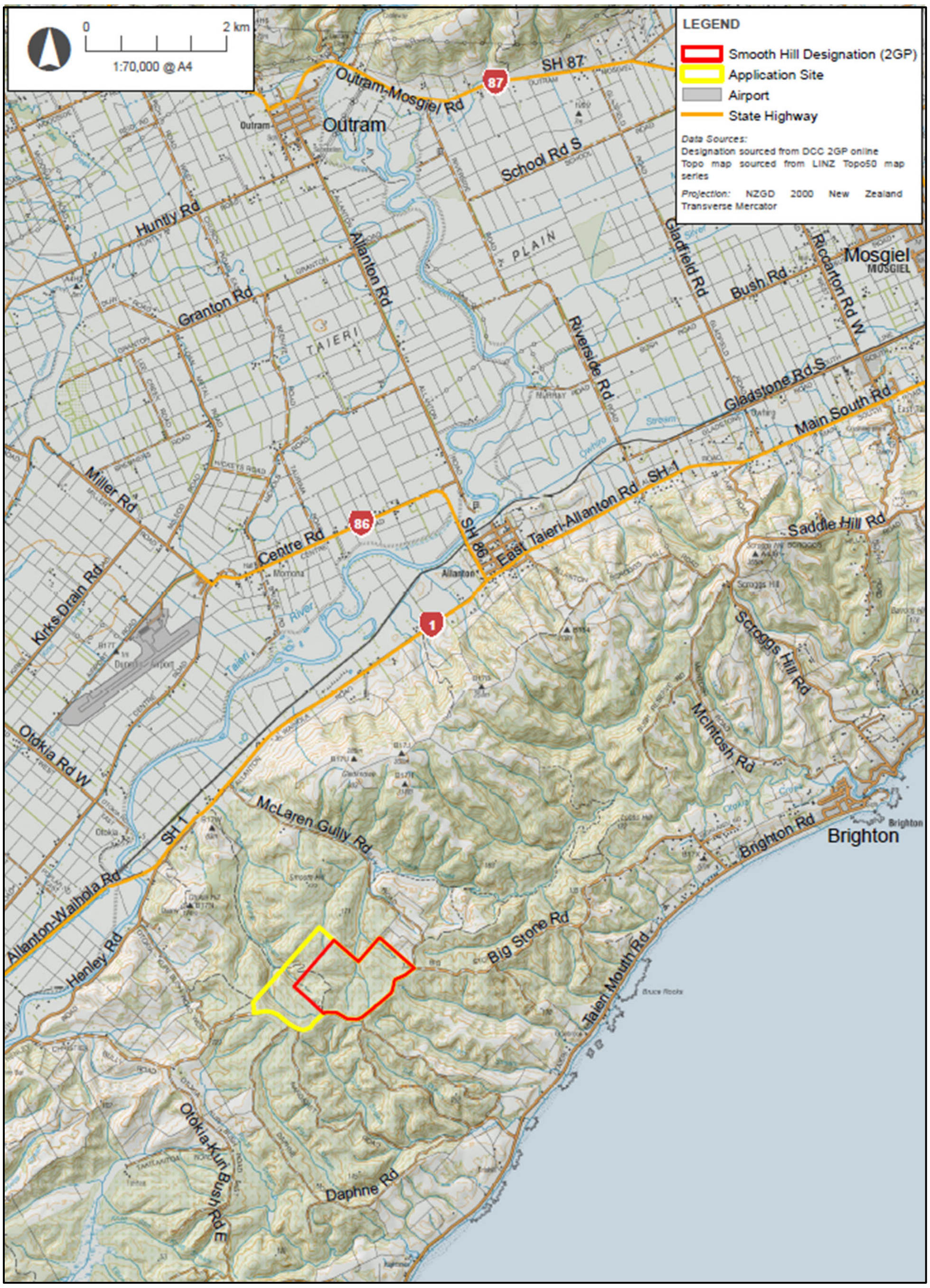
[7] GHD, Smooth Hill Landfill Gas Design Report, May 2021

2. Site description and existing environment

2.1 Site location

The Smooth Hill Landfill (herein referred to as 'The Site') is located approximately 28 km from the CBD of Dunedin. Nearby features include the Dunedin International Airport approximately 4.5 km to the north-northeast, and a cemetery approximately 1.9 km east-northeast. The site is located approximately 2.7 km northeast of the coastline. Figure 2-1 shows the location of the site.

Figure 2-1: Site and surrounding environment **(Updated May 2021)**



2.1.1 Land zoning

The Site is located on land zoned as “coastal rural” in the Dunedin City 2nd Generation District Plan (2GP) Planning Map[8], within a boundary marked for designated use. This designation relates to the use of the site as a future landfill. The designation has been in place since 1996. Adjacent land is zoned as ‘coastal rural’. Rural land zones are allocated within the plan to provide for primary production activities such as pastoral farming, forestry, mining and resource-based activities and also to protect ecosystem services such as water resources and indigenous habitat (2GP, section 16).

There are several small areas within the 2GP archaeological alert layer southwest of the site boundary. These are areas where it is known or anticipated that archaeological remains are present. The 2GP requires people undertaking land development activities across those areas to contact Heritage New Zealand before commencing work (2GP, section 13).

2.2 Topography and effect on wind patterns

The landfill site is located in a natural “amphitheatre”, which is bisected by a larger central ridge and a smaller ridge in the south-western corner – both trending south to north. The site typically has side slopes of 20%. A south to north system of gullies passes through the site, which are dry most of the year with flowing water only after rainfall. The gullies coalesce into a single gully at the north of the site and join a semi -permanent stream that passes under McLaren Gully Rd via a culvert. The stream then joins the Otokia Creek that ultimately flows to the coast near Brighton, approximately 10 km south-east of the landfill site.

Big Stone Road runs along a ridge on the south-eastern edge of the site and is the catchment divide. To the south of Big Stone Road, the land drains directly to the Pacific Ocean via a series of gullies and streams (from north to south Graybrook Stream, Fern Stream, Tutu Stream and Open Stream).

The lowest elevation within the landfill site is the base of the gully at Reduced Level (RL) 100 m rising to the ridgeline on Big Stone Road typically RL 140 m to RL 150 m and up to RL 180 m in the southwest corner of the site.

Regional and local topography can significantly influence the pattern of winds observed or predicted at a site location. GHD has been unable to locate any suitable meteorological data for representative of onsite conditions and has therefore relied on the outputs of meteorological modelling to determine site conditions. It should be noted that an on-site met station has been established and has been collecting information since mid-2020. With time this will provide good quality on--site data. In this report it has been used to provide validation of the completed analysis. The station has been installed in the vicinity of the proposed access to the landfill site from Big Stone Road (see Drawing C702)

A review of the meteorological model outputs as well as surface observations at Dunedin Airport (as detailed in section 8) suggests that local and regional wind fields at the site are influenced by topographical features. An exaggerated terrain map (30 m resolution) is shown for the meteorological model domain in Figure 2-2. Indicative locations of the site (yellow marker) and Dunedin Airport automatic weather Station (AWS) (red marker) are shown on the figure. An aerial photograph which shows local terrain features is shown in Figure 2-3.

The major topographic feature contribution to the regional wind field is the valley within which the Dunedin Airport is located, being the Taieri Plains. Wind fields observed in this valley are strongly aligned with the valley orientation and model predicted wind speeds within the valley

[8] Dunedin City Council 2019. 2nd Generation District Plan (2GP). Retrieved from https://www.dunedin.govt.nz/council/district-plan/2nd-generation-district-plan

are significantly greater in comparison to ridgeline (elevated, site) location. Both are indicative of channelling of regional winds into the valley. Model predicted wind patterns at the site location are less aligned with the valley orientation but are suggested to be more well aligned with wind patterns above the valley (>100 m above sea level).

Analysis of the local wind field predicted shows some local topographical influences during periods of light winds and stable atmospheric conditions. Most notably so is apparent drainage of wind flow (including air pollutants) into the major gulley north of the site. During the infrequently predicted southerly or south-easterly winds, flows moving from site followed this drainage pattern.

Figure 2-2: Local topography (The Site and Dunedin Airport AWS are shown as yellow and red markers, respectively)

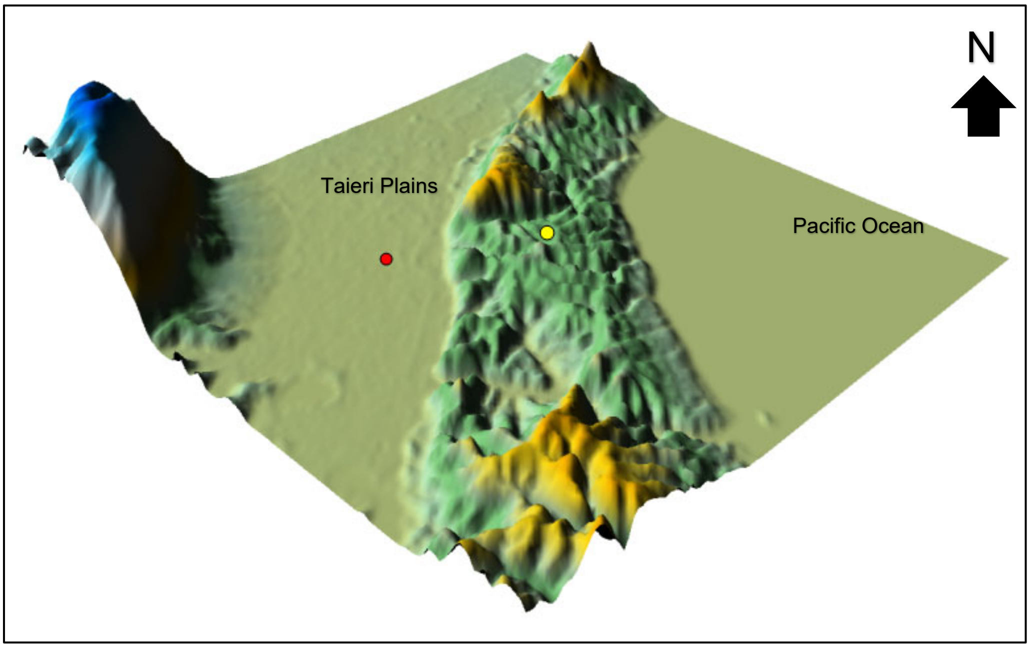
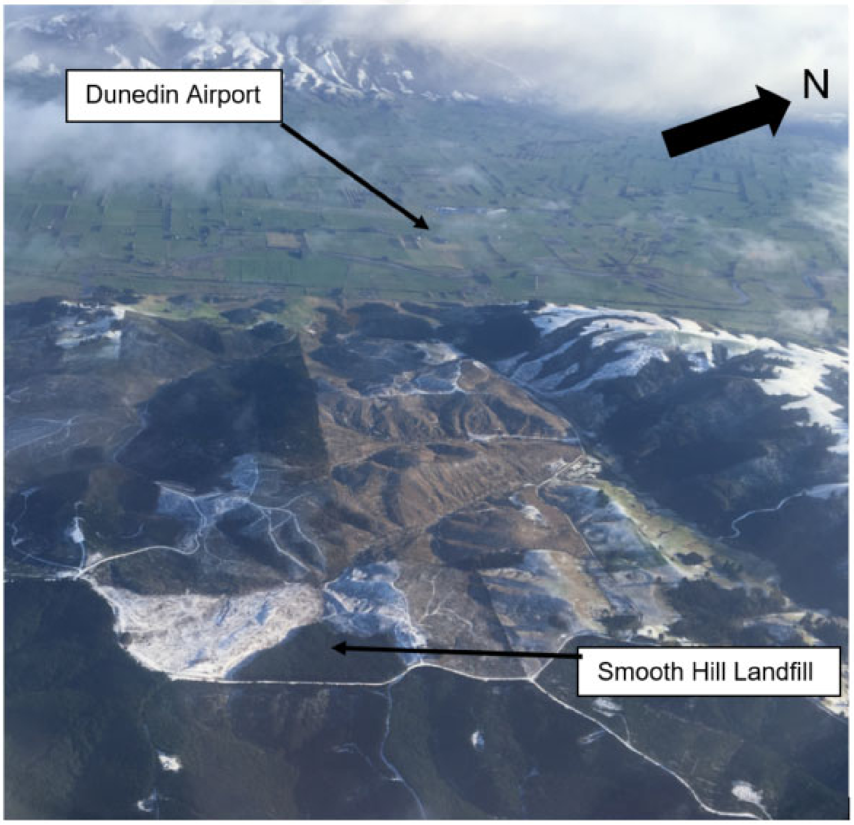


Figure 2-3: Aerial photograph of the site



2.3 Existing air quality

2.3.1 Receiving environment

The Site is located in a rural area and consists of a series of relatively steep gullies towards the north. The Site and surrounding areas are primarily used for forestry activities, of which a large portion of The Site has already been logged and replanted over the past 7~~5~~ years. Given the rural environment, people living in and visiting rural areas generally have a high tolerance for rural activities and their associated effects. Although these people can be desensitised to rural activities, they may still be sensitive to other types of activities (including odours associated with landfills). Therefore, residential dwellings are considered to be sensitive receptors to the effects of air emissions, particularly nuisance odour and dust.

2.3.2 Air pollutants of concern

The contaminants of interest for this assessment are air pollutants associated with the combustion of landfill gas (LFG), these include:

- Particulate matter, expressed as particles with an aerodynamic diameter less than 10 (PM_{10}) and 2.5 ($PM_{2.5}$) micrometres in size
- Oxides of nitrogen (NO_X), particularly nitrogen dioxide (NO_2); sulphur dioxide (SO_2); and
- Carbon monoxide (CO)

In addition to combustion emissions, nuisance dust and odour emissions are considered to be of potential concern.

GHD has identified the following possible sources of air pollutants in the area:

- Dust emissions from forestry-related activities and vehicle traffic along McLaren Gully Road and Big Stone Road (both unsealed)

- Motor vehicle emissions from local roads and State Highway 1 (approximately 3 km west of the landfill footprint)
- Domestic heating emissions (mainly in winter)
- Discharges from agricultural activities, which may include burning of vegetation, aerial spraying, ground-based fertiliser application, etc.

2.3.3 Existing odour sources

The presence of existing odour sources increases the risk of impact from a new industrial site by adding cumulative odour effects. There are currently no significant odorous land uses near The Site, which eliminates the risk of cumulative odour impacts. The nearest land features include residential properties and a cemetery, which are not anticipated to generate odour. The Dunedin International Airport, located approximately 4.5 km from site, is not expected to contribute to odour concentrations from The Site.

2.3.4 Background air quality

ORC has defined three air sheds within the region. Air Zone 1 and Air Zone 2 are identified as likely to breach National Environment Standards for Air Quality[9] (NESAQ) standards for PM_{10}, The Site is located in Air Zone 3 which complies with NESAQ standards. ORC's air quality monitoring is focussed on Air Zones 1 and 2 and therefore the data is not considered representative, as air quality at the site is expected to be excellent.

In the absence of local air quality monitoring data, the GPG ID recommends using default background air quality values, however the guidance does not provide any information on $PM_{2.5}$ or annual average PM_{10} background concentrations. GHD has therefore used annual PM_{10} and 24-hour and annual $PM_{2.5}$ values provided in Auckland Council's guidance document on background concentrations[10] (ACGD), for the Patumahoe monitoring site. The Patumahoe monitoring data is considered to be analogous to The Site as it is located in a rural location with no significant industrial or vehicle emissions sources nearby. A summary of the background concentrations used in this assessment are presented in Table 1.

Table 1 Background air quality concentrations

Contaminant	Parameter	Concentration (µg/m³)	Source
PM_{10}	24-hour	19	GPG ID[11]
	Annual Average	12	ACGD
$PM_{2.5}$	24-hour	11	ACGD
	Annual Average	4	ACGD
SO_2	All averaging periods	0[12]	GPG ID
CO	1-hour average	5,000	GPG ID
	8-hour average	2,000	GPG ID
NO_2	1-hour average	37	GPG ID
	24-hour average	23	GPG ID
	Annual	4	GPG ID

[9] MfE, Resource Management (National Environmental Standards for Air Quality) Regulations, 2004 (NESAQ) (MfE, 2004)

[10] Use of Background Air Quality Data in Resource Consent Applications (2014)

[11] based on the NZTA on-line tool as prescribed in the MFE GPG Industry

[12] MFE GPG Industry only provides urban SO_2 background concentrations. It is inferred that rural SO_2 concentrations are negligible.

2.4 Sensitive receptors

For this assessment the term 'sensitive receptor' includes any person, location, or system that may be susceptible to changes in 'abiotic' factors as a consequence of odours from the landfill. Given the rural location of the landfill the majority of the sensitive receptors identified are nearby residential properties.

2.4.1 Existing receptors

GHD has identified all residential and commercial properties within 3.5 km of the site. These receptors are summarised in Table 2 and shown on Figure 2-4. The table includes potential receptors and the locations of these potential receptors has been based on the most logical place within the property for a dwelling to be established.

GHD is not aware of any current proposals for residential dwellings on these properties. GHD has therefore conservatively assumed dwellings will be built on these two properties. For the McLeod property the most logical location for a dwelling is the relatively flat and sheltered area of land immediately adjacent to McLaren Gully Road (P2). Should a dwelling be established on the McLeod property (P2) closer to the landfill than the assumed location, then additional assessment of odour and dust nuisance effects would need to be undertaken

There are currently a number of rural residential properties northwest of the site between 1.5 and 2.5 km from the landfill footprint. Three rural residences are also located southeast of the site, within 1 km from the landfill footprint. The nearest sensitive receptor is 731 Big Stone Road, approximately 380 m from the landfill footprint. Sensitive receptors are indicated by yellow indicator markers in Figure 2-4. A 1,000 m distance from the landfill footprint has been marked on the figure to assist the viewer in judging the distance of receptors.

2.4.2 Potential receptors

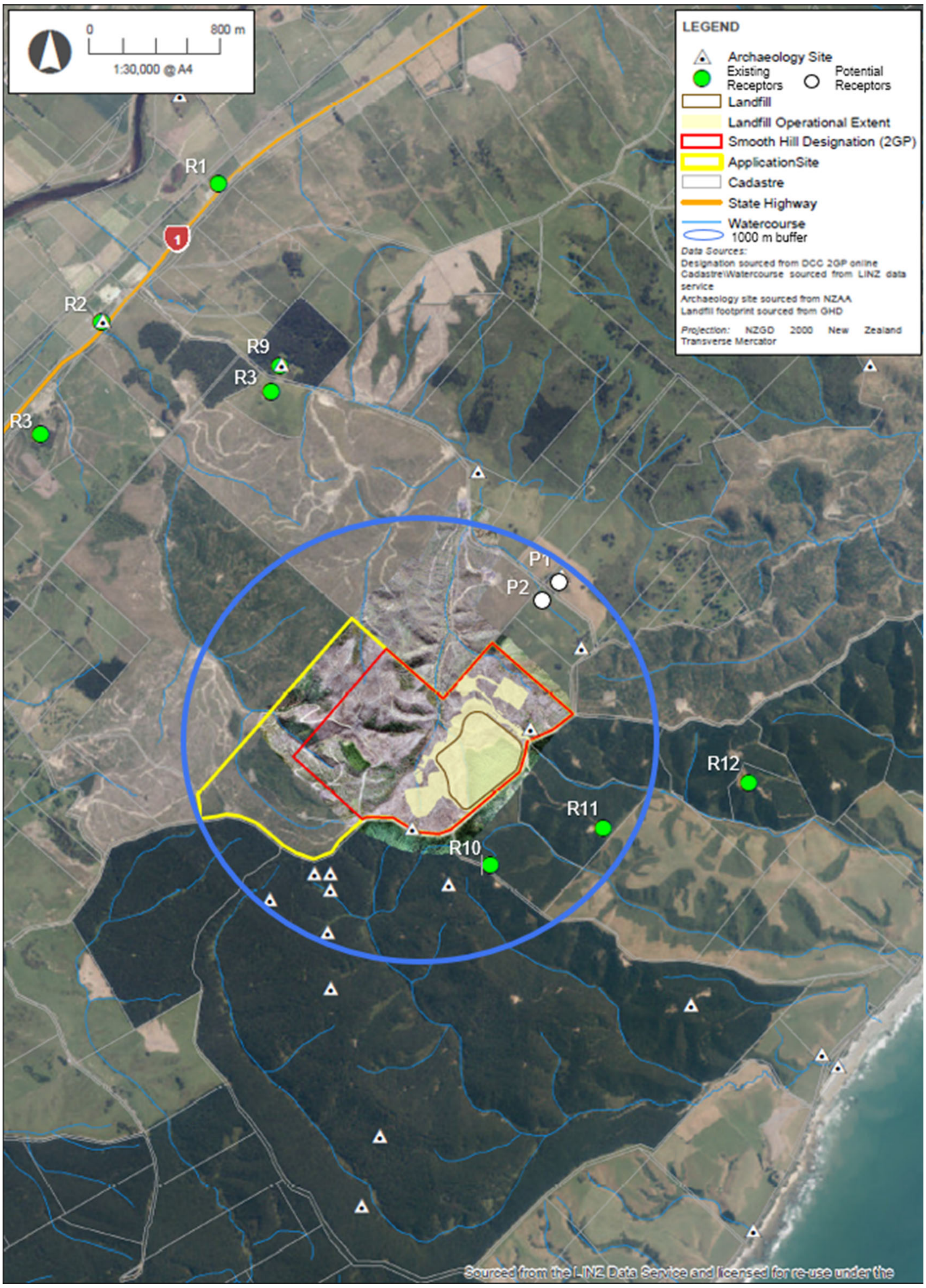
The project team has reviewed the relevant planning provisions and considers that the only potential locations where another residential dwelling could be established is on two parcels of land located immediately northeast of the landfill site. GHD has therefore conservatively included these receptors (identified as 'P1' and 'P2' in Table 2) in this assessment and assumed that a residential dwelling could be established at each of these locations. The approximate location of these properties is shown in Figure 2-4 as white markers. The location of these potential receptors has been based on the most logical place within the property for a dwelling to be established.

GHD is not aware of any current proposals for residential dwellings on these properties. GHD has therefore conservatively assumed dwellings will be built on these two properties. For the McLeod property the most logical location for a dwelling is the relatively flat and sheltered area of land immediately adjacent to McLaren Gully Road (P2). Should a dwelling be established on the McLeod property (P2) closer to the landfill than the assumed location, then additional assessment of odour and dust nuisance effects would need to be undertaken.

Table 2: Sensitive receptors incorporated into the odour assessment

Receptor ID	Type of Receptor	Address	Coordinates (NZTM (2000))	Distance (m)	Direction from the centre of the site
R1	Commercial	Allanton-Waihola Rd	1,384,492 4,908,964	3,456	North northwest
R2	Commercial	Allanton-Waihola Rd	1,383,836 4,908,188	3,200	North northwest
R3	Residential	Allanton-Waihola Rd	1,383,463 4,907,488	2,800	Northwest
R4	Commercial	Henley Road	1,382,967 4,906,979	2.920	Northwest
R5	Residential	Henley Road	1,382,911 4,906,393	2.720	West northwest
R6	Residential	Otokia Kuri Bush Rd	1,383,187 4,906,097	2.375	West
R7	Residential	Otokia Kuri Bush Rd	1,383,140 4,905,877	2.380	West
R8	Residential	McLaren Gully Rd	1,384,914 4,907,906	2,328	North northwest
R9	Residential	McLaren Gully Rd	1,384,855 4,907,761	2.230	North northwest
R10	Residential	Big Stone Rd	1,386,207 4,904,873	380	Southeast
R11	Residential	Big Stone Rd	1,386,889 4,905,095	605	East southeast
R12	Residential	Big Stone Rd	1,387,767 4,905,372	1,380	East
R13	Residential	Big Stone Rd	1,389,469 4,906,149	3.060	East northeast
R14	Residential	Big Stone Rd	1,389,343 4,906,564	3110	Northeast
R15	Residential	Big Stone Rd	1,389,203 4,906,776	3,090	Northeast
P1	Unknown - Potential Receptor	McLaren Gully Rd	1,386,674 4,906,633	970	Northeast
P2	McLeod Property	McLaren Gully Rd	1,386,674 4,906,633	810	Northeast

Figure 2-4: Receptor locations (Updated May 2021)



2.4.3 Road users

Along the southeast boundary the landfill footprint is located within 50 m of Big Stone Road. As stated in GPG Odour, public roads are considered to have a low sensitivity to adverse effects, as road users typical only experience discharges for very short periods of time. However, the potential effects on road users using nearby public roads has been incorporated into this assessment for the purposes of completeness.

3. Description of the proposal

3.1 Landfill construction

The project comprises the construction of a landfill with a waste capacity of approximately 3~~6~~ million cubic metres to provide for the safe disposal of municipal solid waste for a period in the order of 40~~55~~ years. The landfill will be designed to accept municipal solid waste in accordance with the acceptance criteria described in the Design Report[13].

The overall project will broadly comprise of the following:

- Works associated with the development of an operating landfill on the identified footprint area, including:
  - Earthworks to construct the required shape
  - Construction of a low permeability lining system to prevent leachate seepage into the surrounding environment
  - Construction of a leachate collection system above the low permeability lining system
  - Stormwater control around the constructed landfill and ultimate treatment of stormwater before it leaves the site
  - A LFG collection system to collect LFG from the placed waste
  - A leachate management system, including (leachate storage, tanker loading facilities and leachate treatment facilities
- LFG treatment by a LFG plant
- Gas flare(s) and/or gas engines
- Provision of water supplies for operational (non-potable) and staff (potable) requirements
- Upgrade of McLaren Gulley Road and Big Stone Road from State Highway 1 to the site entrance and upgrade of the State Highway 1 junction
- Operational infrastructure such as weighbridges and vehicle wheel wash
- Additional ancillary services including operation of small backup diesel generators to power leachate extraction pumps
- Facilities for site staff, including on-site wastewater disposal
- Maintenance facilities for site plant and equipment

Drawings C102 shows the location of the infrastructure associated with the landfill.

[13] GHD, Waste Futures Phase 2 - Work stream 3 Smooth Hill Landfill, Landfill Concept Design Report, May 2021~~April 2020~~.

3.2 Landfill gas collection infrastructure

Landfill gas collection and destruction is required by the NESAQ to be provided in a landfill that will exceed 1,000,000 tonnes of waste and the system must be in operation before 200,000 tonnes of waste is placed. With the predicted waste stream of 6~~9~~0,000 tonnes per annum, the gas collection and flaring system should be installed and operational within 3 to 4~~2~~ years of commencement of the landfill operation.

LFG management is described in LFG Design Report[14]. In summary, the proposed LFG management system will incorporate the following elements:

- The lining and capping systems described earlier in this report will retain LFG within the landfill and prevent off-site migration
- A LFG collection system comprising a network of collection wells and pipework;
- A destruction system using flaring with the opportunity to generate electricity once LFG quantities are sufficient
- Monitoring to confirm the effectiveness of the system, including LFG monitoring boreholes/wells outside the waste boundary and regular surface monitoring of methane emissions from the completed cap
- Buildings and structures on-site will be designed and constructed to minimise the risk of LFG entry and accumulation[15]
- Subsurface services on-site will be designed and constructed in accordance with relevant standards in relation to LFG as applicable
- Appropriate work, health and safety procedures will be developed and implemented in relation to situations where workers/site users may be at risk of being exposed to LFG emissions

The gas system will comprise vertical wells drilled into the waste after placement of the final capping. The wells will be pumped through surface pipework to a gas destruction system that will be located on a terrace constructed on the north flank of the facilities area. This location is 15 m lower than Big Stone Road and the flare will be largely screened from Big Stone Road and beyond by tree planting and the topography.

Gas destruction will be provided by flaring. The landfill operator may however install a “gas to electricity generation plant” at its’ discretion, however consent is not currently being ~~sort~~sought for this activity. This plant, if fitted, would be located at the prepared terrace where the proposed flare is located.

During filling of the landfill and before installation of permanent wells, horizontal wells will be installed in waste ~~greater~~ to allow initial abstraction of gas. These horizontal gas collection pipes will become progressively redundant as waste reaches its final formation level and permanent gas abstraction wells are installed.

[14] GHD, Smooth Hill Landfill Gas Design Report, May 2021 ~~April 2020~~.

[15] GHD Waste Futures Phase 2 – Workstream 3 Smooth Hill Landfill, Landfill Gas Design Report, May 2021 ~~April 2020~~.

4. Discharges to air

This section of the report describes the various discharges to air associated with the landfill.

4.1 Odour discharges

4.1.1 Sources of odour

Generally, odours originating from landfills have the potential to be objectionable and have nuisance effects beyond the site boundary. The likely sources of odour from The Site include:

- Refuse odours from tipped waste or material awaiting tipping
- Storage of leachate
- Odour from highly malodorous specific wastes
- Excavation activities into previously placed waste
- Landfill gas

~~Green waste as an individual and discrete product will generally not be accepted and will be processed for compost elsewhere in the district. Consequently, there will be minimal odours associated with composted material and therefore odour emissions from this type of activity have not been included in this assessment~~.

Generally cleanfill and bulk green waste is not expected to be disposed at the landfill as these wastes are expected to be diverted from the waste stream and managed at facilities closer to Dunedin. It is however expected that some cleanfill or greenwaste will be comingled with other waste or may from time to time be deposited in the landfill and it has been assumed for the purposes of this assessment that cleanfill and bulk green waste will be deposited at the landfill.

4.2 Dust discharges

Dust emissions from the construction and operation of The Site (with the exception of the LFG combustion plant~~operations~~) are expected to predominantly consist of coarse particles, which are typically greater than 20 microns in diameter. The most common concerns relating to coarse dust discharges are impacts on amenity, visibility and effects on structures (nuisance), however with mitigation these impacts are typically localised to within 100 m of the source.

4.2.1 Sources of dust discharges

Construction dust

Potential sources of dust discharges during the construction of the landfill are similar to those that occur for large earthworks projects (for example subdivision development). Dust generating activities required for the initial phase of construction will include:

- Earthworks for upgrades to McLaren Gully Road and Big Stone Road
- Earthworks for construction of the facilities areas, vehicle access, toe embankment, attenuation basin, and perimeter drainage
- Earthworks associated with the construction of the stage one landfill cell
- Vehicle movements on unpaved surfaces
- Stockpiling of fill or aggregate

It is anticipated that these activities will take place over at least two construction seasons prior to the landfill accepting waste, with a construction season generally being defined as the period from October to April/May the following year.

Further construction will occur periodically during the operation of the site as further project stages are developed with most of the activities outlined immediately above being above being undertaken within the landfill operational area.

Operational dust

Throughout the operation of the landfill, it is anticipated that the following activities will generate dust:

- Disturbance of dry soils on internal roads as a result of wind or traffic movements.
- Earthworks, such as placing of cover material during dry periods.
- Receiving, placing and compacting dry material during windy conditions.
- There is also the potential for there to be short periods of time when there are more vehicles on site as new cells are developed, or when final capping is being placed. Consequently, during these periods there will be additional dust and exhaust emissions from these vehicles.

4.2.2 Combustion emissions associated with increased vehicle emissions

Typically, adverse effects associated with vehicle/machinery emissions in New Zealand are only found in urban areas where there are particularly high traffic levels combined with traffic congestion.~~–~~ During the operational phase of the landfill it is estimated that typically 10 ~~7 to 9~~14 heavy vehicles may access The Site on any particular day. In practice, the total number of heavy vehicles may fluctuate across any given day due to seasonality or operational requirements (including the need for water and trucks) and it has been assumed truck movements could be up to a maximum of 25 per day. In addition to heavy vehicles, there will be construction staff arriving in light vehicles to the site.

Overall, the expected traffic volumes along McLaren Gully Road, Big Stone Road at any given time will be very low. Consequently, the potential for adverse effects is considered to be negligible and no further consideration has been given in this assessment to vehicle emissions.

4.3 Landfill gas extraction system and flare

4.3.1 Overview of landfill gas generation

LFG is a complex mixture of different gases produced by the degradation of biodegradable waste materials deposited within landfill sites. The emission rate and chemical composition of LFG varies depending on many factors including waste type, time, moisture content, temperature, etc. during the anaerobic phase, when decomposition of biodegradable waste materials occurs in the absence of oxygen.

Landfill gas comprises primarily of methane, carbon dioxide, oxygen and nitrogen with trace amounts of reduced sulphur compounds and volatile organic compounds.

The timescale for the evolution of significant quantities of LFG typically varies from three to twelve months following waste deposition and can continue for well over 30 years following the termination of waste landfilling activities.

4.3.2 Landfill gas collection system

The landfill gas extraction system will consist of the following components.

- A Flexible Membrane Liner (FML) and Compacted Clay Liner (CCL) and progressive capping of completed cells to prevent off-site migration of LFG.
- LFG collection pipework (vertical and horizontal extraction wells, condensate drainage points, interconnecting pipework) that will be progressively expanded across the site in line with filling activities.
- A primary flare (enclosed type) and a backup flare (candlestick type) to combust the collected LFG.
- The primary and backup flares will be designed to meet the requirements of the NESAQ.

4.3.3 Landfill gas modelling

In order to develop an understanding of the potential magnitude of LFG emissions from the site over time, GHD developed a LFG emission model for a landfilling period of 40~~55~~ years, which is consistent with the total design capacity of the site.

The model used for this exercise was the United States Environmental Protection Agency (USEPA) (2005) Landfill Gas Emissions Model (LandGEM) Version 3.02. This model was adopted as it is the most commonly used LFG emission model in New Zealand, according to the Ministry for the Environment (2001) A Guide for the Management of Closing and Closed Landfills in New Zealand.

The modelling parameters, assumptions and justifications table can be found in the Landfill Gas Design Report however, a summary of the model outputs is provided in the following Section.

4.3.4 Model outputs

The estimated LFG emission rates for the model are shown in Figure 4-1. Noting that the LandGem model presents the LFG emission rate outputs as m^3/LFG/year, GHD has converted these rates into m^3/LFG/h in this report for consistency with typical industry practice.

Figure 4-1: LFG emission model outputs (Updated May 2021)

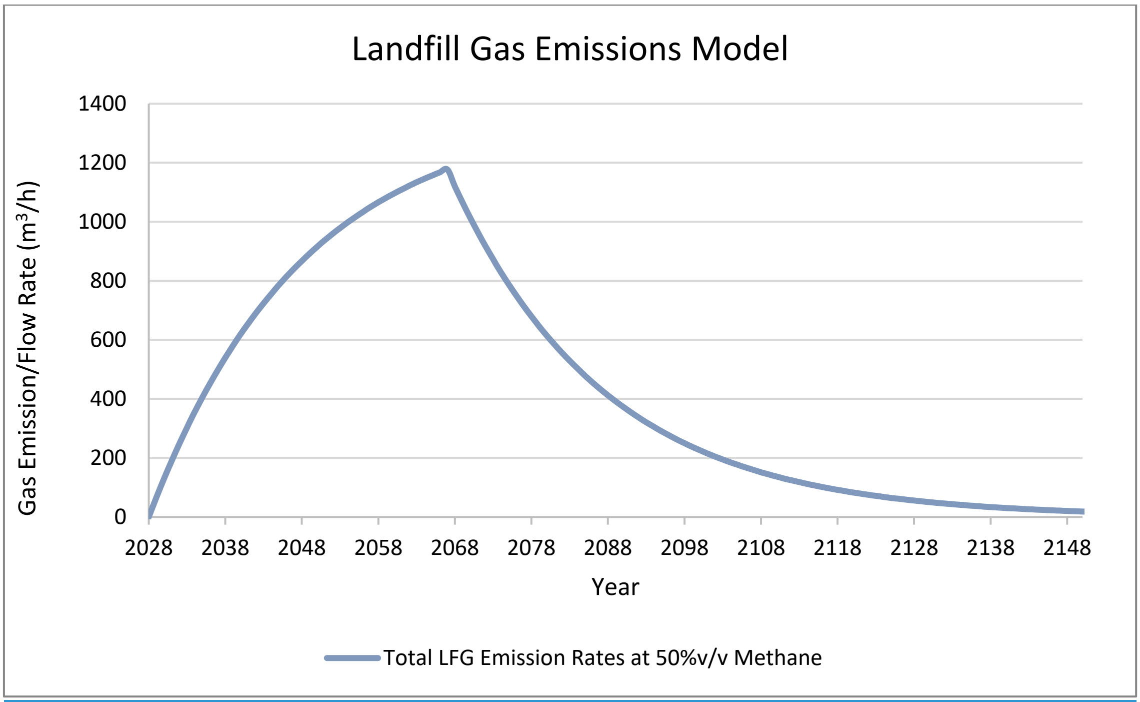


Figure 4-1 shows the following:

- The proposed landfill is expected to start generating LFG in 2028 and will continue to do so for many years after landfilling of waste has ceased in 2066
- The LFG emission rate at the proposed site will peak in 2067 at 1,177 m^3/LFG/h and will steadily decrease every year post 2067
- The LFG emission rate will be greater than 250 m^3/LFG/h (i.e. moderate to large generation rates[16]) between 2033 and 2097 (65 years)
- The LFG generation rates will be greater than 100 m^3/LFG/h at 50% v/v methane (i.e. theoretically sufficient to operate a flare according to the EPA VIC (2015)) from 2030 to 2116 (87 years)

Based on the magnitude and longevity of the estimated emission rates, it is considered that active[17] LFG management using flares and/or engines will likely be required at the site for many decades to appropriately manage the LFG emitted.

- ~~The proposed landfill is expected to start generating LFG in 2024 and will continue to do so for many years after landfilling of waste has ceased in 2078.~~
- ~~The LFG emission rate at the proposed site will peak in 2078 at 1,927 m³/LFG/h and will steadily decrease every year post 2078.~~
- ~~The LFG emission rate will be greater than 250 m³/LFG/h (i.e. moderate to large generation rates[18]) between 2026 and 2118 (93 years).~~
- ~~The LFG generation rates will be greater than 100 m³/LFG/h at 50~~60~~% v/v methane (i.e. theoretically sufficient to operate a flare from 2024 to 2137 (114 years).+~~

~~Based on the magnitude and longevity of the estimated emission rates, it is considered that active LFG management using flares and/or engines will likely be required at the site for many decades to appropriately manage the LFG emitted.~~

4.3.5 Emissions from the landfill gas flare -

The combustion of LFG in the flares will generate a variety of air discharges. The principal air pollutants include NO_X, CO, SO_2, PM_{10} and $PM_{2.5}$ and small amounts of volatile organic compounds (VOC).

Emissions of NO_X, CO and particulate matter have been calculated using USEPA AP-42 emission factors, specifically Chapter 2.4, Municipal Solid Waste Landfills (draft, October 2008) (AP42).

For the purposes of this assessment PM_{10} and $PM_{2.5}$ emissions have been assumed to comprise 100% of the total particulate emission.

NO_2 emissions have been conservatively assumed to comprise 100% of the NO_X emission.

GHD notes that the USEPA AP42 emission factors are based on methane comprising 50% of LFG, whereas based on our experience of New Zealand Landfills the composition of methane is typically up to 60%. GHD has therefore adjusted emission rates to account for the higher proportion of methane by multiplying NO_2, CO and particulate emissions by 60/50 (1.2)

[16] According to EPA Victoria (Australia) (2015) *BPEM, Siting, design, operation and rehabilitation of landfills*, Section 6.7.1 on page 35

[17] i.e under vacuum

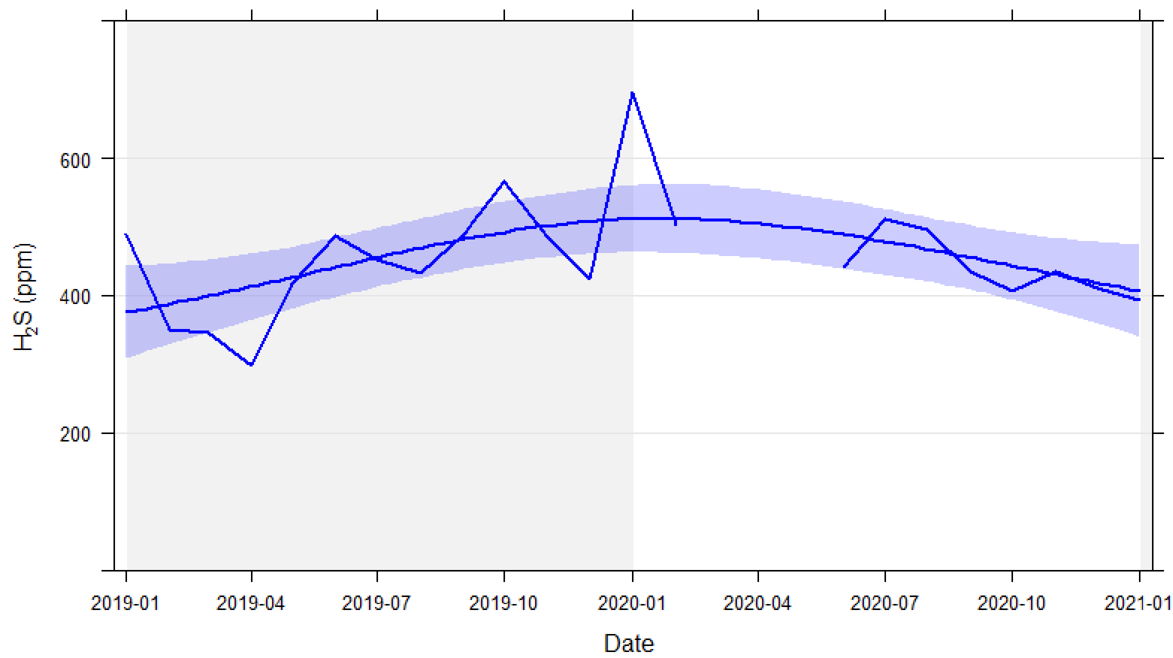
~~[18] According to EPA Victoria (Australia) (2015) *BPEM, Siting, design, operation and rehabilitation of landfills*, Section 6.7.1 on page 35~~

SO_2 emissions have been based on a mass balance approach in accordance with the guidance contained in AP42. This assumes that 100% of the sulphur in the LFG is converted to SO_2 as it is combusted in the flare.

H_2S is the main source of sulphur with other reduced sulphides typically found at trace levels. The trace amounts of reduced sulphur compounds are negligible when compared to the concentration of H_2S in LFG and therefore contributions from these compounds have been assumed to be zero.

The concentration of H_2S varies greatly depending on the type of waste accepted, with higher concentrations associated with landfills that accept large amounts of gypsum, industrial waste and biosolids from municipal waste~~-~~water treatment plants. GHD has reviewed H_2S concentration data from Green Island Landfill, as the volume and composition of waste is likely to be representative of what will be placed at the Site, albeit that generally cleanfill and bulk green waste is not expected to be disposed at the landfill (see Section 4.1.1). The concentration of H_2S in the gas at Green Island is typically between 400 and 500 ppm (Refer to Figure 4-2), which is consistent with other landfills around New Zealand. Given the expectations for the waste stream ~~will essentially be the same as Green Island~~, the levels of H_2S are expected to be similar or lower than those at Green Island. Due to the moderate to high levels of H_2S it is important that emphasis is placed on odour control measures (as discussed in Section 5) and that the effectiveness of these measures is constantly assessed, and ongoing improvements made to minimise the potential for odour nuisance.

Figure 4-2 Green Island H_2S data measured at the ring main sampling point



For this assessment SO_2 emissions have been based on the maximum H_2S concentration measured at Green Island of 500 ppm (761 mg/m³). Based on a conservative maximum LFG emission rate of 1,927 m³/LFG/h (a previous estimated value based on a smaller landfill size) and a SO_2 concentration of 1,429 mg/m³ (761 mg/m³ x 1.88 (molecular weight conversion from H_2S to SO_2) the emission rate of SO_2 has been estimated to be 2.9 kg/hr.

The destruction efficiency of the flares is expected to be greater than 99.9% and therefore emissions of VOC are predicted to be at very low levels.

LFG will primarily be combusted in the enclosed ground flare, however if the flare develops a fault or is taken off-line for maintenance a backup candle stick flare will be used. Combustion emissions from the two types of flares is expected to be similar, however the destruction efficiency of VOC in the candlestick flare will be lower than the enclosed flare.

Regardless of which flare is used, given the relatively low VOC discharge rate combined with the distance to the nearest sensitive receptors the potential for effects from these compounds is considered to be negligible and therefore atmospheric dispersion modelling of these compounds is not considered necessary.

For the purposes of this assessment, it has been assumed the flare will be 8 m tall and 2.5 m in diameter.

Note the landfill is a potential source of LFG to the atmosphere. – However, this will be controlled by:

- Installation of daily and intermediate cover material.
- Permanent capping of the landfill and installation of permanent LFG wells as soon as practicable.
- Installation of intermediate horizontal and vertical LFG wells as the landfill is developed and prior to permanent capping to capture LFG.

Table 3 Flare emissions (Updated May 2021)

Pollutant	Typical Rate kg/10^6 dscm CH_4	Typical Rate kg/10^6 dscm of Landfill Gas	Emission Rate Kg/hr
Nitrogen dioxide	757	379	0.76
Carbon monoxide	884	442	0.88
PM_{10}	286	143	0.29
$PM_{2.5}$	286	143	0.29
Sulphur dioxide	-	-	2.9

4.1 Other potential sources

There is the potential for emissions to air from other minor sources at the landfill, including the operation of small backup diesel generators to power leachate extraction pumps. The generator will be located close to the LFG plant on the lower facilities platform. It is estimated that the total capacity of diesel generators for this purpose would be 200 kW, which is below the maximum heat generation capacity of 5 MW (for a site location in Air Zone 3), as set out in Rule 16.3.4.2 of the Otago Regional Air Plan. The minimum stack height(s), as a condition to the rule is 8.5 m above ground level. The potential for off-site effects from this activity are considered to be negligible, given the small amount of pollutants generated, limited period of operation and significant distance to the nearest boundary. GHD considers this to be a minor issue with no special consent conditions required, with the exception that the generators are appropriately tuned and maintained and stack discharges orientated vertically, as is considered best practice.

5. Mitigation measures

5.1 Odour mitigation measures

This section of the report presents the odour management measures that will be implemented to minimise offsite odours from the operation of the landfill. It is important to note that even with best practice management measures it is not possible to completely eliminate odours at a landfill or internalise odour within the site boundary. Operational practices at the site will be based on those currently used at Green Island Landfill and amended where necessary to represent best practice operation standards for landfills in New Zealand. The following essentially provides a summary of the odour management practices that are set out in the draft Landfill Management Plan (LMP).

5.1.1 Waste acceptance controls

Odour control begins with careful management of odorous waste receipt and delivery. Details of the following activities will be established as part of a Landfill Management Plan. Activities that are typically utilised to successfully control odour include:

- Implementing protocols to forewarn of the arrival of odorous wastes (examples include biosolids and offal) at the landfill so that proper preparations can be made to mitigate odour emissions once the waste is received at the tip face i.e. to cover as soon as the waste is placed.
- Refuse will be placed in sealed truck and trailer units or bins while transported to site (no open bin trucks).
- Wastewater biosolids will be treated (stabilised with lime) prior to arriving at The Site.
- Training weighbridge staff to identify potentially odorous or unexpected highly odorous deliveries, and to hold such deliveries until such time as tip face operators have measures in place to place and cover the waste quickly and mitigate emissions that occur.

5.1.2 Waste handling and landfill management

Appropriate management of waste and landfill are required to minimise potential odour effects. The following methods (at a minimum) shall be employed at The Site:

- Implementing and maintaining good housekeeping standards on the site
- Keeping the size of the working face to a minimum
- The refuse tip head will be located close to the refuse placement area to avoid pushing the refuse a long distance that would otherwise increase the odour potential. As the refuse placement area changes, the tip head will closely follow that placement area
- Landfill cells will be filled from the base of the valley. The landfill sequence outlined in the Design Report[19] (and Drawings C210 to C214) envisages filling Stage 1 located in the northern part of the site followed by Stage 2 in the north-eastern part of the site. Both stages are located at least 180 m from Big Stone Road. Filling of these stages is likely to take 15 to 16 years. ~~to the top of the cell (bottom up), or top down for Stages 2, 4 and 5 (see Drawing C203).~~

[19] GHD, Waste future 2 – Work stream 3 Smooth Hill Landfill, Landfill Concept Design Report, May 2021

- Works areas shall be covered at the end of each working day and no refuse shall remain exposed overnight
- Mowing landfill surfaces that are grassed to allow effective surface emission monitoring.
- Undertaking instantaneous surface monitoring (ISM) on a regular basis to identify any areas of capping that need to be remediated
- Scheduling activities such as extensive excavations into old waste (an activity that is only undertaken under exceptional circumstances) that have increased potential to generate odour to days when wind direction is away from sensitive receptors
- Conducting regular walk-over inspections of the landfill to identify any damage to the cover system and to monitor the effectiveness of the mitigation measures employed
- Implementing systems for identifying areas for improvement and recording corrective actions
- Maintaining a log of all odour complaints, including investigations by Site Management to identify the source, actions taken to minimise odour emissions, and feedback to the complainant

5.1.3 Leachate management

Rates of leachate generation are expected to be at their highest during operation when waste is being placed, however this is mitigated as much as possible through careful management of the active landfill face including the use of daily and intermediate cover. Leachate generated within the landfill will flow to the leachate collection system at the base of the landfill from where it will be pumped out and stored in enclosed tanks for up to 72 hours prior to being removed off site for treatment and disposal. Providing the leachate collection system and tanks are managed appropriately it is not expected that leachate storage will be a significant source of odour. Leachate odour controls are described in the Design Report[20] and Drawing C403.

5.1.4 Additional mitigation measures

Should the above mitigation measures prove insufficient at controlling offsite odour to acceptable levels the following additional mitigation measures could be implemented.

Odour neutralising sprays

If required, the supply of a trailer mounted odour cannon can be deployed upwind of the odour source to provide improved distribution and mixing of odour neutralisers towards receptors. The particular conditions under which odour sprays will be used, will be set out in the Landfill Management Plan (LMP).

Air conditioning system installation

If nearby residential receptors are experiencing significant landfill odour, air conditioning systems could be installed at each of these properties to allow them to keep their windows and doors closed during periods where they are affected.

Highly odourous waste disposal control procedures

Disposing of highly odourous waste such as biosolids or offal has the greatest potential to cause odour nuisance. If this type of waste is being found to cause odour nuisance effects, the following control measures could be implemented:

[20] GHD, Waste Future Phase 2 – Work stream 3 Smooth Hill Landfill, Landfill Concept Design, May 2021

- Transportation routes to the landfill can be optimised to minimise the amount of time spent on local roads and waiting at intersections.
- Deliveries could be arranged so that trucks are not waiting outside the gate prior to the landfill opening for the day.
- Transport to the landfill shall be arranged so that deliveries arrive between the hours of 10 am and 4 pm, as this time of day generally provide better odour dispersion conditions.
- Deliveries of highly odourous waste shall be prioritised and allowed directly to the tip-head.
- A dedicated temporary disposal area shall be developed for biosolids area within the active landfill face and this waste shall be placed directly into a prepared hole and immediately covered.
- Placement areas shall be located as far as practicable from the nearest sensitive receptors.
- A stockpile of suitable cover material shall be located near to the disposal area to allow the waste to be immediately covered.
- The bins shall be completely emptied as far as practicable to minimise the amount of residual material retained in the bin which can cause odour nuisance as the truck leaves the site and travels back to its next pick-up point.
- During low wind speed conditions (winds less than 3 m/s) an odour cannon shall be setup and operated downwind of the disposal area.
- Investigation of odour complaints shall be undertaken to determine the contributing factors and identification of improvements to odour control procedures. If it is determined that all odour mitigation measures were being implemented effectively at the time of the complaint and that the complaint is directly attributed to the placement of highly odourous waste, then waste from this customer will no longer be accepted until it can be demonstrated that the level of odour from the waste has reduced to acceptable levels.

5.1.5 Measures to identify and control abnormal odour

Should excessive odour be generated by the landfill from activities that fall outside of normal operation then the following measures will be implemented as a staged approach to identifying and remediating the cause of odour.

- Identifying and covering odorous waste
- Stop further deliveries from any identified~~odorous~~ source of the odourous waste
- Redistribute odour sprayers
- Alter the odour spray chemical dose rate
- Repair obvious leaks in gas system
- Repair obvious deficiencies in the landfill cover
- Move the tipping to a remote area until wind is favourable
- Undertake surface emissions survey

5.2 Dust mitigation measures

Adverse effects of dust depend on the size of the particles emitted, while the below mitigation measures are targeted at nuisance dust, they will also assist managing emissions of smaller size fractions, such as PM_{10} and $PM_{2.5}$ which have the potential to cause health effects.

The following mitigation measures will be implemented at all times on site to minimise the potential for off-site dust emissions, as far as practicable.

5.2.1 Construction dust mitigation measures

Dust management and suppression will be an important part of mitigating and avoiding off-site effects associated with the construction and operation of the site. The following measures, as discussed in the draft LMP, will be implemented during construction and operation of the landfill to control dust emissions. An adequate supply of water will need to be secured for this activity (estimated at up to 40 m^3 per day):

- Visual dust inspections will be carried out on a regular basis throughout the day
- Watercarts or fixed sprinklers will be used to control dust generated from haul roads
- Where visual inspections find instances of dust leaving the boundary of the site, the intensity of dust control measures should be increased, including increasing dust suppression (watering) rate
- During high-wind speeds (wind speeds above 5 m/s) delay/reduce rate of works and/or further increase the rate of watering
- Establish vehicle speed limits (typically less than 15 km/hour) to reduce wheel generated dust emissions
- Where practicable, those parts of the site that are paved should be kept clean and free from waste and dust through regular sweeping and/or hosing down
- Street sweeping should be regularly carried out on paved roads and at the site entrance/exit
- Controlling dust from any excavation by placing material directly into trucks where possible
- If material being excavated is very dry, using water sprays to increase surface moisture
- Where material is placed in temporary stockpiles, use water in dry windy conditions to control the dust potential or cover, if practicable, prior to re-use or long--term storage
- Limit the height of uncovered stockpiles to reduce wind entrainment. Stockpiles exceeding 3 m in height have a higher risk of discharging dust
- Long term stockpiles should be suitably covered to avoid dust generation
- Take account of daily weather forecast wind speed, wind direction and spoil conditions before commencing dust generating activities

Data collected by the onsite weather station will be used to inform site staff if the winds speed (measured at a height of 10 m above ground level) are above the 5 m/s trigger. The onsite weather station was installed in July 2020 and records the following parameters: wind speed and direction, temperature, relative humidity and rainfall.

The estimated maximum daily water supply volume required to control dust emissions of 40 m^3 has been based on our experience for other projects of a similar size, rainfall and temperature and will be further refined as part of detailed design.

5.2.2 Operational dust mitigation measures

Following the initial construction phase, it is expected that the site access road will be sealed as far as the wheel wash (see Drawing C702). Other measures in order to minimise dust emissions from the landfill include:

- A maximum speed limit of 30 km/hr~~.~~ will apply in all areas of the site
- Permanent roads on the site should be sealed and well maintained
- Wheel wash to prevent mud/dirt from being tracked along the access road on to public roads
- Water-carts will be used on both sealed and unsealed roads as required during dry periods. Generally visual observation is used to judge the need for water carts
- Temporary roads on the landfill will be properly maintained and graded
- Dust generating wastes will be treated as a special waste. The customer will be required to dampen down the load prior to delivery to site, and special controls will be implemented at the disposal point, e.g. water sprays, waste pit, etc.

5.3 Landfill gas combustion emissions mitigation measures

The LFG extraction system will ensure that the placed waste is kept under negative pressure which will minimise fugitive emissions. The gas extraction system will be progressively expanded as new filling stages are developed and will be constantly tuned by landfill gas technicians to maximise gas capture.

The flares that will be installed onsite to combust LFG will be designed to meet the requirements of the NESAQ. Specifically, by ensuring that the flare has minimum gas retention time of 0.5 seconds and that the minimum temperature in the flare is greater than 750 °C, the destruction efficiency of the flare will be very high, typically greater than 99.9%. The flare will also be at least 8 m high which, combined with the hot buoyant gas being discharged, will ensure that emissions of VOC and unburnt methane will be a trace levels and therefore it is very unlikely for theses pollutants to cause adverse off-site effects.

5.3.1 Design of the Landfill Gas Flares

The principal flare will be appropriately designed to meet all of the NESAQ requirements, namely:

1. Have a flame arrestor
2. Have an automatic backflow prevention device, or an equivalent device, between the principal flare and the landfill
3. Have an automatic isolation system that ensures that, if the flame is lost, no significant discharge of unburnt gas from the flare occurs
4. Have a continuous automatic ignition system
5. Have a design that achieves a minimum flue gas retention time of 0.5 seconds
6. Be designed and operated so that gas is burned at a temperature of at least 750°C
7. Have a permanent temperature indicator
8. Have adequate sampling ports to enable emission testing to be undertaken
9. Provide for safe access to sampling ports while any emission tests are being undertaken

The backup flare will be designed to meet the following requirements:

1. A flame arrestor
2. An automatic backflow prevention device, or an equivalent device, between the backup flare and the landfill

3. An automatic isolation system that ensures that, if the flame is lost, no significant discharge of unburnt gas from the flare occurs

~~1.~~4. A continuous automatic ignition system

6. Regulatory requirements

The following Section summarises the assessment requirements of some of the key regulations and planning documents relevant to discharges to air from The Site. A full statutory assessment of the proposal is set out in the AEE Report.

6.1 Consideration of Resource Management Act 1991

There are a number of sections within the RMA[21] which are relevant to the assessment of odour and dust from The Site.

Given that odour and dust are considered to cause effects on amenity values, people and communities, the RMA requires that they are appropriately managed. As the compounds that have the potential to cause odour effects are mobilised as air contaminants, these discharges are controlled by section 15 of the RMA.

Section 15(1) of the RMA states that discharges from industrial or trade premises are only allowed if they are authorised by a regional plan, a resource consent or by New Zealand regulations. If the activity is prohibited under the plan then a resource consent cannot be obtained.

Section 17 of the Act imposes a general duty on every person to avoid, remedy or mitigate any adverse effect on the environment arising from any activities the individual may conduct or have carried out on their behalf.

Section 17(3)(a) allows an enforcement order to be made or served that can be made or served by the Environment Court or and Enforcement Officer. These require a person to cease doing something that is, or is likely to be, noxious, dangerous, offensive or objectionable to such an extent that it has or is likely to have an adverse effect on the environment.

6.2 Consideration of separation distances

The consideration of separation distance between sensitive neighbours, particularly residential dwellings, and odour/dust-generating activities is important when assessing the likely impacts of an activity, as a suitable separation can help to mitigate nuisance effects on occasions when standard mitigation measures cannot be entirely effective (for example when strong dry winds occur). By having a suitable separation distance, odour/dust emissions can be dispersed, diluted and deposited to such an extent that their effects at sensitive locations should be minimised to an acceptable level.

The Auckland Council (AC) discussion document on Separation Distances for Industry[22] prepared by Emission Impossible recommends a separation distance of 1,000 m and

~~In the absence of separation distance guidelines for dust/odour discharges in New Zealand,~~ the Environment Protection Authority Victoria (EPA Victoria) separation distance guidelines recommend a distance of 500 m for Type 2 landfill[23], which Smooth Hill is classified as.

GHD has identified one receptor within 500 m of the landfill and four receptors within 1,000 m.

While receptors have been identified within the recommended buffers by the respective regulators, the AC document states that *“Separation distances are indicative, not absolute*

[21] Ministry for the Environment (1991) Resource Management Act (2018 update)

[22] Emission Impossible 2012. Separation Distances for Industry – A discussion document. Prepared for Auckland Council 9 July 2012.

[23] A landfill receiving municipal (putrescible) waste

criteria, and may be adjusted having regard to specific site circumstances. In such circumstances applicants should provide a robust, clear and compelling justification for amending the recommended separation distances. And the EPA Victoria guidance considers buffer distances to be 'generic' and do not take account of site-specific factors of emission and how they are dispersed.

Furthermore, ~~have been used in New Zealand. GHD gave consideration to using the guidance in the EPA Victoria guidance, however the guidance is considered to be '*generic'* and does not take account of site specific factors of emission and how they are dispersed.~~

GPG Industry states that *"…the EPA Victoria guidelines (and other similar guidance) are generic. Most of the separation distance guidelines are based on the protection of amenity values at sensitive locations. They do not generally consider risk, or potential health effects. It is also important to note that they do not take into account site specific factors which may influence discharge rates and how they are dispersed (e.g., the specific processes and emission controls used on site). They are also applied in all directions and so do not take into account the effects of local topography and meteorology.*"

Overall GHD considers that ~~Based on EPA Victoria guidance the Smooth Hill Landfill is a Type 2 landfill[24] and recommends a buffer distance of 500 m from buildings or structures.~~

careful consideration must be given when applying generic buffer distances for landfills ~~such as the EPA Victoria guidance of 500 m~~, as in some instances this buffer may be either, insufficient or too conservative. For this GHD has undertaken detail analysis of odour discharges as part of this assessment to better understand the potential for odour nuisance, particularly for those receptors located within 1,000 m of the landfill. Further discussion on buffer distances is provided in Section 9.3.

[24] ~~; a landfill receiving municipal (putrescible) waste~~

7. Assessment criteria

7.1 Odour and dust emission assessment criteria

7.1.1 Qualitative Odour and Dust Assessment Criteria

~~7.1.2 Ministry for the environment odour and dust assessment criteria~~

The primary concern with odour and dust is its ability to cause an effect that could be considered ‘offensive or objectionable’. In order to assess whether an odour or dust event has the potential to be offensive or objectionable MfE recommends that the FIDOL (frequency, intensity, duration, offensiveness and location) factors are considered using the guidance provided in GPG Odour and GPG Dust. The FIDOL factors concerning odour and dust are summarised in Table 4.

Table 4 FIDOL Factors

FIDOL Factor	Description
Frequency	The **frequency** of odour or dust discharges relates to how often an individual is exposed.
Intensity	The **intensity** relates to the concentration of odour or dust.
Duration	The **duration** relates to the length of time that an individual is exposed.
Offensiveness	**Offensiveness** relates to the ‘hedonic tone’ of the odour, which may be pleasant, neutral or unpleasant. In terms of dust, **offensiveness** relates to the type of dust.
Location	The sensitivity of **locations** in the receiving environment, which is characterised by land uses surrounding the site.

~~7.1.3~~7.1.2 Odour Modelling Assessment Criteria

Odour assessment modelling criteria are presented on Page 51 of GPG Odour. Given the low density of receptors in the rural area surrounding the landfill, it would be reasonable to classify the receiving environment as moderately sensitive, corresponding to an odour concentration of 5 OU/m³ on a 0.1th percentile basis.

Table 5 Odour modelling criteria (GPG Odour) (Updated May 2021)

Sensitivity of the receiving environment	Concentration	Percentile
High (worst-case impacts during unstable to semi-unstable conditions)	1 OU/m³	0.1% and 0.5%
High (worst-case impacts during neutral to stable conditions)	2 OU/m³	0.1% and 0.5%
Moderate (all conditions)	5 OU/m³	0.1% and 0.5%
Low (all conditions)	5-10 OU/m³	0.5%

7.2 Landfill gas combustion emissions assessment criteria

7.2.1 The national environmental standards for air quality (NESAQ) regulations 2004

The NESAQ are regulations made under the Resource Management Act 1991, which aims to set a guaranteed minimum level of health protection for all New Zealanders. This includes controlling greenhouse gas emissions at landfills. The relevant regulations to LFG combustion emissions at are Regulations 26 and 27.

Regulation 26 and 27 set the requirement that large landfills (as set out in Regulation 25) collect LFG and meet a maximum surface methane concentration of 5,000 ppm. In addition, the NESAQ requires the collected gas to be flared, or used as a fuel or to generate electricity.

The flare(s) will meet the technical specifications and conditions of operation specified in Regulation 27.

7.2.2 Health-effects based assessment criteria

GPG ADI recommends an order of priority when determining the most appropriate assessment criteria to be used for air quality assessments. The documents provided below set out the minimum requirements that ambient air quality should meet in order to protect human health and the environment. This order of priority for the pollutants of concern are outlined by the MfE as follows:

- Ministry for the Environment, Resource Management (National Environmental Standards for Air Quality) Regulations, 2004 (NESAQ)
- Ministry for the Environment, Ambient Air Quality Guidelines (2002 update) (NZAAQG)
- Regional Air Quality Targets (RAQT) – Otago Ambient Air Quality Targets (OAQT)
- World Health Organisation air quality guideline (WHO AQG) Global Update 2005

Based on the order of priority outlined above the air quality assessment criteria relevant to this project have been presented in Table 6.

Table 6 Health-Effects Based Air Quality Assessment Criteria

Pollutant	Threshold Concentration (µg/m³)	Averaging Period	Source of Assessment Criteria
NO_2	200	1-hour	NESAQ
NO_2	100	24-hour	NZAAQG
CO	30,000	1-hour	NZAAQG
CO	10,000	8-hour	NESAQ
SO_2	570	1-hour	NESAQ
SO_2	350	1-hour	NESAQ
SO_2	120	24-hour	NZAAQG
PM_{10}	50	24-hour	NESAQ
PM_{10}	20	Annual	NZAAQG
$PM_{2.5}$	25	24-hr	WHO
$PM_{2.5}$	10	Annual	WHO

~~7.2.4~~7.2.3 Ecological guidelines

The MfE also provide guidelines for the protection of ecosystems. Table 6 presents the guidelines applicable to this assessment.

Table 7 Ecological Based Air Quality Assessment Criteria

Pollutant	Threshold Concentration (µg/m³)	Averaging Period
SO_2		
• Agricultural crops • Forest and natural vegetation • lichen	30 20 10	Annual and winter average Annual and winter average Annual
NO_2	30	Annual

~~7.2.5~~7.2.4 Regulation 17 of the NESAQ

In addition to the standards in the NESAQ, there are also regulations which limit the ability of consent authorities to grant consent in airsheds that do not meet the standards. For PM_{10} the relevant regulations are Regulation 17 (1) – (2) which state:

"17 Certain applications must be declined unless other PM_{10} discharges reduced

A consent authority must decline an application for a resource consent (the proposed consent) to discharge PM_{10} if the discharge to be expressly allowed by the consent would be likely, at any time, to increase the concentration of PM_{10} (calculated as a 24-hour mean under Schedule 1) by more than 2.5 micrograms per cubic metre in any part of a polluted airshed other than the site on which the consent would be exercised.

However, subclause (1) does not apply if—

a. *the proposed consent is for the same activity on the same site as another resource consent (the existing consent) held by the applicant when the application was made; and*
b. *the amount and rate of PM_{10} discharge to be expressly allowed by the proposed consent are the same as or less than under the existing consent; and*
c. *discharges would occur under the proposed consent only when discharges no longer occur under the existing consent."*

Given that The Site is not located in a polluted airshed, Regulation 17 is not relevant to this assessment.

8. Meteorological modelling

The closest meteorological station relative to The Site is located at Dunedin airport, approximately 4.5 km away (note previous comments regarding establishment of an on-site station in 2020). While the station is relatively close it is unlikely to be representative of onsite conditions as it is located in a wide valley, whereas the Site is in surrounded by complex terrain. GHD is not aware of any suitable local meteorological data and has therefore undertaken metrological modelling to better understand local wind conditions.

8.1 Meteorological modelling methodology

8.1.1 Model selection

A site specific, three-dimensional meteorological data set was developed using the CALMET (v7) diagnostic meteorological model. A 22.5 by 22.5 km CALMET grid was established with 150 m grid spacing and 11 vertical layers (up to 4,000 m elevation). The CALMET model was configured in 'Hybrid mode', with key model inputs including:

- Surface meteorological observations from Dunedin Airport Automatic Weather Station (AWS).
- Upper air data derived from The Air Pollution Model (TAPM) (v4), utilised as an initial guess field in the Hybrid mode configuration.
- Land use and terrain data.

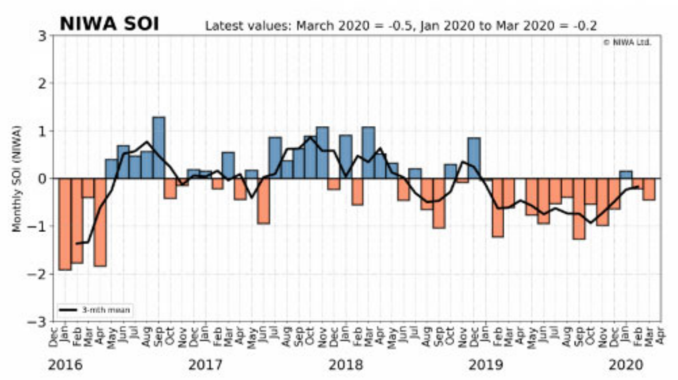
The output of the CALMET model is utilised as critical meteorological input in to the CALPUFF air dispersion model, as described in Section 11.2.

8.1.2 Model period

A three-year modelling period (2017-2019) was selected which includes the most recent available surface observations from the Dunedin Airport AWS. Completing a meteorological assessment for a three-year model period to allow for a greater model reliability, as many more potential worst-case meteorological conditions are captured in the ultimate dispersion modelling exercise.

The three-year model period selected suitably captures both El Niño and La Niña phases of the El Niño-Southern Oscillation (ENSO). The strength and phases of the ENSO during the model period is shown in Figure 8-1.

Figure 8-1 Southern Oscillation Index



Credit National Institute of Water and Atmospheric Research

8.2 CALMET model inputs

8.2.1 Surface observations

Surface meteorological observations were available from the automatic weather station located at Dunedin Airport operated by the Meteorological Service of New Zealand Limited (MetService).

The Dunedin Airport AWS is located approximately 4.5 km north-northeast of The Site. While the distance between the site and the AWS is minimal, there are significant differences in land use and topography at the two locations. Importantly the Dunedin Airport AWS is located within a valley with approximate orientation southwest to northeast. The AWS is located approximately 2-3 km from the south-eastern valley wall, which extends to a ridge of approximately 200 m between the AWS and site.

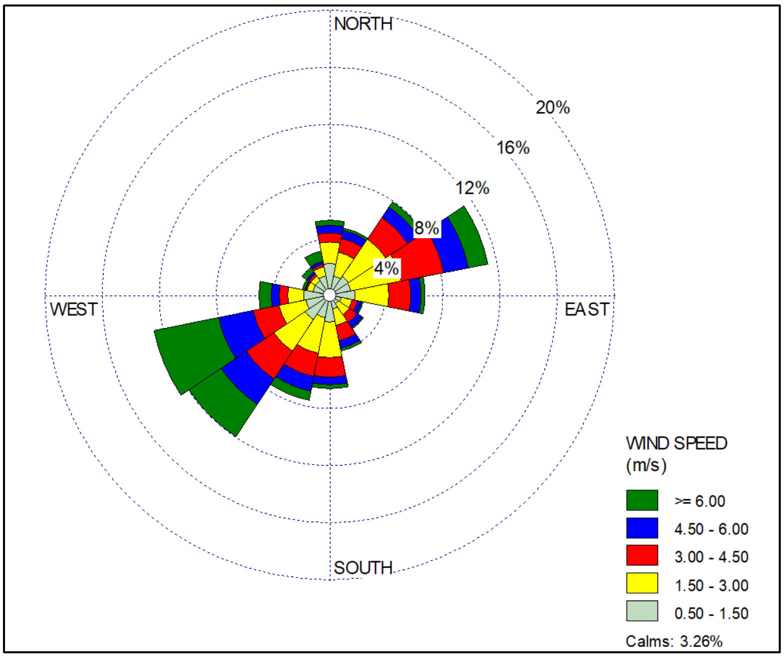
The location of the AWS is a significant factor in the selection of an appropriate radius of influence for surface observations as specified in section 8.3.

The following data are sourced from the Dunedin Airport AWS and are utilised as inputs to the CALMET hybrid mode configuration as surface observations:

- wind speed and direction (measured at 10 m)
- temperature, relative humidity and surface pressure (measured at 2 m)
- cloud coverage (amount and height).

A wind rose developed for the Dunedin Airport AWS using wind speed and direction data is presented in Figure 8-2. The wind rose shows a dominant wind pattern that is aligned with the valley orientation. This pattern is most evident during periods of strong winds (>6 m/s) where winds are most frequent from (west-southwest, southwest and east-northeast). Light through moderate winds are well distributed with the exception of the northwest and southeast directions. A very low frequency of winds are observed from the northwest and southeast (perpendicular to the orientation of the valley), suggesting that valley slope flows are not significant influence on winds at Dunedin Airport.

Figure 8-2 Wind rose from observed data at Dunedin Airport AWS (2017-2019) - average Wind Speed = 3.1 m/s



8.2.2 Upper air data

The TAPM prognostic model was run to obtain a coarse three-dimensional meteorological gridded dataset for the subject site for the selected model period. This dataset is based on synoptic observations, local terrain and land use information with a resolution of 1,000 m.

TAPM model parameters are summarised in Table 8.

Table 8 TAPM model parameters

Parameter	Value
Modelled Period	01 January 2017 12:00 am – 31 December 2019 11:59 pm
Domain centre	UTM: 59H 440,599 mE, 4,909,370 mS Latitude =-45° 58.0' Longitude = 170° 14.0'
Number of vertical levels	25
Number of Easting Grid Points	41
Number of Northing Grid Points	41
Outer Grid Spacing	30,000 m x 30,000 m
Number of Grid Levels	4
Grid Level Horizontal Resolution	Level 2 – 10,000 m Level 3 – 3,000 m Level 4 – 1,000 m

Outputs from the TAPM model at both the Dunedin Airport AWS and site locations are shown as wind rose (for 2019) in Figure 8-3 and Figure 8-4 respectively. The following are observed from the wind roses:

- The predicted wind pattern at Dunedin Airport AWS (Dunedin AWS) location appears oriented with valley flow with dominant wind directions being west-southwest and east-northeast. The general pattern of wind predicted by TAPM is similar to the pattern of observed winds, however it is apparent that TAPM is over predicting the valley effect and is not capturing the true variability in wind directions at the site. Furthermore, TAPM is predicting average wind speeds that are greater than those observed at the Dunedin AWS. It is expected that this is an artefact of a high frequency of strong winds (>6 m/s) predicted from west-southwest.
- As expected due to the ridgeline location, the predicted wind patterns at the site location appears less oriented with the valley with a significant westerly component wind. Additionally, the high frequency of winds from east-northeast/east predicted at Dunedin AWS are shifted north to northeast at the site location.
- Analysis of TAPM predicted wind speed and direction aloft (120 m) at the Dunedin AWS location showed a distribution of wind directions more closely aligned with the site location than the Dunedin AWS location (in valley). This observation suggests that the winds at the site location are more likely representative of the regional wind pattern, with winds at the Dunedin AWS highly influenced by topographical location (valley).

Figure 8-3 TAPM output wind rose - Dunedin Airport AWS location (2017-2019) – average wind speed = 4.0 m/s

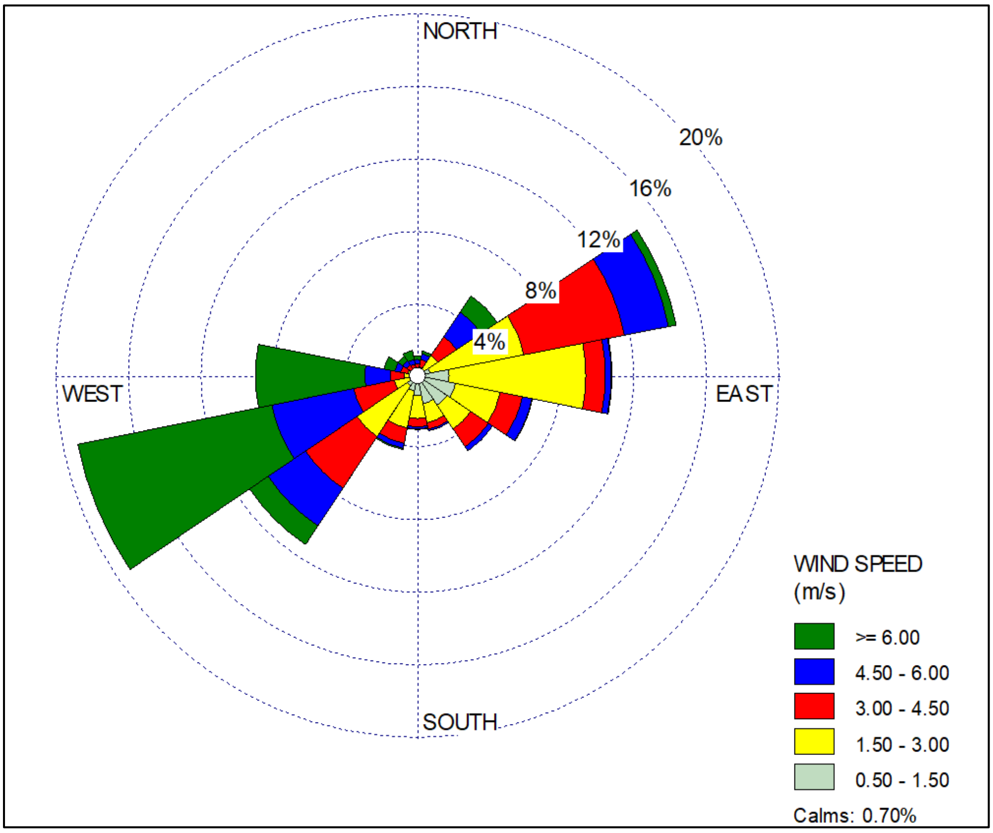
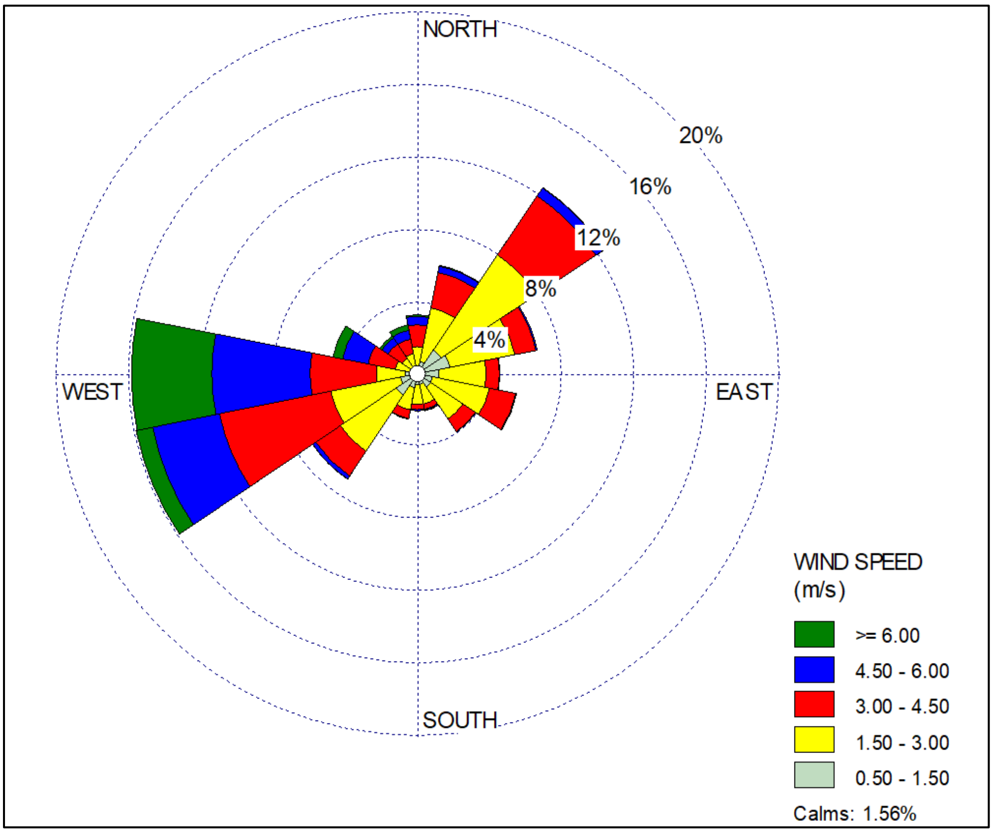


Figure 8-4 TAPM output wind rose - site location (2017-2019) – average wind speed = 3.1 m/s



8.2.3 Land use

Land use data was extracted from the New Zealand Land Cover Database (2012) v 4.1, produced by Landcare Research. A figure showing land use types and surface roughness lengths for the CALMET domain are shown in Figure 8-5 and Figure 8-6 respectively.

Of importance to note, the site is located within a large area of land primarily used for forestry activities. As observed in Figure 8-6 the forest land use is associated with a large surface roughness length increasing mechanically generated turbulence in winds and consequently increasing the degree of pollutant dispersion in the environment.

Figure 8-5 CALMET land use types for model domain - site location (red outline) and Dunedin AWS location (dark green point) shown

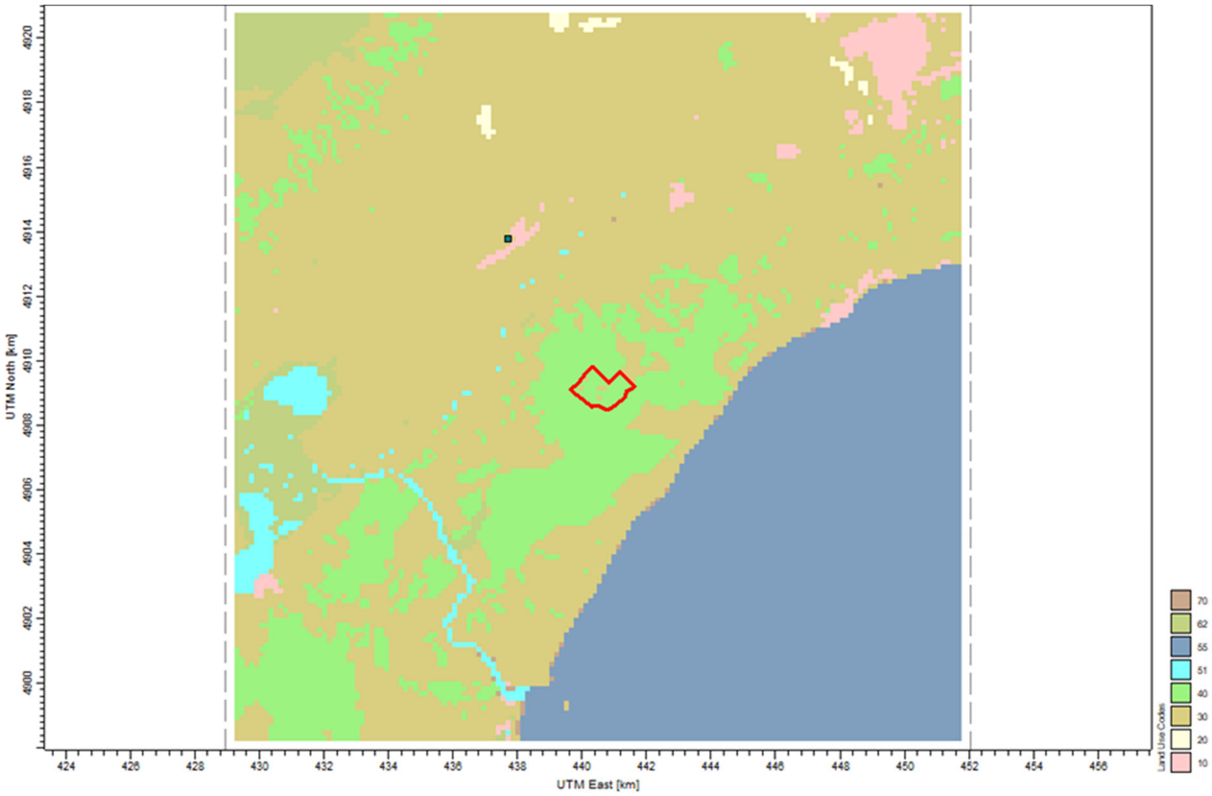
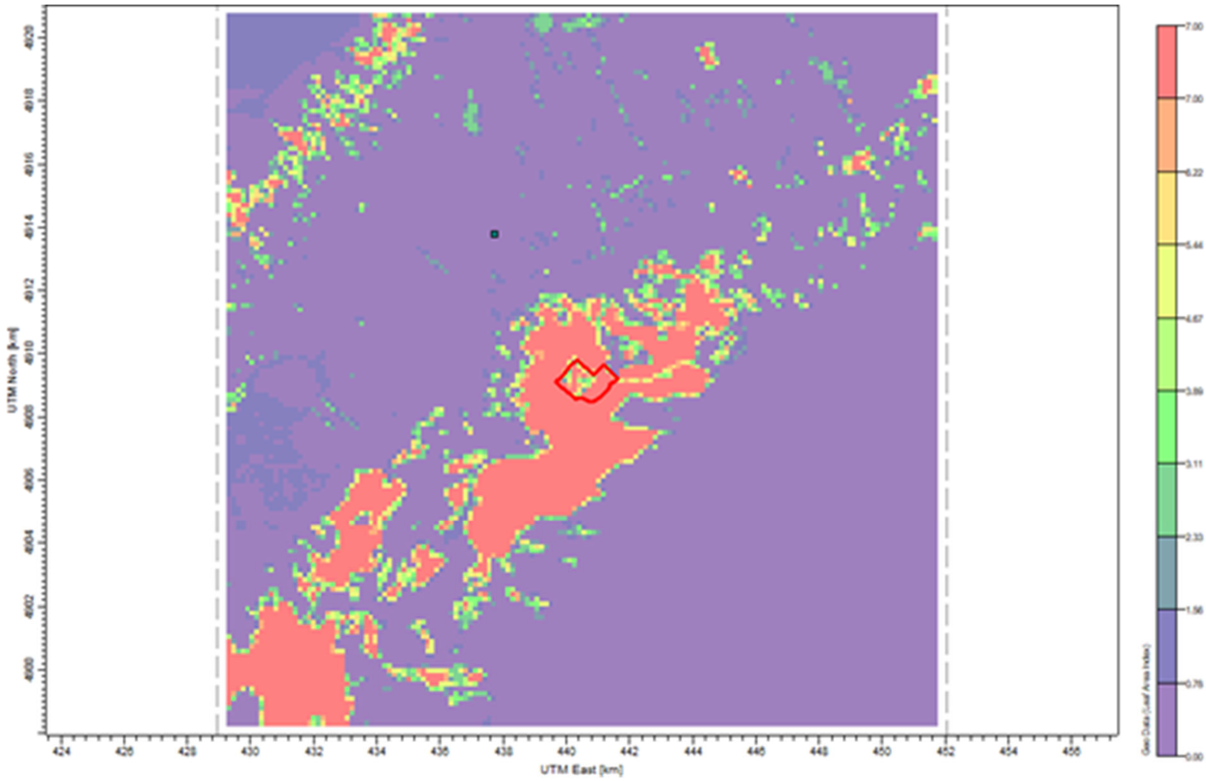


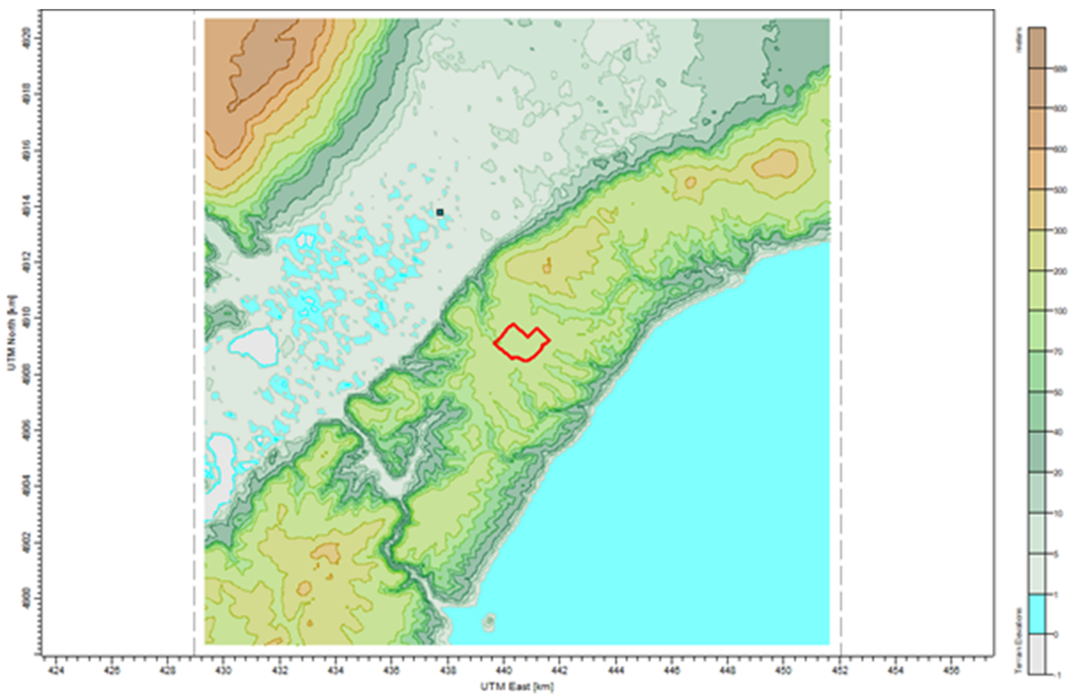
Figure 8-6 CALMET surface roughness length for model domain - site location (red outline) and Dunedin AWS location (dark green point) shown



8.2.4 Terrain

30 m resolution terrain data was sourced for the CALMET domain from NASA Shuttle Radar Topography Mission (SRTM) Version 3.0 Global 1 arc second data. A figure showing terrain elevations for the CALMET domain is shown in Figure 8-7.

Figure 8-7 CALMET terrain elevations for model domain - site location (red outline) and DUNEDIN AWS location (dark green point) shown



8.3 CALMET model settings

The USEPA approved version of CALMET (version 7) was used to resolve the wind field around the subject site to 150 metres spatial resolution. Upon completion of the broad scale TAPM modelling runs, a CALMET simulation was set up to run for the model period, combining the three dimensional gridded data output from the TAPM model with the site specific surface data from the Dunedin Airport AWS.

CALMET was configured with settings selected in consideration of the guidance outlined in the *Generic Guidance and Optimum Model Settings for the CALPUFF Modeling (sic) System for Inclusion into the 'Approved Methods for the Modeling (sic) and Assessments of Air Pollutants in NSW, Australia'*[25] *(NSW CALPUFF Guidance)*. A summary of CALMET model settings is shown in Table 9. A full register of CALMET settings is provided in Appendix A.

[25] TRC Environmental Corporation 2011, Generic Guidance and Optimum Model Settings for the CALPUFF Modeling System for Inclusion into the 'Approved Methods for the Modeling and Assessments of Air Pollutants in NSW, Australia', prepared for NSW Office of Environment and Heritage, March 2011

Table 9 CALMET model settings

Parameter	Value
Modelled period	1 January 2017 – 31 December 2019
Mode	Hybrid (NOOBS = 1)
UTM zone	59
Domain origin (centre)	Easting: 429.250 km Northing: 4898.250 km
Domain size	150 x 150 at 0.15 km resolution (22.5 km x 22.5 km)
Number of vertical levels	10
Vertical levels (m)	20, 40, 80, 160, 320, 640, 1200, 2000, 3000, 4000
CALMET settings for hybrid mode	TERRAD = 1.0 km RMAX1 = 3.0 km RMAX2 = 10.0 km RMIN = 0.1 km R1 = 2.0 km R2 = 5.0 km
Initial guess field	TAPM .m3d file used as an initial guess field for CALMET as described in 8.2.2
Surface data	Dunedin Airport AWS as described in 8.2.1 E: 437.729 km N: 4913.776 km
Land use and terrain data	Land use as described in section 8.2.3 Terrain as described in section 8.2.4

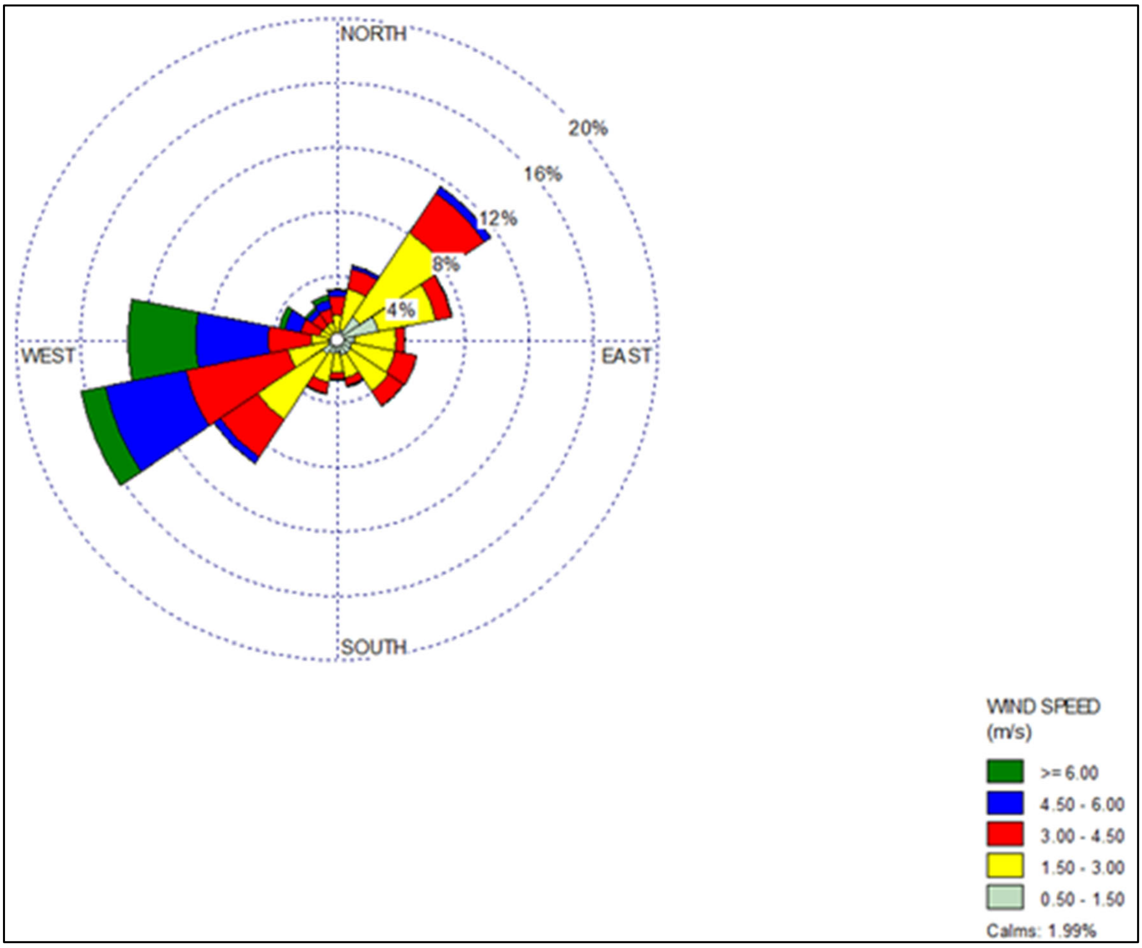
8.4 CALMET model outputs

8.4.1 Pattern of winds

Outputs from the CALMET model at site location is shown as a wind rose (for 2017- 2019) in Figure 8-8. The following is observed from the wind rose:

- The pattern of wind predicted by the CALMET model is mostly reflective of that predicted by TAPM at site. This is expected due to the low radius of influence (R1) selected in the Hybrid mode configuration for the purposes of reducing the contribution of observations from Dunedin Airport AWS (in valley) to the final wind field at The Site.
- The average predicted wind speed is 3.1 m/s, equivalent to the wind speed predicted by TAPM at The Site.
- While the general pattern of wind is similar to the TAPM wind rose, slight changes are observed in the distribution of wind speeds from each direction. These changes are likely associated blocking and slope flow influences on the predicted wind field. A review of the hourly wind animation fields found that during calm winds and stable atmospheres, uniformity of wind field was reduced and wind field appeared to confirm to the most significant localised terrain features.

Figure 8-8 CALMET output wind rose at site location 2017 - 2019 - average wind speed = 3.1 m/s



8.4.2 Model sensitivity tests (TERRAD)

The CALMET model was configured with a radius of terrain features (TERRAD) of 1 km, which is consistent (for this model configuration) with recommendations on the website of the code owners[26] as below:

> *If TERRAD is too small, then the nearby valley wall will not be seen. If TERRAD is too large, then the hill three valleys away is seen, instead of the one nearby. TERRAD on the order of 5 to 10 grid lengths expressed in km (see discussion on terrain resolution) is usually appropriate.*

To test the CALMET model sensitivity to this parameter, an additional model was configured with a TERRAD of 4 km. This TERRAD is more aligned with the generic guidance as presented in the NSW CALPUFF Guidance which recommends a minimum TERRAD of 5 km for all applications, however is inconsistent with recommendations from the model developers.

To assist in the sensitivity analysis, meteorological observations from the site were reviewed. An automatic weather station was installed at site during June 2020, and as of this sensitivity analysis being carried out, a total on nine complete months of data were available (July 2020-March 2021 inclusive).

Figure 8-9 shows three wind roses as described below:

i) Site observations for period July 2020-March 2021 inclusive

[26] http://www.src.com/calpuff/FAQ-answers.htm#3.3.1 accessed 14.04.2021

ii) CALMET predictions where TERRAD = 1 km (for nine months in 2019, including only months where site observations are available)

iii) CALMET predictions where TERRAD = 4 km (for nine months in 2019, including only months where site observations are available)

It is noted that the comparison period is for less than one year and the year being compared is not consistent between observations and CALMET predictions. However, any inter-annual variability is not expected to lead to changes in wind patterns beyond the patterns discussed below.

A comparison of wind rose i) and wind rose ii) shows fair agreement between the two data sets, with average wind speeds being similar and the dominant east-west pattern also consistent between the two. Of note is a high frequency of winds from the northeast in wind rose ii) that is not observed in wind rose i).

A comparison of wind rose i) and wind rose iii) is similar to that with ii), however the high frequency of northeast winds is exaggerated further, and is shifted further north. Again, it is noted that this pattern is not seen in the site measurements. Additional winds from the north-northeast in this model configuration are at the expense of other direct easterly winds and to a lesser extent southeasterlies.

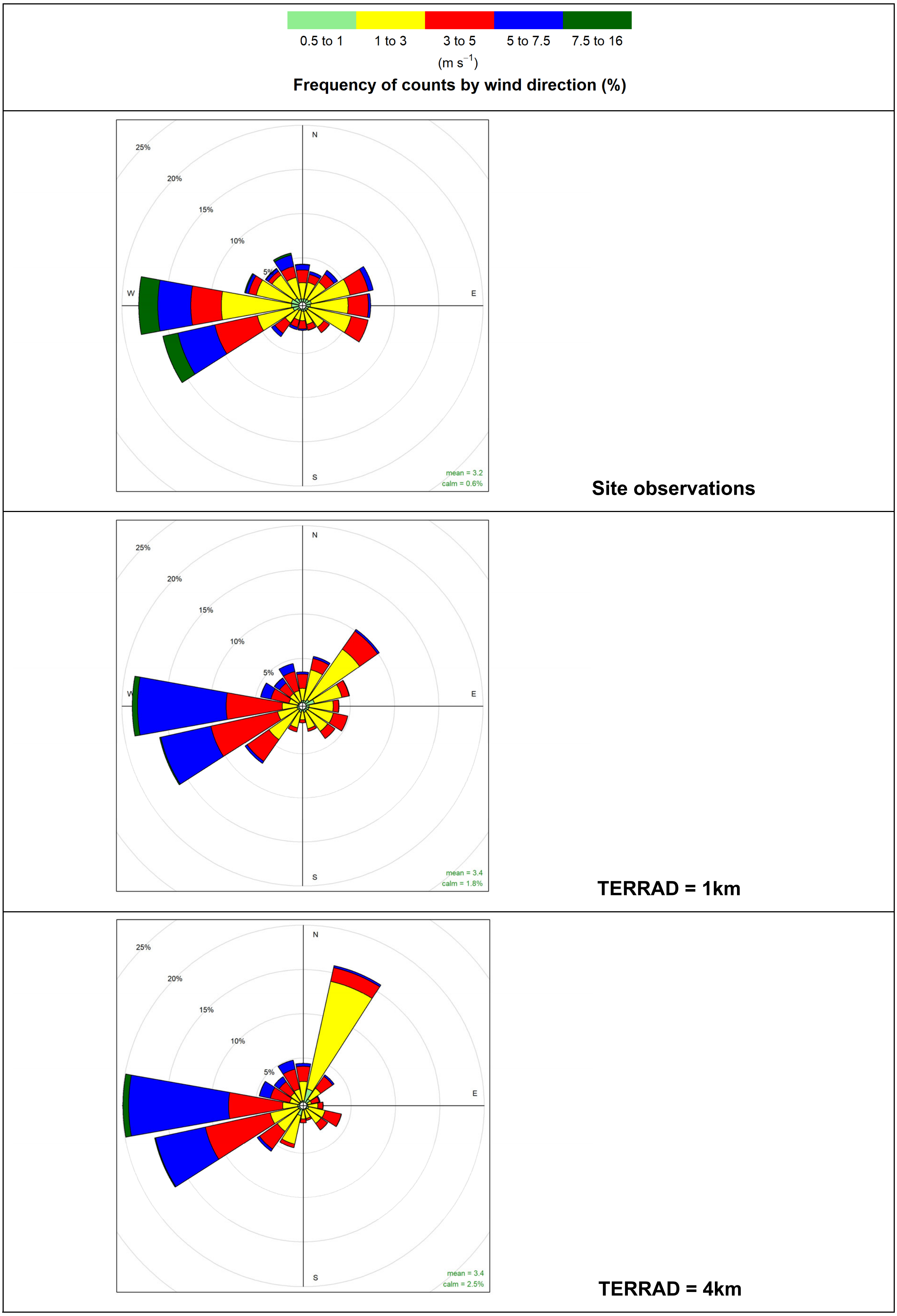
Overall, it is apparent that increasing TERRAD from 1 km to 4 km produces a CALMET wind field which predicts a higher frequency of terrain influenced wind flows which are inconsistent with ~~what~~onsite observations.~~is observed in reality.~~

As such, CALMET modelling with a TERRAD of 1 km is considered appropriate and consequently this is the value that has been adopted in this assessment.~~.~~

8.4.3 Model sensitivity tests (MPDF)

A sensitivity test was carried out to assess the influence of CALPUFF's MPDF function on the model output. The test showed a slight variation in the pattern of dispersion of pollutants, however there was an insignificant difference in the maximum levels predicted, especially when considering the low concentrations predicted in the modelling assessment, with respect to guideline values (refer to Section 11.3). Given the small difference that the MPDF function makes on the model outputs for this particular application the model was run with MPDF off.

Figure 8-9 Comparison of wind roses for i) site observations (top), ii) CALMET predictions with TERRAD = 1km (middle), iii) CALMET predictions with TERRAD = 4km (bottom)



~~8.4.2~~8.4.4 Atmospheric stability

Atmospheric stability substantially affects the capacity of a pollutant such as gas, particulate matter or odour to disperse into the surrounding atmosphere upon discharge and is a measure of the amount of turbulent energy in the atmosphere.

There are six Pasquill-Gifford classes (A-F) used to describe atmospheric stability, and these classes are grouped into three stability categories; stable (classes E-F), neutral (class D), and unstable (classes A-C). The climate parameters of wind speed, cloud cover and insolation (solar radiation) are used to define the stability category as shown in Table 10. As these parameters vary from day to night, there is a corresponding variation in the occurrence of each stability category.

Table 10 Stability class descriptions

Stability category	Wind speed range (m/s)	Stability characteristics
A	0 – 2.8	Extremely unstable atmospheric conditions, occurring near the middle of day, with very light winds, no significant cloud
B	2.9 – 4.8	Moderately unstable atmospheric conditions occurring during mid-morning/mid-afternoon with light winds or very light winds with significant cloud
C	4.9 – 5.9	Slightly unstable atmospheric conditions occurring during early morning/late afternoon with moderate winds or lighter winds with significant cloud
D	≥6	Neutral atmospheric conditions. These occur during the day or night with stronger winds, during periods of total cloud cover or during the twilight period
E	3.4 – 5.4	Slightly stable atmospheric conditions occurring during the night-time with significant cloud and/or moderate winds
F	0 – 3.3	Moderately stable atmospheric conditions occurring during the night-time with no significant cloud and light winds

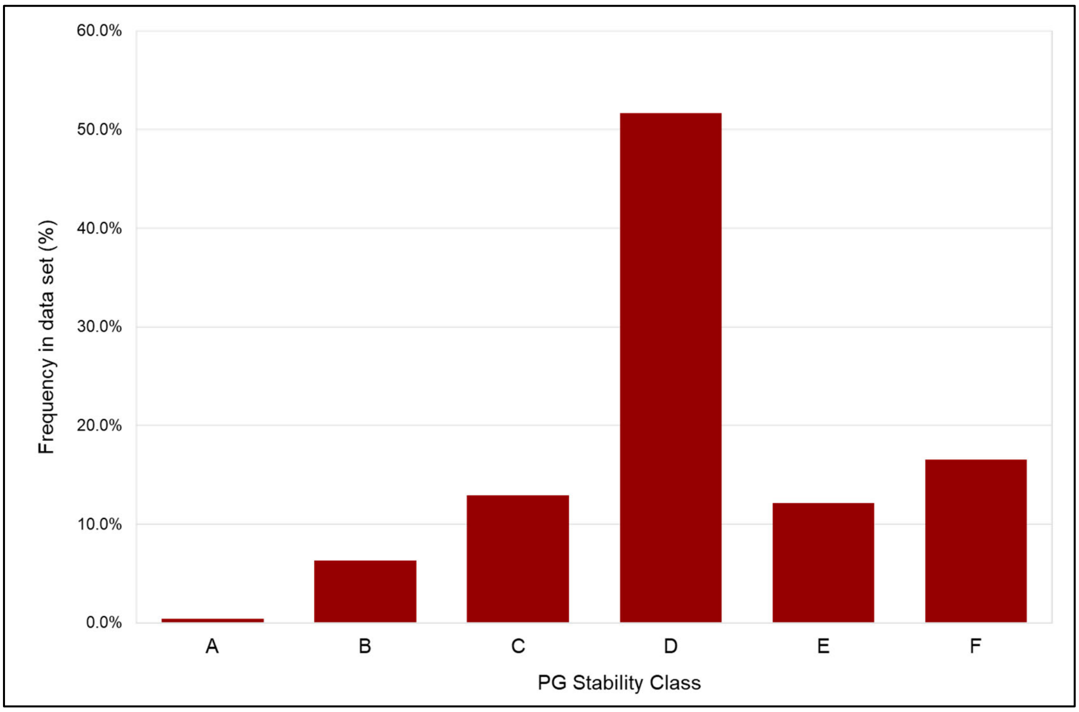
Notes:

- Data sourced from the Turner's Key to the P-G Stability Categories, assuming a Net Radiation Index of +4 for daytime conditions (between 10:00 am and 6:00 pm) and –2 for night-time conditions (between 6:00 pm and 10:00 am)
- E and F class stability classes assumed to only occur at night, during Net Radiation Index categories of –2.

Figure 8-10 shows the frequency of stability class for all hours of the model generated dataset. The following observations were made:

- Neutral atmosphere conditions (class D) are the dominant stability state of the atmosphere occurring approximately 50 per cent of the time
- Stable conditions (classes E and F) occur approximately 30 per cent of the time
- Unstable atmospheres (classes A, B and C) occur approximately 20 per cent of the time.

Figure 8-10 CALMET distribution of atmospheric stability classes



9. Assessment of landfill odour

9.1 Green Island odour complaints

GHD has reviewed the odour complaints register for Green Island landfill between 2017 and 2019 to better understand the odour potential from The Site.

Green Island landfill is considered to be an adequate comparison as it is of a similar size to Smooth Hill although it is noted that it is located in a comparatively residential areas compared to Smooth Hill. It is GHD's understanding that similar management and operating practices will be used at Smooth Hill, however Smooth Hill will be fully lined, compared with Green Island which is unlined. Consequently there will be much better control of fugitive LFG at Smooth Hill and less potential for off-site odour.

The majority of the complaints from Green Island Landfill pertained to LFG, excavating into waste and inadequate cover on odourous waste. Information regarding time of day and wind speed was not consistently recorded on the register, however the majority of complaints were located up to 350 m from the landfill. GHD consider that these complaints coincided with 'normal' site operations of the landfill.

Eight complaints were received up to 1 km from the site. All of these complaints were attributed to the acceptance of odourous loads from Tahunua wastewater treatment plant while they were undertaking repairs and consequently odours of this nature are not considered typical.

Composting operations were also identified as a source of odour, however unlike Green Island no composting activities will be undertaken at The Site consequently the potential for odour complaints will be reduced when compared to Green Island.

Green Island accepts up to 100,000 tonnes of refuse per year and is considered to be a relatively small sized waste handling operation. Green Island landfill operation follows the best practice guidelines which is reflected in the relatively small number of complaints received, typically between 20 and 30 per year. The number of complaints observed at Green Island contrasts with larger operations such as Redvale and Hampton Downs which receive between 100 to 200 complaints each year.

9.2 Green Island odour complaints (updated)

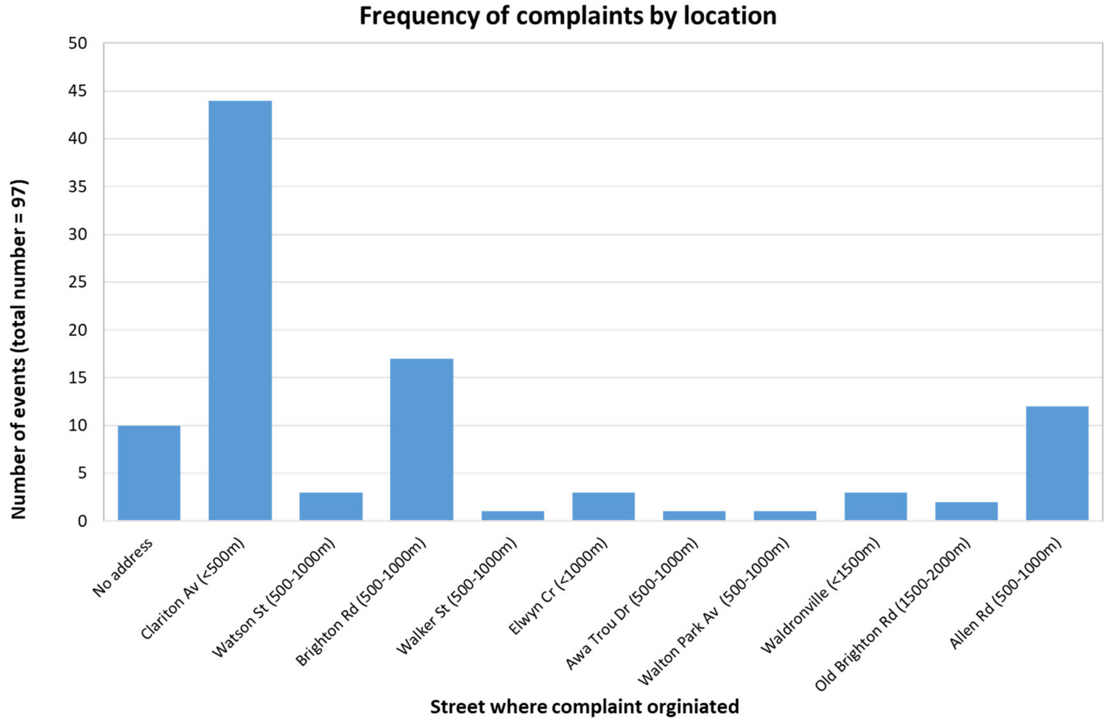
GHD has reviewed the odour complaints register for Green Island landfill between 2017 and 2021 to better understand the odour potential from The Site. A total of 105 complaint records were provided for the period 19 August 2017 through 26 January 2021. Of the 105 complaint records, eight were either not deemed valid due to either, being deemed a double countering of a single event, or where events were not clearly defined as being associated with odour. A total of 97 valid odour complaints are discussed in the following section.

Street addresses and wind conditions were provided for most complaint events, and assessment of this data found that complaints typically occurred when the Green Island Landfill was upwind of the complainant.

9.2.1 Location of complaints

Complaints were recorded at various locations within 2,000 m of Green Island Landfill, however the significant majority of the complaints were from a number of repeat complainants at Clariton Avenue (within 500 m east) and Brighton Road (500-1,000 m southeast/south). The frequency of complaints by location is presented in Figure 9-1. Complaints recorded at distances between 1,000 m and -2,000 m from the Green Island Landfill are infrequent.

Figure 9-1 Frequency of complaints at Green Island Landfill by complaint location



9.2.2 Contributing factors to complaints

The frequency of complaints attributed to potential reasons for odour complaints is presented in Figure 9-2. Of the total of 97 complaints analysed, there were 18 occurrences where no contributing factor was listed, leaving 79 occurrences where a contributing factor could be associated with the event with some confidence.

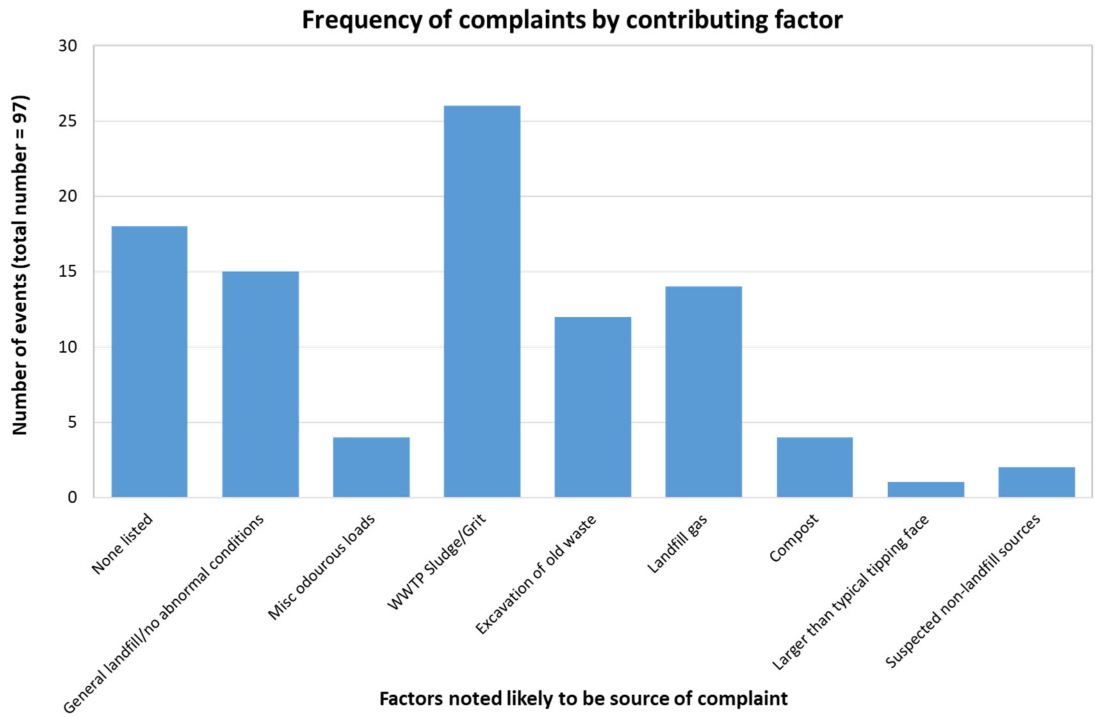
Of these 79 occurrences, approximately 18% were associated with general landfill odour and where site staff could not identify any abnormal events that could have caused the complaint.

A primary contributor to complaints is the receipt, handling and re-handling of wastes incoming from local wastewater treatment plants. Sludge, grits and digester wastes from these wastewater treatment plants were identified as potential contributing factors for approximately 33% of the complaints.

The escape of landfill gas was another frequent contributor (18%) to complaints. The complaints record shows that during 2018 and in to 2019, landfill gas was a prominent issue, with works being carried out to improve the collection of gas. The works themselves also contributed to landfill gas issues, with extraction systems sometimes not running to allow for maintenance. Furthermore, these works led to issues associated with excavation of old refuse (discussed below).

Excavation of old refuse contributed to approximately 15% of complaints during the period. The complaints record states that excavation of old fill areas was carried out as part of the landfill gas collection improvement works, for the creation of asbestos disposal pits and other issues requiring reforming of the landfill.

Figure 9-2 Frequency of complaints at Green Island Landfill by potential contributing factor



9.2.3 Management of key issues at Smooth Hill

Many of the key factors contributing to odour complaints at Green Island Landfill are not expected to be of concern at Smooth Hill based on key landfill design and management measures as discussed through section 3 and 5. These matters are discussed in Table 11 below.

Table 11 Relevance of factors contributing to odour complaints (Updated May 2021)

Factor	% of complaints	Relevance to Smooth Hill
General landfill/no abnormal conditions	19%	As the source is not well defined, the relevance of these complaints to operations at the Site is not known.
Miscellaneous odourous loads	5%	The detail surrounding miscellaneous odourous loads is not known, however it is expected that management of the Site in accordance with the waste acceptance measures as described in 5.1.1 will significantly reduce the probability of odourous complaints associated with miscellaneous odours loads (including offal).
WWTP Sludge/Grit	33%	The Site will receive wastewater treatment plant waste. The complaints log for Green Island Landfill notes that these waste types were frequently received without warning and therefore effective management of the delivery could not be achieved. The site will be operated in accordance with the waste acceptance measures and highly odourous material disposal measures listed in section 5.1.1 and 5.1.5 respectively. With effective implementation of these measures, the risk of odour complaints associated with receipt of sludge/biosolids will be significant reduced in comparison to the Green Island Landfill.

Factor	% of complaints	Relevance to Smooth Hill
Excavation of old waste	15%	Effective design, operation and management measures for the Site will reduce the requirement for any excavation in to old refuse. However, where this is required, management measures are listed in 5.1.2 to prevent these activities leading to offsite odour impacts.
Landfill gas	18%	A modern landfill gas collection and destruction system has been designed as described in section 3.2 which will significantly reduce the likelihood of landfill gas leading to offsite odour impacts.
Compost	5%	Composting is not proposed to be undertaken at the Site and therefore complaints associated with composting are not relevant.
Larger than typical tipping face	1%	Maintenance of an appropriately sized tipping face is included in the management measures presented in section 5.1.2.

~~9.2~~9.3 Separation distances

As discussed in Section 6.3 a buffer distances of between ~~EPA Victoria recommend a buffer distance of~~ 500 m and 1,000 m is recommended for landfills which accept putrescible (municipal) waste. ~~, solid inert waste and fill material.~~ MfE suggests that separation distances are indicative, not absolute criteria, and may be adjusted having regard to specific site circumstances.

Smooth Hill will be a modern lined landfill with an efficient LFG collection system. The Site will also incorporate a range of best practice mitigation measures to reduce off-site odour. These factors combined with favourable meteorological conditions, lessen the primacy of the factors which support these ~~a 500 m~~ separation distances. Considering the above, it is GHD's opinion that the circumstances at Smooth Hill provide support for departing from the recommended separation distance.

Considering the stringent mitigation controls in place to minimise odour emissions and having reviewed the Green Island complaints register (as discussed in Sections 9.1 and 9.2) it is reasonable to assume that under usual operating conditions offsite odours are unlikely to cause nuisance at offsite sensitive receptor locations.

In relation to The Site, there is currently one receptor ~~(R10)~~ located within 500 ~~380~~ m of ~~from~~ the landfill footprint and only four receptors within 1,000 m. The following FIDOL assessment will provide a more detailed understanding of the odour potential ~~at R10~~for these receptors and all other identified receptor locations.

~~9.3~~9.4 Environmental effects assessment of odour

Odours associated with landfill operations are generally accepted by the majority of the population to be unpleasant. It is therefore essential that the landfill is operated appropriately to minimise the potential for off-site odour nuisance.

While every effort is made to minimise odour emissions from the landfill, there will always be the potential for odour to be detectable off-site on occasions. GHD has therefore used the qualitative FIDOL assessment tool, as described in Section 1.1.1, to determine the potential for odours to be considered offensive or objectionable by off-site receptors.

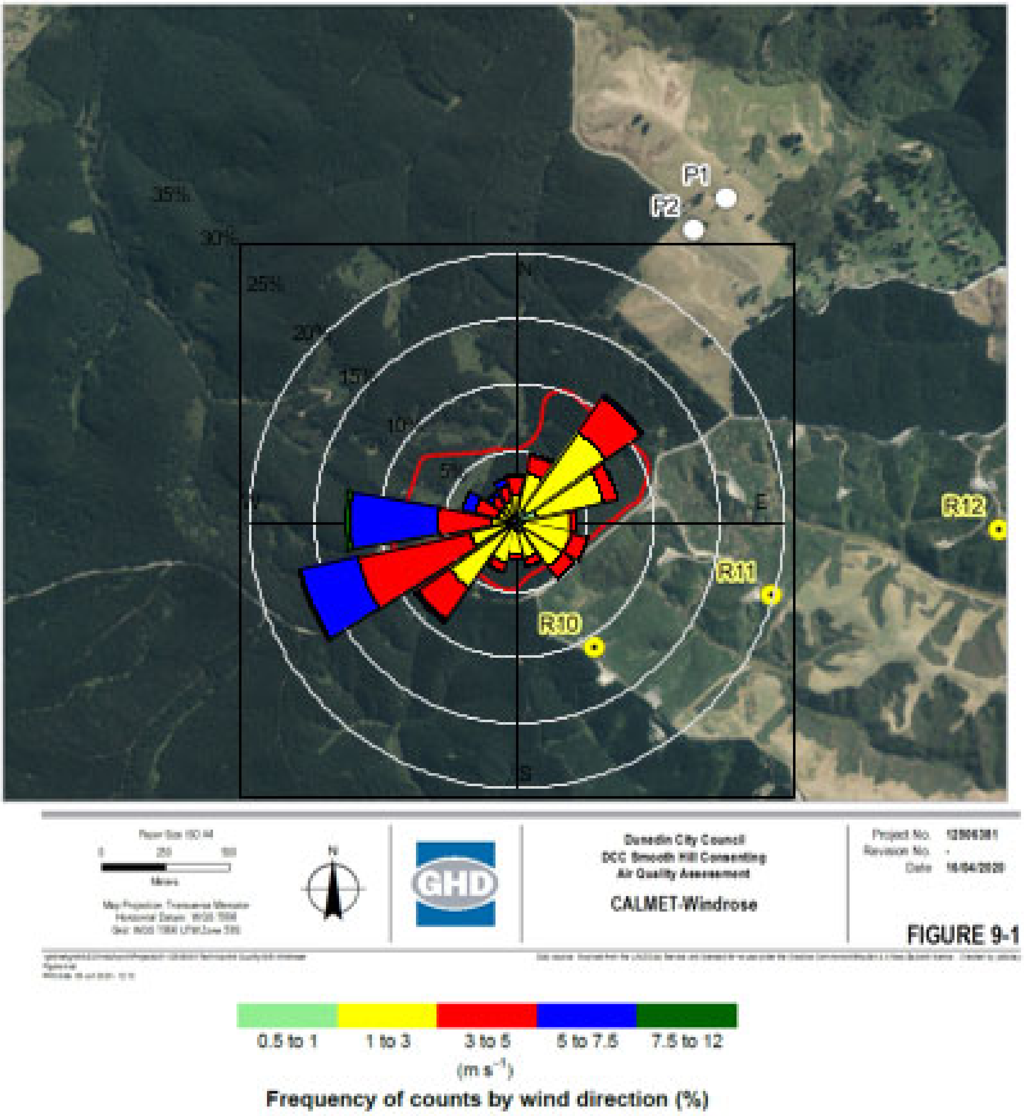
~~9.3.1~~9.4.1 Frequency

CALMET modelled wind speeds have been used to understand the frequency in which receptors may experience nuisance odours from The Site, this data is presented in Table 12. Figure 9-3 presents the CALMET data as a windrose which has been overlayed on a figure of The Site with the closest receptors in view.

Table 12 Wind speed frequency distribution – CALMET (2017 to 2019)

Direction (blowing from)	% of wind					
	0.5 -1.0	1.0 – 3.0	3.0 – 5.0	5.0 – 7.5	7.5– 25.0	Total
N	0.2	1.4	1.4	0.2	0.0	3
NNE	0.3	3.0	1.3	0.2	0.0	5
NE	0.6	7.5	3.2	0.2	0.0	11
ENE	1.2	5.1	1.0	0.0	0.0	7
E	0.4	3.3	0.6	0.0	0.0	4
ESE	0.4	3.3	1.4	0.0	0.0	5
SE	0.5	3.4	1.1	0.0	0.0	5
SSE	0.4	2.1	0.5	0.1	0.0	3
S	0.4	1.7	0.4	0.0	0.0	3
SSW	0.3	2.4	0.7	0.0	0.0	4
SW	0.3	5.7	3.1	0.2	0.0	9
WSW	0.2	2.9	8.6	4.3	0.2	16
W	0.2	1.5	4.0	6.8	0.5	13
WNW	0.1	1.1	1.6	0.9	0.0	4
NW	0.1	0.9	1.0	0.4	0.0	2
NNW	0.1	1.1	1.1	0.5	0.0	3
Sub-Total (%)	6	46	31	14	1	98
Calms						2
Missing						0
Total						100

Figure 9-3 CALMET Wind data (2017 -2019) presented as a Windrose



GHD consider that light winds with speeds less than 3 m/s have the greatest potential to carry odour off-site. Analysis of low wind speeds from The Site is presented in Table 13.

Data presented in Table 13 show that some receptors may experience wind conditions which have the potential to cause odour nuisance for a moderate amount of time. The following classification has been used to determine how likely the receptors could be impacted:

- 0-5% = Low,
- 5-10% = Moderate,
- >10% = High.

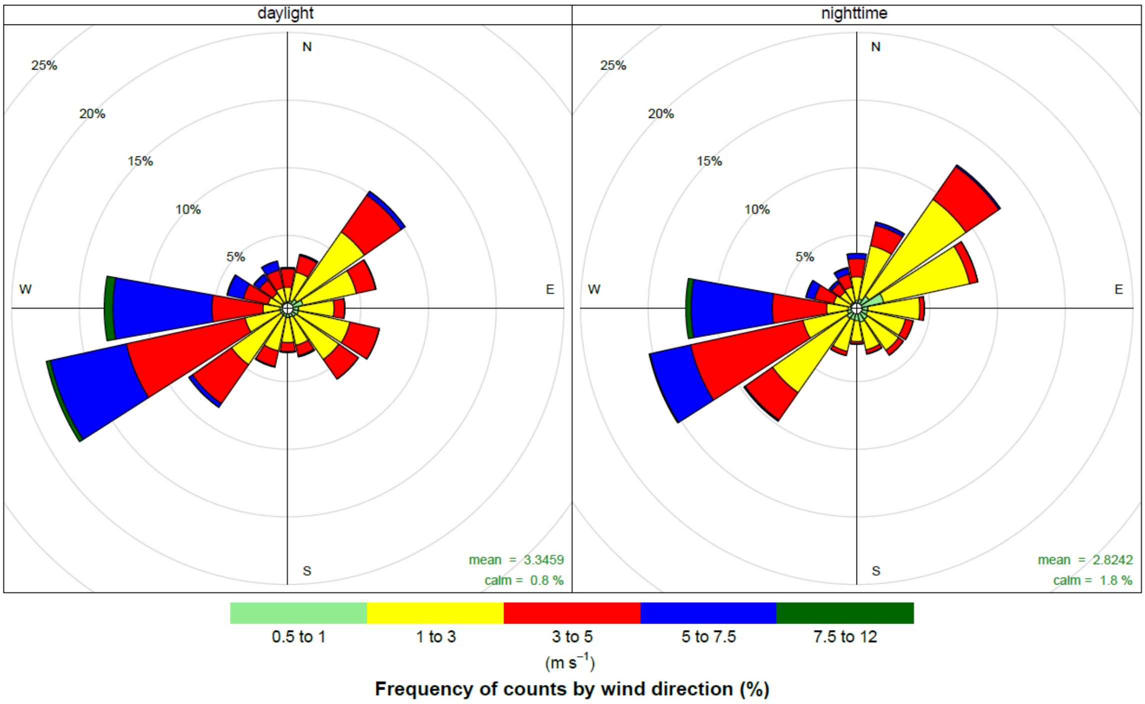
Table 13 Frequency of low-speed winds (<3 m/s)

Receptor ID	% of low wind speed Winds	Receptor ID	% of low wind speed Winds
R1	3	R9	3
R2	3	R10	1
R3	4	R11	1
R4	4	R12	2
R5	4	R13	3
R6	4	R14	6
R7	4	R15	6
R8	3	P1	6
P2	6		

Based on the data provided in Table 11, it is expected that R14, R15, P1 and P2 will experience light winds from The Site for approximately 6% of the year and the nearest receptors R10, R11 and R12 are expected to receive light winds from The Site between 1% and 2% of the year.

The day/night wind roses in Figure 9-4 shows that the frequency of light winds during daylight hours is significantly lower than during the night-time as is expected due to solar radiation (convective heating of the air column) during the day period. This is important, as people are more susceptive to experiencing odour effects during the day (i.e. times when they are working outside and not indoors asleep). The values presented in Table 10 are therefore considered to provide a worst-case assessment of those periods of time that people would likely experience odour.

Figure 9-4 Wind rose of daytime/night-time hours



While some of the sensitive receptors are at locations where suitable winds (< 3 m/s) occur a moderate amount of time, these wind conditions would have to coincide with significant odour being generated by the landfill for adverse effects to occur.

Light winds provide the worst-case scenario for ground-based odour sources (as mechanical mixing is higher with increasing wind speeds) the unique topography of The Site and surrounding area will promote odour to flow down slope and away from nearby receptors (R10, R11 and R12).

Overall, GHD considers that the frequency of low wind speed conditions which can carry odour in a relatively undiluted manner towards neighbouring residences and to cause any potential odour nuisance as minimal.

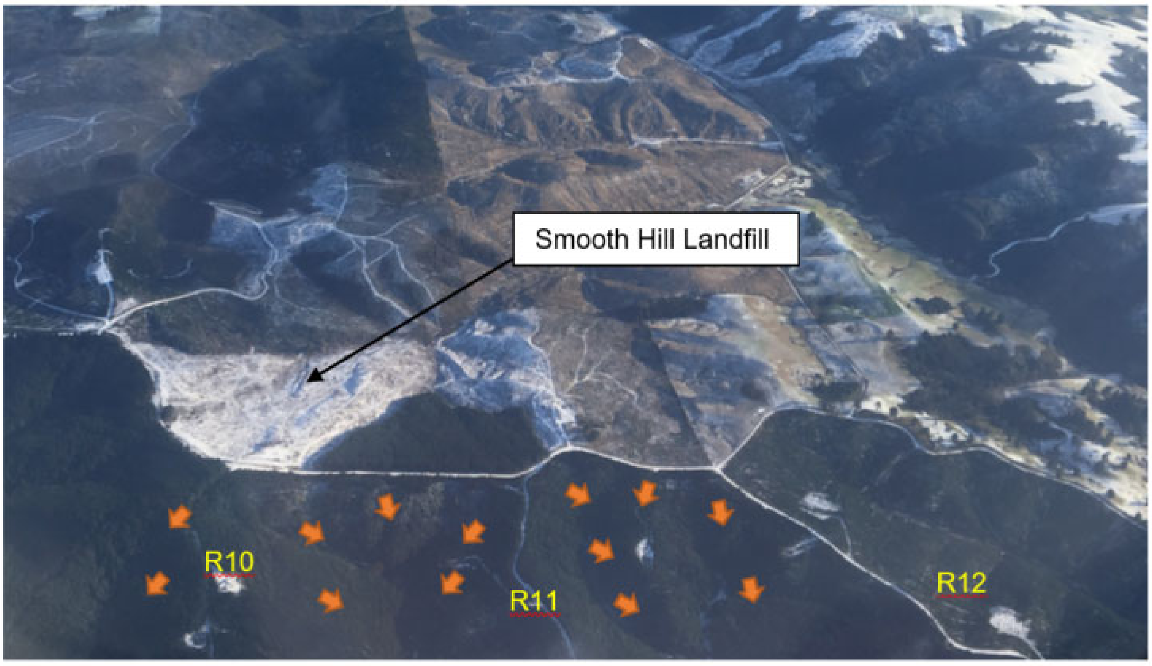
~~9.3.2~~9.4.2 Intensity

Odour associated with landfill operations can have a strong intensity and can be considered offensive and objectionable, particularly if an undisclosed malodourous load is deposited or if the LFG collection system is not operating efficiently. However, based on GHD’s experience under normal operations, a distinct sweet odour is usually only detected in close proximity of the source and a weak to distinct odour might be detected out to 500 m from the boundary. This is supported when looking at complaint records for other landfills.

Receptors, R10, R11 and R12 are located on separate ridgelines at approximately the same elevation as the completed stages of the landfill. During the majority of the filling operations, the working areas (which have the greatest potential to discharge odour), will be at a lower elevation than the ridgeline of these receptors. This factor combined with receptors being located on ridgelines will aid in mitigating odours, as they will stay close to the surface and flow downslope away from the receptors. Consequently any odours detected at these locations are likely to be diluted in strength.

Figure 9-5 presents an aerial photograph of The Site and shows how odours, depicted as orange arrows, are expected to interact with the topography.

Figure 9-5 Effect of terrain features on odour dispersion



Overall, considering the distance of The Site to sensitive receptors, and favourable meteorological conditions, odour from the landfill will undergo significant dilution as it travels towards receptors. This will likely result in off-site odour having a low intensity and consequently reduce the likelihood of offensive or objectionable odours occurring at these receptors.

~~9.3.3~~9.4.3 Duration

The frequency and intensity factors are dependent on the strength of emissions and meteorological conditions. While this can also be stated for duration, (i.e. how long wind conditions are experienced) it is primarily the response time of operation staff to significant odour events, which has the greatest impact on the duration of off-site odours. In the occurrence of an odour event, the mitigation measures which are set out in Section 5.1 will be implemented, and therefore the duration of any event should be short and intermittent. It is GHD's opinion that a response time of up to 2 hours is reasonable to appropriately address the majority of gross odour discharges.

As landfill stages approach their finished level, there may be greater potential for receptors (particularly R10, given its locality to The Site) to experience odours from The Site. During this period of the filling, it is recommended that operational staff will take additional care to ensure mitigation measures are implemented at all times to minimise the potential for off-site odour impacts. In addition, it is understood that once the landfill reaches the completed height final capping will be placed, once capping is placed it is not expected that these cells will be a significant source of odour.

~~9.3.4~~9.4.4 Offensiveness

When detected off-site, unmitigated odours associated with landfills are generally considered to be offensive, and odours associated with The Site are no different. LFG typically has a sweet odour that can be offensive if it is also associated with a high intensity. Odours associated with waste such as biosolids and offal are highly offensive and required stringent controls to be in place to prevent off-site effects.

~~9.3.5~~9.4.5 Location

To a large extent the location of the source in proximity to sensitive receptors is possibly the most important of the FIDOL factors. With increased distance odours have more time to disperse and become lower in intensity through dilution or chemical changes in the atmosphere as they travel from source to receptor.

While the site and the surrounding land is located in a rural area, which would typically be expected to have a lower level of amenity, landfill odours are unlikely to be considered commensurate with typical rural type odours that might be detected.

Table 8 identifies R14, R15, P1 and P2 as receiving low wind speeds with the potential to carry odour from the site 6% of the time. These receptors are not in the downwind location of the expected valley drainage flows and given that the distance of these locations from The Site is approximately 1 km (and further), it is unlikely that these locations will experience offensive or objectionable odour during normal operation.

For this project there is one property within the EPA Victoria buffer distance of 500 m (R10). The majority of receptors are approximately 1 km or further. Based on the EPA Victoria guidance, it is assumed that R10 may be more susceptible to experiencing offensive odour than other receptors. However, taking into consideration the following:

- Low likelihood of calm/low speed wind conditions blowing from the landfill toward the receptor (approximately 1%);
- The terrain is likely to mitigate the effects of odour as R10 is not affected by down-valley drainage flows.
- A range of best practice mitigation measures will be implemented to control odour.
- site staff will be made aware of the importance of mitigation measures when filling near the south-eastern boundary.

Consequently, GHD considers that there is a limited potential for odour nuisance to occur at R10 during normal operation of the landfill.

Effect landfill footprint relocated further to the west

Various configurations of the landfill have been assessed, which included relocating the landfill slightly further to the west. Overall, it is considered that moving the landfill to the west would provide a reduction in the intensity and frequency of odour experienced by the nearest sensitive receptors, however given the relatively small change in the separation distance, the reduced potential for odour nuisance effects is not considered to be significant.

~~9.3.6~~9.4.6 FIDOL conclusion

In general, undiluted odours associated with landfills (refuse, leachate and LFG) are considered to be offensive in nature when experienced by off-site receptors.

While the Landfill and surrounding area is located in a rural area, which would typically be expected to have a lower level of amenity, landfill odours are unlikely to be considered commensurate with typical rural type odours that might be detected. Therefore, the nearby 15 residential dwellings are likely to have a higher sensitivity to odour effects than would generally be expected for the locality. In particular, one residential receptor is located within 500 m of The Site (and within the recommended EPA Victoria separation distance guideline) and consequently has the greatest potential to be affected.

The following summarises the findings of the FIDOL odour assessment:

- There is a low frequency of light/calm wind speeds (required to carry undiluted odour) blowing from The Site towards receptors
- Light winds will tend to follow the contour of the valley (valley drainage flows). These drainage flows will keep odours close to ground level, and therefore odours are unlikely to migrate up valley walls to reach receptors
- The nearest receptors (R10 and R11) are on their own ridgelines, which means that they are less likely to be impacted by landfill odours, as odour will typically migrate down the sides of the ridgeline to lower lying areas
- There are no receptors downwind of the valley drainage flow (travelling from south or south-easterly toward the north of the valley)
- Receptors R10, R11 and R12 have the greatest potential to experience off-site odour, particularly if mitigation measures are not appropriately implemented while refuse is being placed in the south-eastern areas of the landfill

While there is the potential for nearby receptors to experience odour from the landfill from time-to-time, given the following factors: receptors are not predicted to be downwind of the landfill for significant periods of time; nearby receptors are not located down-valley; the landfill will be constructed in accordance with best practice engineering designs; and, a range for appropriate mitigation measures will be implemented, it is considered unlikely that any odours detected at the nearby receptors will be considered 'offensive or objectionable'. Consequently, odour impacts on nearby receptors are not considered to be significant.

Odour effects on public road users

The potential odour impact on road users is considered to be low based on the following considerations:

- The limited duration that odour events will occur and the coincidence they will be present at the time a road user is driving past the landfill
- The short time frame that odour will be encountered and infrequency of vehicles using Big Stone Road
- Stringent mitigation will be in place to minimise off-site odour

This is finding is also supported by 'MfE Odour' which considers road users as having a low sensitivity to odour with the reasoning that "…*Roads users will typically be exposed to adverse effects from air discharges for only short periods of time"*.

9.4.7 Odour dispersion modelling

In order to support the findings of the FIDOL assessment, odour dispersion modelling was carried out for one expected worst-case scenario. The odour dispersion modelling utilised publicly available odour emission rate measurements from a New Zealand landfill to predict peak odour concentrations at the nearest sensitive receptor. The worst-case scenario placed key odour generating sources at the boundary of the site closest to the nearest sensitive receptor.

The odour dispersion model included emissions for the following sources:

- Active tipping face – limited to 300 m^2 in order to maintain effective waste to cover ratio (which is consistent with the proposed maximum size of the working face)
- Daily cover – limited to three months' worth of tipping faces ~27,000 m^2

Emissions from other landfill sources including intermediate cover and final cover have not been considered in the odour dispersion model, as it is expected that effective capping and landfill gas extraction will prevent any significant odour emission from these areas.

Odour emission rates for the modelled sources are selected based on odour measurements conducted at Redvale Landfill in 2016[27]. The selected odour emission rates are presented in Table 14 below.

Table 14 Odour emission sources (Updated May 2021)

Source	Specific odour emission rate ($OU/m^2/s$)	Source area (m^2)	Total odour emission rate (OU/s)
Tipping face	0.36	300	108
Daily cover	0.022	27,000	594

The emission rates in Table 14 were modelled using the CALPUFF dispersion model and using three years of meteorological data as discussed in section 8. Emissions were modelled from daily cover areas for all hours of the model period, with emissions from the active tipping face

[27] Tonkin & Taylor Ltd 2019, Auckland Regional Landfill Air Quality Assessment, prepared for Waste Management NZ Ltd, May 2019

modelled only between the waste receival hours of 8:00 am through 5:30 pm (rounded to 6:00 pm for modelling purposes).

Dispersion modelling results were output as the 99.9th percentile odour concentration at each sensitive receptor for comparison against the odour criteria, and at each grid point for the production of contour plots.

The maximum predicted 99.9th percentile odour concentration predicted at the receptor nearest to the odour emission sources was 0.13 OU, approximately 2.5% of the 5 OU criteria, or 13% of the most stringent 1 OU criteria. The dispersion modelling results show that tipping face and daily cover emission rates would need to be approximately 40 times greater than those modelled before the 5 OU criteria is exceeded at the nearest receptor while the worst-case tipping location is being used.

Multiplying the modelled emission rates by 40 gives emission rates for tipping face and the daily cover of 14.4 OU/m²/s and 0.88 OU/m²/s respectively. A review of emission rates from Australian landfills[28] found that the average[29] of nine tipping face emission rates was 3.1 OU/m²/s, with only one landfill having an emission rate greater than 14.4 OU/m²/s. Given the cooler climate at the site, it is not likely that the odour emission rate from the tipping face would be comparable to the very high rates measured at some large Australian landfills.

Based on the very low (40x less than criteria) predicted odour concentration at the nearest sensitive receptor for the worst-case tipping location, the odour dispersion modelling supports the conclusion of the FIDOL assessment, being that odour impacts at nearby residences are not likely to be significant where odour management measures (presented in section 5.1) are employed during the operation of the landfill.

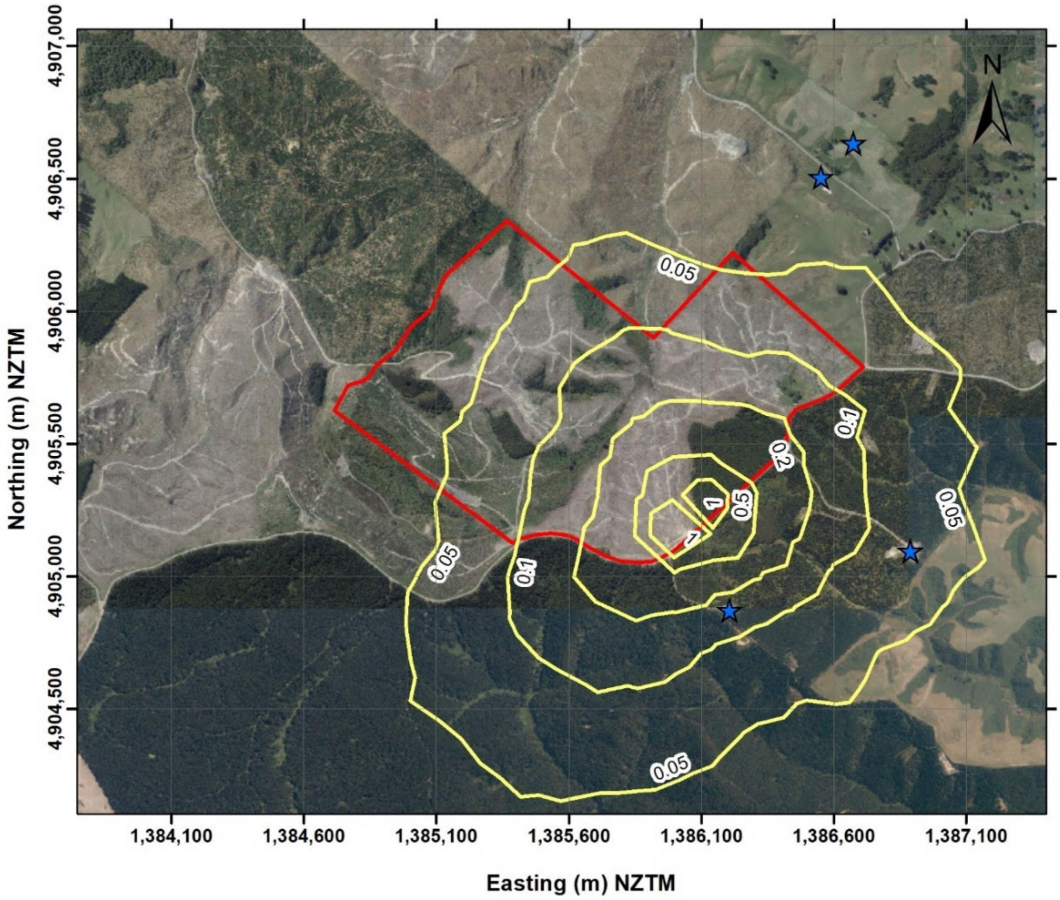
A 99.9th percentile odour concentration contour plot is provided in Figure 9-6. The contour plot shows a consistent pattern of dispersion in all directions, with greater impacts to the northwest, northeast and southwest, consistent with the pattern of light winds predicted. The impacts remain closest to the site boundary towards the nearest sensitive receptor to the southeast.

Overall the findings from the odour modelling assessment, support the FIDOL assessment findings that providing the proposed mitigation measures are implemented appropriately, the nearest sensitive receptors are unlikely to experience odour nuisance effects.

[28] Table 3.2 of Tonkin & Taylor Ltd 2019

[29] Assuming maximum value where any range of values is presented

Figure 9-6 99.9th percentile predicted 1-hour odour concentrations (OU) (Updated May 2021)



10. Assessment of dust emissions

A qualitative assessment of the potential effects associated with the proposed activities is required to determine the potential for the activities to generate nuisance dust that might affect the neighbouring community. This is undertaken in accordance with GPG Dust using the FIDOL assessment tool. As the FIDOL factors for both the construction and operation of the landfill are by in large the same, a summary of the FIDOL assessment is presented in Table 15. Further discussion regarding specific factors during the construction and operation of The Site is discussed in Section 10.1 and Section 10.2 respectively.

Table 15 Dust FIDOL factors

FIDOL	Comment
Frequency	Typically nuisance dust requires winds greater than 5 m/s for it to travel more than 300 m from the source. Based on Table 12 winds greater than 5 m/s from are only expected 15% of the year from all directions, with the majority of these from west. The likelihood therefore of the nearest sensitive receptors being downwind of the site during period of high wind speeds for significant periods of time is considered to be low.
Intensity	Based on experience at other landfills and various construction sites there is the potential for dust concentrations to be high. However, assuming the range of recommended mitigation measured are implemented, off-site dust concentrations are expected to be low.
Duration	Dust events correlating with dust issues are exacerbated under dry, windy conditions – this is discussed further in Section 10.1 and Section 10.2. The duration of dust effects is dependent on mitigation measures not being implemented and the wind conditions at the time of the dust event. Assuming on-site mitigation is implemented, off-site dust effects are typically expected to be of short duration as the time taken to implement mitigation measures is a short duration (< 1 hour).
Offensiveness	Dust can lead to amenity issues such as visual amenity (dust clouds) and dust deposition on property, including vehicles, washing lines and rooftops. While these events can lead to nuisance over extended and frequent exposure, the nature of a standalone event is not considered highly offensive. Given the mitigation proposed to minimise dust effects (such as on-site vehicle speed limits and the use of water carts), it is expected that the offensive nature of the dust will be low.
Location	Generally, people living in and visiting rural areas generally have a high tolerance for rural activities and their associated effects. Dust effects associated with the landfill are considered to be consistent with that already existing in the area from forestry activities.

10.1 Environmental effects assessment of construction dust

Typically nuisance dust requires winds greater than 5 m/s for it to travel beyond the site boundary and with appropriate mitigation these effects are localised to 100 m from the dust source.

The initial construction of the landfill is estimated to span two phases, with each phase starting in October and ending in April/May. The Site experiences high wind speeds (>5 m/s) predominantly from the west and generally speaking, the construction phase period will typically experience low rainfall days. However, considering the nearest receptor is more than 350 m from the landfill boundary it is not expected that there will be any discernible dust at these locations when appropriate dust mitigation measures implemented.

Based on the construction activities of the landfill and FIDOL factors it is unlikely that dust emissions during the construction of the landfill will cause any adverse effects beyond the site boundary.

10.2 Environmental effects assessment of operational dust

The greatest potential for nuisance dust to occur from the operation of the landfill is from the acceptance of dusty waste and vehicle movements on unpaved roads, particularly the perimeter road which circuits the landfill.

Based on the information provided in Table 7, winds blowing towards receptors with a speed >5 m/s are expected to occur 14% of the time. MfE states that nuisance dust effects are generally only experienced within 300 m of unmitigated dust sources. Assuming that the strict onsite protocols for containing dust are followed, dust may travel up to 100 m from the source. As the nearest receptor (where sensitivity to dust is increased) is greater than 300 m from the landfill, it is not expected that there will be any significant dust deposited at these locations.

Based on the operational activities of the landfill and considering the FIDOL factors it is unlikely that operational dust emissions will cause any adverse effects beyond the site boundary.

11. Assessment of landfill gas combustion emissions

11.1 Atmospheric dispersion modelling methodology

The modelling of emissions associated with the flare has been undertaken using the atmospheric dispersion model (Version 7). CALPUFF has been used extensively in New Zealand and Australia and is a recommended model in the MfE GPG ID especially for sites surrounded by complex terrain and where sea-breeze conditions can occur.

The CALPUFF model was setup in accordance with the guidance found in MfE ADM and the New South Wales, Office of Environment and Heritage document which provides generic guidance and optimal settings for CALPUFF[30].

CALPUFF is a non-steady state Lagrangian Gaussian puff model which contains modules for determining complex terrain effects, overwater transport, coastal interaction effects, building downwash, wet and dry removal of pollutants, and simple chemical transformation. That is to say that the model can predict the effects of time- and space-varying meteorological conditions on pollutant dispersion, transformation and removal from the atmosphere.

11.2 CALPUFF model settings

The CALMET data described in Section 8 has been incorporated into the atmospheric dispersion modelling assessment to determine the potential effects associated with the operation of the flares.

Ground-level air concentrations were predicted over 4 km Cartesian receptor grid covering a 8 km by 8 km domain which was centred on the project site. The resolution of the modelling grid was 150 m.

The emission data input into the model is presented in Table 16 and the CALPUFF input file is presented in Appendix B.

The gas exit velocity of 11.3 m/s was calculated based on a discharge flow rate of 200,103 m^3/hr (55.5 m^3/s)[31] and a flare area of 4.9 m^2. Assuming a 8 m tall flare, the gas residence time would be approximately 0.7 seconds which is greater than the minimum requirement of 0.5 seconds required by the NESAQ (Regulation 27).

GHD has checked the above values with Windsor Engineering (a local manufacturer of landfill gas flares) and has been advised that a typical design velocity would be between 10 m/s and 20 m/s. GHD is therefore comfortable with the value of 11.3 m/s used in the model as this is at the lower end of what would be typical.

The stack exit temperature has conservatively used 500 °C as it assumes some rapid cooling at the flare tip, where in reality the flare will be designed to maintain a temperature of at least 750°C for the entire period of time that the gas resides in the flare. A value of 500 °C is therefore considered conservative as the buoyancy of the plume is lower and consequently less dispersive.

[30] Generic Guidance and Optimum Model Settings for the CALPUFF Modeling System for Inclusion into the 'Approved Methods for the Modeling and Assessments of Air Pollutants in NSW, Australia', March 2011.

[31] Model based on previous landfill gas model estimates. These have now been revised and are significantly lower. However, we have retained these more conservative values for the purpose of modelling.

Table 16 Modelled emission data

Parameter	Value
Source Coordinates (NZTM) (x)	1,386,024
Source Coordinates (NZTM) (y)	4,905,959
Elevation AMSL (m)	117.6
Flare Diameter (m)	2.5
Flare Height (m)	8
Exit Gas Temperature (°C)	500
Gas Exit Velocity (m/s)	11.3
Pollutant Emission Rates	Refer to Section 4.3.5

11.3 Environmental effects assessment of landfill gas combustion emissions

This section of the report presents the results of the assessment to determine the effects associated with emissions from the flare(s).

11.3.1 Nitrogen dioxide

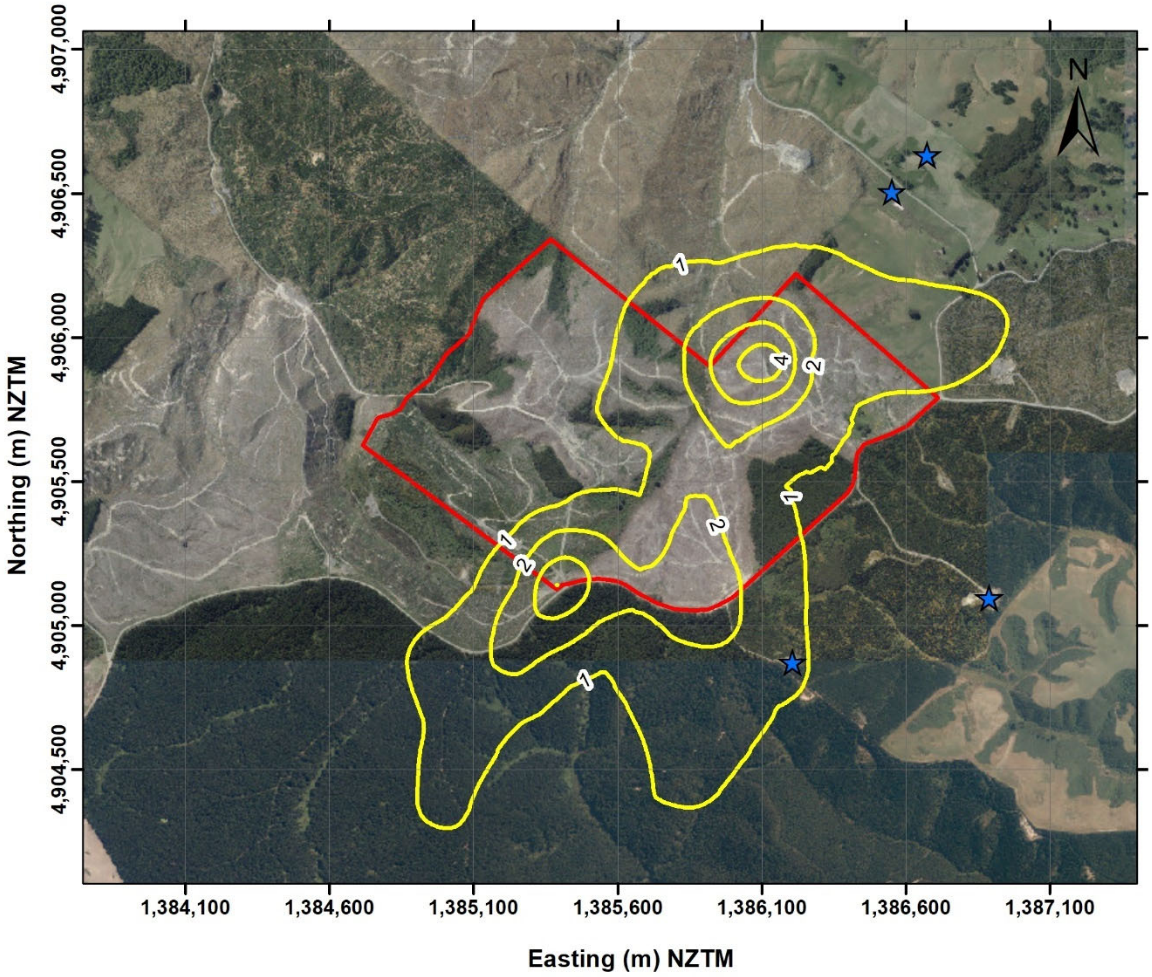
The predicted 99.9%ile 1-hour and 24-hour average NO_2 concentration are presented in Table 17. A graphical presentation of the 1-hour 99.9%ile NO_2 concentrations associated with the flare are presented in Figure 11-1. Predicted 1 and 24-hour average NO_2 concentrations, including background, are predicted to be well below the relevant health-effect based assessment criteria at all off-site locations. The potential for adverse health effects associated with NO_2 emissions is expected to very low. The maximum off-site annual average NO_2 concentration was 0.1 µg/m³ which is well less than the ecological guideline of 30 µg/m³. Consequently there is limited potential for adverse effects on the environment

Table 17 Predicted ground-level concentrations of NO_2 (Updated May 2021)

Receptor ID	1-Hour 99.9%ile NO_2 Concentration (µg/m³)		24-Hour Average NO_2 Concentration (µg/m³)	
	Site contribution	Site contribution + background	Site contribution	Site contribution + background
Assessment Criteria	200		100	
Maximum Offsite	**4.30**	**41.30**	**1.82**	**24.82**
R1	0.13	37.13	0.06	23.06
R2	0.14	37.14	0.06	23.06
R3	0.17	37.17	0.06	23.06
R4	0.14	37.14	0.06	23.06
R5	0.14	37.14	0.05	23.05
R6	0.16	37.16	0.06	23.06
R7	0.17	37.17	0.06	23.06
R8	0.24	37.24	0.10	23.10

R9	0.24	37.24	0.10	23.10
R10	1.10	38.10	0.38	23.38
R11	0.52	37.52	0.16	23.16
R12	0.41	37.41	0.10	23.10
R13	0.28	37.28	0.10	23.10
R14	0.28	37.28	0.10	23.10
R15	0.31	37.31	0.12	23.12
P1	0.47	37.47	0.23	23.23
P2	1.33	38.33	0.58	23.58

Figure 11-1 Maximum predicted (99.9 %ile) 1-hour NO_2 concentrations (µg/m³) (Excluding Background) (Updated May 2021)



11.3.2 Carbon monoxide

The predicted 1-hour and 8-hour average CO concentrations are presented in Table 18. Predicted 1 and 8-hour average CO concentrations, including background, are predicted to be well below the relevant health-effect based assessment criteria at all off-site locations. The potential for adverse health effects associated with CO emissions is expected to low.

Table 18 Predicted ground-level concentrations of CO (Updated May 2021)

Receptor ID	1-Hour CO Concentration ($\mu g/m^3$)		8-Hour Average CO Concentration ($\mu g/m^3$)	
	Site contribution	Site contribution + background	Site contribution	Site contribution + background
Assessment Criteria	30,000		10,000	
Maximum Offsite	**10.32**	**5,010.32**	**5.4**	**2,005.40**
R1	0.84	5,000.84	0.24	2,000.24
R2	1.08	5,001.08	0.24	2,000.24
R3	0.72	5,000.72	0.12	2,000.12
R4	0.6	5,000.60	0.12	2,000.12
R5	0.6	5,000.60	0.12	2,000.12
R6	0.48	5,000.48	0.24	2,000.24
R7	0.48	5,000.48	0.24	2,000.24
R8	1.32	5,001.32	0.36	2,000.36
R9	0.84	5,000.84	0.24	2,000.24
R10	2.4	5,002.40	1.2	2,001.20
R11	1.44	5,001.44	0.36	2,000.36
R12	1.08	5,001.08	0.24	2,000.24
R13	0.48	5,000.48	0.24	2,000.24
R14	0.96	5,000.96	0.24	2,000.24
R15	0.96	5,000.96	0.36	2,000.36
P1	1.92	5,001.92	0.48	2,000.48
P2	2.76	5,002.76	1.68	2,001.68

11.3.3 Particulate matter (PM_{10})

The predicted 24-hour and annual average PM_{10} concentrations are presented in Table 19. Predicted 24-hour and annual average PM_{10} concentrations, including background, are predicted to be well below the relevant health-effect based assessment criteria at all off-site locations. The potential for adverse health effects associated with PM_{10} emissions is expected to low.

Table 19 Predicted ground-level concentrations of PM_{10} (Updated May 2021)

Receptor ID	24-Hour PM_{10} Concentration (µg/m³)		Annual Average PM_{10} Concentration (µg/m³)	
	Site contribution	Site contribution + background	Site contribution	Site contribution + background
Assessment Criteria	50		20	
Maximum Offsite	**0.72**	**19.72**	**0.04**	**12.04**
R1	0.02	19.02	0.01	12.01
R2	0.02	19.02	0.01	12.01
R3	0.02	19.02	0.01	12.01
R4	0.02	19.02	0.01	12.01
R5	0.02	19.02	0.01	12.01
R6	0.02	19.02	0.01	12.01
R7	0.02	19.02	0.01	12.01
R8	0.04	19.04	0.01	12.01
R9	0.04	19.04	0.01	12.01
R10	0.14	19.14	0.01	12.01
R11	0.06	19.06	0.01	12.01
R12	0.04	19.04	0.01	12.01
R13	0.04	19.04	0.01	12.01
R14	0.04	19.04	0.01	12.01
R15	0.05	19.05	0.01	12.01
P1	0.08	19.08	0.01	12.01
P2	0.22	19.22	0.01	12.01

11.3.4 Particulate matter ($PM_{2.5}$)

The predicted 24-hour and annual average $PM_{2.5}$ concentrations are presented in Table 20. Predicted 24-hour and annual average $PM_{2.5}$ concentrations, including background, are predicted to be well below the relevant health-effect based assessment criteria at all off-site locations. The potential for adverse health effects associated with $PM_{2.5}$ emissions is expected to low.

Table 20 Predicted ground-level concentrations of $PM_{2.5}$

Receptor ID	24-Hour $PM_{2.5}$ Concentration (µg/m³)		Annual Average $PM_{2.5}$ Concentration (µg/m³)	
	Site contribution	Site contribution + background	Site contribution	Site contribution + background
Assessment Criteria	25		10	
Maximum Offsite	0.72	11.72	0.04	4.04
R1	0.02	11.02	0.01	4.01
R2	0.02	11.02	0.01	4.01
R3	0.02	11.02	0.01	4.01
R4	0.02	11.02	0.01	4.01
R5	0.02	11.02	0.01	4.01
R6	0.02	11.02	0.01	4.01
R7	0.02	11.02	0.01	4.01
R8	0.04	11.04	0.01	4.01
R9	0.04	11.04	0.01	4.01
R10	0.14	11.14	0.01	4.01
R11	0.06	11.06	0.01	4.01
R12	0.04	11.04	0.01	4.01
R13	0.04	11.04	0.01	4.01
R14	0.04	11.04	0.01	4.01
R15	0.05	11.05	0.01	4.01
P1	0.08	11.08	0.01	4.01
P2	0.22	11.22	0.01	4.01

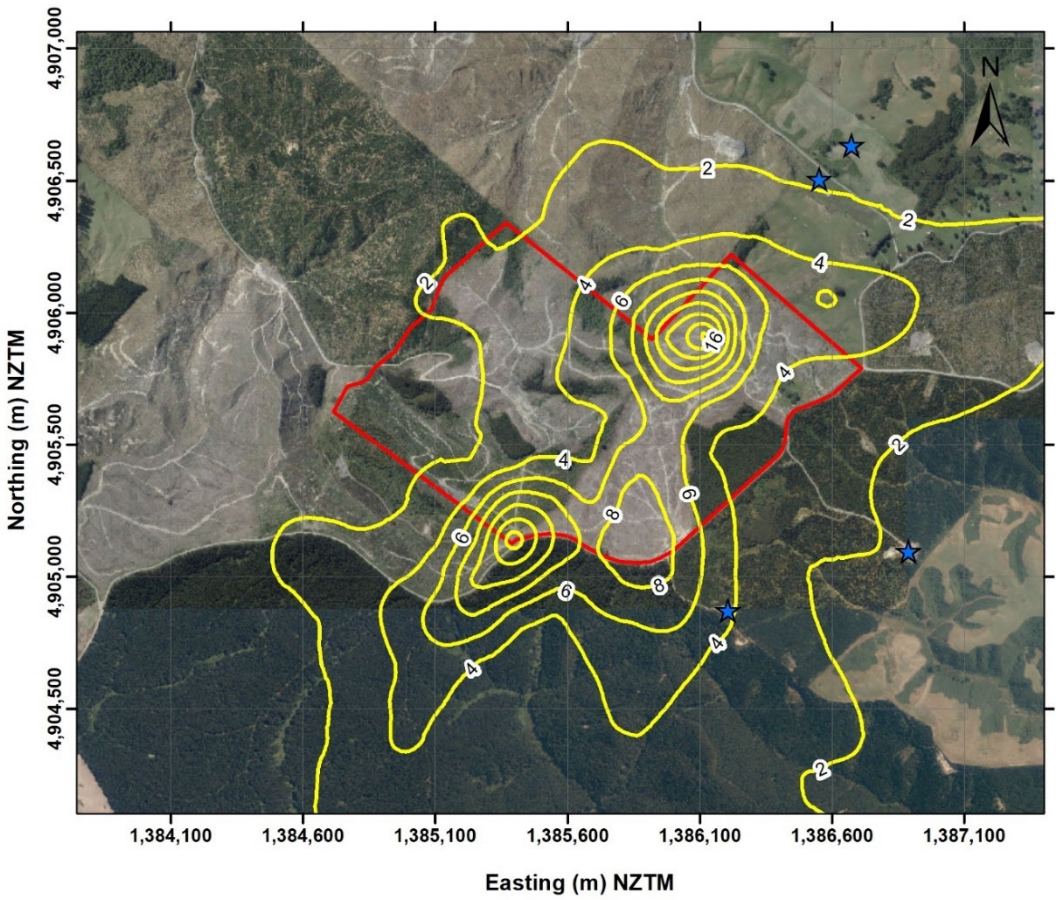
11.3.5 Sulphur dioxide

The predicted 99.9%ile 1-hour and 24-hour average SO_2 concentration are presented in Table 21. A graphical presentation of the maximum 1-hour SO_2 concentrations associated with the flare are presented in Figure 11-2. Predicted 1 and 24-hour average SO_2 concentrations, including background, are predicted to be well below the relevant health-effect based assessment criteria at all off-site locations. The potential for adverse health effects associated with SO_2 emissions is expected to be low. The maximum off-site annual average SO_2 concentration was 0.4 µg/m³ which is well less than the most stringent ecological guideline of 10 µg/m³. Consequently there is limited potential for adverse effects on the environment

Table 21 Predicted ground-level concentrations of SO_2

Receptor ID	Maximum-Hour NO_2 Concentration (µg/m³)		1-Hour 99.9%ile NO_2 Concentration (µg/m³)		24-Hour Average NO_2 Concentration (µg/m³)	
	Site contribution	Site contribution + background	Site contribution	Site contribution + background	Site contribution	Site contribution + background
Assessment Criteria	570		350		120	
Maximum Offsite	33.5	33.5	16.2	16.2	6.9	6.9
R1	2.8	2.8	0.5	0.5	0.2	0.2
R2	3.5	3.5	0.5	0.5	0.2	0.2
R3	2.3	2.3	0.6	0.6	0.2	0.2
R4	2.0	2.0	0.5	0.5	0.2	0.2
R5	1.8	1.8	0.5	0.5	0.2	0.2
R6	1.6	1.6	0.6	0.6	0.2	0.2
R7	1.7	1.7	0.6	0.6	0.2	0.2
R8	4.1	4.1	0.9	0.9	0.4	0.4
R9	2.8	2.8	0.9	0.9	0.3	0.3
R10	7.6	7.6	4.2	4.2	1.5	1.5
R11	4.5	4.5	2.0	2.0	0.6	0.6
R12	3.5	3.5	1.5	1.5	0.4	0.4
R13	1.6	1.6	1.0	1.0	0.4	0.4
R14	3.0	3.0	1.0	1.0	0.4	0.4
R15	3.0	3.0	1.2	1.2	0.5	0.5
P1	6.1	6.1	1.8	1.8	0.9	0.9
P2	9.0	9.0	5.0	5.0	2.2	2.2

Figure 11-2~~11-2~~ Maximum predicted 1-hour SO_2 concentrations (µg/m³)
(Updated May 2021)



12. Conclusions

12.1 Potential effects from odour discharges on nearby residential receptors

The potential for nuisance odour effects has been assessed using the FIDOL (frequency, intensity, duration, offensiveness/character and location) assessment tool and odour dispersion modelling. ~~and to a lesser degree consideration of the recommended landfill separation distances.~~

In general, undiluted odours associated with landfills (refuse, leachate and LFG) are considered to be offensive in nature when experienced by off-site receptors.

While the Landfill and surrounding area is located in a rural area, which would typically be expected to have a lower level of amenity, landfill odours are unlikely to be considered commensurate with typical rural type odours that might be detected. Therefore, the nearby residential dwellings are likely to have a higher sensitivity to odour effects than would generally be expected for the locality. ~~In particular, one residential receptor is located within 500 m of The Site (and within the recommended EPA Victoria separation distance guideline) and consequently has the greatest potential to be affected.~~

Analysis of local topography and wind patterns and consideration of nearby receptor locations (distance and direction from the site) provided much of the odour FIDOL discussion. The following summarises the findings of the odour assessment:

- There is a low frequency of light/calm wind speeds (required to carry undiluted odour) blowing from The Site towards receptors
- Light winds will tend to follow the contour of the valley (valley drainage flows). These drainage flows will keep odours close to ground level, and therefore odours are unlikely to migrate up valley walls to reach receptors
- The nearest receptors (R10 and R11) are on their own ridgelines, which means that they are less likely to be impacted by landfill odours, as odour will typically migrate down the sides of the ridgeline to lower lying areas.
- There are no receptors downwind of the valley drainage flow (travelling from south or south-easterly toward the north of the valley)
- Receptors R10, R11 and R12 have the greatest potential to experience off-site odour, particularly if mitigation measures are not appropriately implemented while refuse is being placed in the south-eastern areas of the landfill

Smooth Hill Landfill is proposing to undertake a range of mitigation measures to control off-site odour; including having stringent controls in relation to acceptance and placement of waste, designed and installing an appropriate system to collect and destroy LFG; storing leachate in enclosed tanks, and implementing a range of best practice operational odour mitigation measures to minimise the frequency and intensity of any odour discharges.

While there is the potential for nearby receptors to experience odour from the landfill from time-to-time, given the following factors: receptors are not predicted to be downwind of the landfill for significant periods of time; nearby receptors are not located down-valley; the landfill will be constructed in accordance with best practice engineering designs; and, a range for appropriate mitigation measures will be implemented, it is considered unlikely that any odours detected at the nearby receptors will be considered 'offensive or objectionable'. This assessment is also supported by the findings of the odour dispersion modelling assessment which predicted odour concentrations to be below the relevant assessment criteria at the nearest sensitive receptors locations. Consequently odour impacts on nearby receptors are not considered to be significant.

12.2 Odour effects on public road users

The potential odour impact on road users is considered to be low based on the following considerations:

- The limited duration that odour events will occur and the coincidence they will be present at the time a road user is driving past the landfill
- The short time frame that odour will be encountered and infrequency of vehicles using Big Stone Road
- Stringent mitigation will be in place to minimise off-site odour

This is finding is also supported by 'MfE Odour' which considers road users as having a low sensitivity to odour with the reasoning that "…*Roads users will typically be exposed to adverse effects from air discharges for only short periods of time"*.

12.3 Potential effects from dust discharges

There is the potential for dust discharges from the construction and operation of the landfill to cause nuisance effects. However a range of best practice mitigation measures will be undertaken to control dust discharges, which combined with the relatively large separation distances to the nearest sensitive receptors and that receptors are generally elevated compared to the site, means that there is limited potential for nuisance effects from dust discharges. Overall, it is considered that providing the proposed mitigation measures are undertaken it is unlikely that off-site receptors will experience adverse effects.

12.4 Potential effects from combustion gases

Combustion emissions from the flare(s) have been assessed using the results of atmospheric dispersion modelling and it has been determined that off-site concentrations of the pollutants of concern are predicted to be well below levels which can cause offsite effects. Consequently there is limited potential for adverse off-site effects associated with flare discharges.

13. Summary of operational requirements to control discharges to air

This section of the report presents the recommended operational requirements that will be used to control air discharges associated with the landfill.

13.1 Odour Control Measures

13.1.1 Waste Acceptance Controls

- Protocols will be implemented to forewarn of the arrival of odorous wastes (examples include biosolids and offal) at the landfill so that proper preparations can be made to mitigate odour emissions once the waste is received at the tip face i.e. to cover as soon as the waste is placed
- Refuse will be placed in sealed truck and trailer units or bins while transported to site (no open bin trucks)
- Wastewater biosolids will be treated (stabilised with lime) prior to arriving at The Site
- Training weighbridge staff to identify potentially odorous or unexpected highly odorous deliveries, and to hold such deliveries until such time as tip face operators have measures in place to place and cover the waste quickly and mitigate emissions that occur

13.1.2 Waste handling and landfill management

- Implementing and maintaining good housekeeping standards on the site
- Keeping the size of the working face to a minimum
- The refuse tip head will be located close to the refuse placement area to avoid pushing the refuse a long distance that would otherwise increase the odour potential. As the refuse placement area changes, the tip head will closely follow that placement area
- Landfill cells will be filled from the base of the valley to the top of the cell (bottom up) for Stage 1 and 2 and top down for Stage 2, 4 and 5
- Works areas shall be covered at the end of each working day and no refuse shall remain exposed overnight
- Mowing landfill surfaces that are grassed to allow effective surface emission monitoring (noting that bird management requires grass to be kept to between 200-300 mm (Boffa Miskell 2020)
- Undertaking instantaneous surface monitoring (ISM) on a regular basis to identify any areas of capping that need to be remediated
- Scheduling activities such as excavations into old waste (an activity that is only undertaken under exceptional circumstances) that have increased potential to generate odour to days when wind direction is away from sensitive receptors
- Conducting regular walk-over inspections of the landfill to identify any damage to the cover system and to monitor the effectiveness of the mitigation measures employed
- Implementing systems for identifying areas for improvement and recording corrective actions

- Maintaining a log of all odour complaints, including investigations by Site Management to identify the source, actions taken to minimise odour emissions, and feedback to the complainant

13.1.3 Measures to identify and control abnormal odour.

Should excessive odour be generated by the landfill from abnormal operation then the following measures will be implemented as a staged approach to identifying and remediating the cause of odour. Identifying and covering odourous waste.

- Stop further deliveries from any identified odorous source
- Redistribute odour sprayers
- Alter the odour spray chemical dose rate
- Repair obvious leaks in gas system
- Repair obvious deficiencies in the landfill cover
- Move the tipping to a remote area until wind is favourable
- Undertake surface emissions survey

~~13.1.3~~13.1.4 Additional mitigation measures

Should the above mitigation measures prove insufficient at controlling offsite odour to acceptable levels the following additional mitigation measures could be implemented.

Odour neutralising sprays

If required, the supply of a trailer mounted odour cannon can be deployed upwind of the odour source to provide improved distribution and mixing of odour neutralisers towards receptors. The particular conditions under which odour sprays will be used, will be set out in the Landfill Management Plan (LMP).

Air conditioning system installation

If nearby residential receptors are experiencing significant landfill odour, air conditioning systems could be installed at each of these properties to allow them to keep their windows and doors closed during periods where they are affected.

Highly odourous waste disposal control procedures

Disposing of highly odourous waste such as biosolids or offal has the greatest potential to cause odour nuisance. If this type of waste is being found to cause odour nuisance effects, the following control measures could be implemented:

- Transportation routes to the landfill can be optimised to minimize the amount of time spent on local roads and waiting at intersections
- Deliveries can be arranged so that trucks are not waiting outside the gate prior to the landfill opening for the day
- Transport to the landfill can be arranged so that deliveries arrive between the hours of 10 am and 4 pm, as this time of day generally provide better odour dispersion conditions
- Deliveries of highly odourous waste can be prioritised and allowed directly to the tip-head
- A dedicated temporary disposal area could be developed for biosolids area within the active landfill face and this waste shall be placed directly into a prepared hole and immediately covered

- Placement areas could be located as far as practicable from the nearest sensitive receptors
- A stockpile of suitable cover material could be located near to the disposal area to allow the waste to be immediately covered
- The bins could be completely emptied as far as practicable to minimise the amount of residual material retained in the bin which can cause odour nuisance as the truck leaves the site and travels back to its next pick-up point
- Investigation of odour complaints should be undertaken to determine the contributing factors and identification of improvements to odour control procedures. If it is determined that all odour mitigation measures were being implemented effectively at the time of the complaint and that the complaint is directly attributed to the placement of highly odourous waste, then waste from this customer will no longer be accepted until it can be demonstrated that the level of odour from the waste has reduced to acceptable levels

13.2 Dust mitigation measures

13.2.1 Construction dust mitigation measures

The following measures will be implemented during construction and operation of the landfill to control dust emissions.

- Visual dust inspections will be carried out on a regular basis throughout the day
- Watercarts or fixed sprinklers will be used to control dust generated from haul roads
- Where visual inspections find instances of dust leaving the boundary of the site, the intensity of dust control measures should be increased, including increasing dust suppression (watering) rate
- During high-wind speeds (wind speeds above 5 m/s) delay/reduce rate of works and/or further increase the rate of watering
- Establish vehicle speed limits (typically less than 15 km/hour) to reduce wheel generated dust emissions
- Where practicable, those parts of the site that are paved should be kept clean and free from waste and dust through regular sweeping and/or hosing down
- Street sweeping should be regularly carried out on paved roads and at the site entrance/exit
- Controlling dust from any excavation by placing material directly into trucks where possible
- If material being excavated is very dry, using water sprays to increase surface moisture
- Where material is placed in temporary stockpiles, use water in dry windy conditions to control the dust potential or cover, if practicable, prior to re-use or long-term storage
- Limit the height of uncovered stockpiles to reduce wind entrainment. Stockpiles exceeding 3 m in height have a higher risk of discharging dust
- Long term stockpiles should be suitably covered to avoid dust generation
- Take account of daily weather forecast wind speed, wind direction and spoil conditions before commencing dust generating activities

13.2.2 Operational dust mitigation measures

Following the initial construction phase, it is expected that the site access road will be sealed up to the main office building. Other measures in order to minimise dust emissions from the landfill include:

- A maximum speed limit of 30 km/hr. will apply in all areas of the site
- Permanent roads on the site should be sealed and well maintained
- Wheel wash to prevent mud/dirt from being tracked along the access road on to public roads
- Water-carts will be used on both sealed and unsealed roads as required during dry periods. Generally visual observation is used to judge the need for water carts.
- Temporary roads on the landfill will be properly maintained and graded
- Dust generating wastes will be treated as a special waste. The customer will be required to dampen down the load prior to delivery to site, and special controls will be implemented at the disposal point, e.g. Water sprays, waste pit, etc.

14. Limitations

This report: has been prepared by GHD for Dunedin City Council and may only be used and relied on by Dunedin City Council for the purpose agreed between GHD and Dunedin City Council as set out in Section 1 of this report.

GHD otherwise disclaims responsibility to any person other than Dunedin City Council and Council officers, consultants, the hearings panel and submitters associated with the resource consent and notice of requirement process for the Smooth Hill Landfill Project arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Dunedin City Council and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Appendices

Appendix A – CALMET input file

CALMET Parameters

CMET4 - Hybrid Mode
TERRAD - 1

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_v7_all.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)	3
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	2017
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	2
IBSEC	Starting second	0
IEYR	Ending year	2019
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)	59
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	150
NY	Meteorological grid - number of Y grid cells	150
DGRIDKM	Meteorological grid spacing (km)	0.15
XORIGKM	Meteorological grid - X coordinate for SW corner (km)	429.2500
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	4898.2500
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	1
NPSTA	Number of precipitation stations	0
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)	1
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)	-1.0,-0.5,0.0,0.5,1.0,1.0,1.0,1.0,1.0,1.0
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)	3
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)	1
R1	Relative weight at surface of step 1 fields and observations (km)	2
R2	Relative weight aloft of step 1 field and observations (km)	5
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)	0.05
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 B – CALPUFF input file

CALPUFF Parameters

CPUF1 - Discrete receptors - 3.2 m stack diameter

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	40
NPTDAT	Number of PTEMARB.DAT input files	0
NARDAT	Number of BAEMARB.DAT input files	0
NVOLDAT	Number of VOLEMARB.DAT input files	0
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2017-01-01-02-0000-2017-01-29-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2017-01-29-00-0000-2017-02-26-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2017-02-26-00-0000-2017-03-25-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2017-03-25-00-0000-2017-04-21-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2017-04-21-00-0000-2017-05-19-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2017-05-19-00-0000-2017-06-15-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2017-06-15-00-0000-2017-07-12-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2017-07-12-00-0000-2017-08-09-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2017-08-09-00-0000-2017-09-05-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2017-09-05-00-0000-2017-10-02-00-0000.DAT

INPUT GROUP: 0 -- Input and Output File Names		
Parameter	**Description**	**Value**
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2017-10-02-00-0000-2017-10-30-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2017-10-30-00-0000-2017-11-26-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2017-11-26-00-0000-2017-12-24-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2017-12-24-00-0000-2018-01-20-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2018-01-20-00-0000-2018-02-16-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2018-02-16-00-0000-2018-03-16-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2018-03-16-00-0000-2018-04-12-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2018-04-12-00-0000-2018-05-09-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2018-05-09-00-0000-2018-06-06-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2018-06-06-00-0000-2018-07-03-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2018-07-03-00-0000-2018-07-30-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2018-07-30-00-0000-2018-08-27-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2018-08-27-00-0000-2018-09-23-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2018-09-23-00-0000-2018-10-20-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2018-10-20-00-0000-2018-11-17-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2018-11-17-00-0000-2018-12-14-00-0000.DAT

INPUT GROUP: 0 -- Input and Output File Names		
Parameter	**Description**	**Value**
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2018-12-14-00-0000-2019-01-10-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2019-01-10-00-0000-2019-02-07-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2019-02-07-00-0000-2019-03-06-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2019-03-06-00-0000-2019-04-02-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2019-04-02-00-0000-2019-04-30-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2019-04-30-00-0000-2019-05-27-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2019-05-27-00-0000-2019-06-24-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2019-06-24-00-0000-2019-07-21-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2019-07-21-00-0000-2019-08-17-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2019-08-17-00-0000-2019-09-14-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2019-09-14-00-0000-2019-10-11-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2019-10-11-00-0000-2019-11-07-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2019-11-07-00-0000-2019-12-05-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2019-12-05-00-0000-2019-12-31-23-0000.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	2017
IBMO	Starting month	1

INPUT GROUP: 1 -- General Run Control Parameters		
Parameter	**Description**	**Value**
IBDY	Starting day	1
IBHR	Starting hour	2
IBMIN	Starting minute	0
IBSEC	Starting second	0
IEYR	Ending year	2019
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)	1
IOVERS	Output dataset format for binary files (1 = version 2.1, 2 = version 2.2)	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)	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

INPUT GROUP: 2 -- Technical Options		
Parameter	**Description**	**Value**
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)	0
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	PM10

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)	59
UTMHEM	Hemisphere (N = northern, S = southern)	S
RLAT0	Latitude of projection origin (decimal degrees)	0.00N

INPUT GROUP: 4 -- Map Projection and Grid Control Parameters		
Parameter	**Description**	**Value**
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	150
NY	Meteorological grid - number of Y grid cells	150
NZ	Meteorological grid - number of vertical layers	10
DGRIDKM	Meteorological grid spacing (km)	0.15
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)	429.2500
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	4898.2500
IBCOMP	Computational grid - X index of lower left corner	1
JBCOMP	Computational grid - Y index of lower left corner	1
IECOMP	Computational grid - X index of upper right corner	150
JECOMP	Computational grid - Y index of upper right corner	150
LSAMP	Use sampling grid (gridded receptors) (T = true, F = false)	F
IBSAMP	Sampling grid - X index of lower left corner	1
JBSAMP	Sampling grid - Y index of lower left corner	1
IESAMP	Sampling grid - X index of upper right corner	2
JESAMP	Sampling grid - Y index of upper right corner	2
MESHDN	Sampling grid - nesting factor	1

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
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

INPUT GROUP: 5 -- Output Options		
Parameter	**Description**	**Value**
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)	3
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
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

INPUT GROUP: 11 -- Chemistry Parameters		
Parameter	**Description**	**Value**
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
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
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

INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
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)	0.2, 0.2, 0.2, 0.2, 0.2, 0.2, 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
WSCAT	Wind speed categories for stability classes 1 to 6 (m/s)	1.54, 3.09, 5.14, 8.23, 10.80
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
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
NSPLIT	Number of puffs created from vertical splitting	3
IRESPLIT	Hour for puff re-split	0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
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

INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
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	1
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	0
IARU	Units used for area source emissions (e.g., 1 = g/m**2/s)	1
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
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 -- Non-gridded (Discrete) Receptor Information		
Parameter	**Description**	**Value**

INPUT GROUP: 17 -- Non-gridded (Discrete) Receptor Information		
Parameter	**Description**	**Value**
NREC	Number of discrete receptors (non-gridded receptors)	680
NRGRP	Number of receptor group names	0

This report has been prepared by Peter Stacey an Air Quality Consultant at GHD. Peter has over 16 years experience as an Air Quality Consultant and has the following qualifications and institutional memberships BSc, GradDip(Bus), and has been certified by the Clean Air Society of Australia and New Zealand as a Certified Air Quality Professional. The author would also like to acknowledge the assistance of Judy Brown (Senior Air Quality Consultant) and Danny Craggs (Environmental Engineer) in the preparation of this report.

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Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
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